Salmon and Steelhead
Habitat Limiting Factors Report

for the

CEDAR – SAMMAMISH BASIN
(Water Resource Inventory Area 8)

Prepared by:

John Kerwin
Washington Conservation Commission
Olympia, Washington

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"…salmon are among the oldest natives of the Pacific Northwest, and over millions of years they learned to inhabit and use nearly all the region's freshwater, estuarine and marine habitats. …From a mountaintop where an eagle carries a salmon carcass to feed its young, out to the distant oceanic waters of the California Current and the Alaska Gyre, the salmon have penetrated the Northwest to an extent unmatched by any other animal. They are like silver threads woven deep into the fabric of the Northwest Ecosystem. The decline of salmon to the brink of extinction is a clear sign of serious problems. The beautiful tapestry that the Northwesterners call home is unraveling; its silver threads are frayed and broken."

Excerpt from: Salmon Without Rivers: a History of the Pacific Salmon Crisis. By Jim Lichatowich, 1999. Island Press

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Contributing Authors of Individual SubArea Chapters

SubArea	Principle Author
Marine Nearshore	Jim Brennan, King County
Snohomish Direct Drainages	Frank Leonetti, Snohomish County
Boeing Creek	Brian Murray, King County
Pipers Creek	Katherine Lynch, Seattle Public Utilities
Hiram Chittenden Locks	Fred Goetz, US Army Corps of Engineers
Lake Washington Ship Canal and Lake Union	Doug Houck, King County
Lake Washington	Kurt Fresh, WA. Dept. of Fish and Wildlife
Thornton Creek	Katherine Lynch, City of Seattle
Lyon Creek	Brent Lackey, King County
McAleer Creek	Brent Lackey, King County
Juanita Creek	Stacey Rush, City of Kirkland
Kelsey Creek	Kit Paulsen, City of Bellevue
Coal Creek	Kit Paulsen, City of Bellevue
May Creek	Brent Lackey, King County
Lower Cedar River	Anne Bikle, King County and Keith Kurko, City of Seattle
Upper Cedar River	Dwayne Paige and Keith Kurko, City of Seattle
Sammamish River	John Lombard, King County
Swamp/North Creeks	Frank Leonetti, Snohomish County
Little Bear Creek	Frank Leonetti, Snohomish County
Bear Creek	Ray Heller, King County
Lake Sammamish	Deborah Lester, King County
East Lake Sammamish Tributaries	Kollin Higgins, King County
West Lake Sammamish Tributaries	Kit Paulsen, City of Bellevue
Issaquah Creek	Kollin Higgins, King County
Lewis Creek	Kit Paulsen, City of Bellevue
Hydrologic Regime Screening Analysis of 3rd Order and Higher Streams in WRIA 8	David Hartley, King County

Reviewers

This report would not have been possible without the support and cooperation of many reviewers and participants. In addition to the authors listed above, other reviewers of various chapters are listed below.

Name	Affiliation
Dave Beauchamp	UW Cooperative Fisheries Research Unit
Laura Blackmore	King County
Jim Brennan	King County
Scott Brewer	King County
Geoff Clayton	Chamber of Commerce
Doug Houck	King County
Jonathon Frodge	King County
Maggie Glowacki	Seattle Public Utilities
Kirk Lakey	WA Department of Fish and Wildlife
Kate O'Laughlin	King County
Cleve Steward	Sustainable Fisheries Foundation
Jean White	King County
Karen Fevold	King County

Other Contributors

Ken Rauscher ……King County
Kerry LaFranchi ……City of Bellevue
Laurie McCain ……..King County
Ron McFarlane ……. NWIFC and Conservation Commission
Jennifer Cutler …….. NWIFC and Conservation Commission
Andy Kohler ……. NWIFC and Conservation Commission (formerly)

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Fish Distribution Maps

The Fish Distribution Maps were initially developed through a workshop held in May 1999. Individuals from numerous governmental agencies, Indian tribes and non-profit organizations, and private citizens knowledgeable about salmonid utilization in the watershed participated. Information from databases, including StreamNet, SSHIAP and the WDFW Spawning Ground Survey Database were also utilized. The initial work product was further reviewed and refined during a workshops in 2000 and 2001.

Fish Barrier Map

The Fish Barrier Maps shown in this report were initially developed by using information from field notes and databases including StreamNet, SSHIAP, the WDFW Fish Barrier Database and the Washington Department of Transportation fish barrier database. The City of Bellevue provided GIS coverages for streams in their jurisdiction and the Adopt-A-Stream Foundation, under contract with King County, provided coverages for their work in north Sammamish River tributary streams.

Program Manager:

Ed Manary, Washington CC

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I. Introduction

Many stocks of the wild salmonid populations in the Puget Sound ecoregion have declined. In March 1999, the National Marine Fisheries Service (NMFS) listed Puget Sound chinook salmon as a "Threatened" species under the Endangered Species Act (ESA). In November 1999, the U.S. Fish and Wildlife Service (USFWS) listed bull trout as a "Threatened" species under the ESA.

The Habitat Limiting Factors Report

As a first step in the long-term commitment to salmonid recovery in Water Resource Inventory Area 8 (WRIA 8), representatives from the Washington Conservation Commission and the WRIA 8 Technical Committee worked collectively to develop this Habitat Limiting Factors Report. The purpose of this report is to provide a current "snapshot in time" of the existing salmonid species and anthropogenic caused habitat conditions that limit the natural production of salmonids in the Cedar – Sammamish Watershed and the independent drainages to Puget Sound from Elliott Bay north to approximately the King County – Snohomish County line. This area is collectively termed WRIA 8 for the purposes of this report.

This report:

- Provides a summary of what is known about current and past salmonid species and habitat conditions in the WRIA for future reference;
- Provides baseline information for the WRIA (based on currently available data) for potential use in the implementation of an adaptive management program;
- Identifies limiting habitat factors in the WRIA, key findings, and associated data gaps that will be useful in building the WRIA 8 Salmonid Conservation Plan; and
- Provides guidance for policy makers to determine next steps and direct resources for the recovery process.

Focus on Limiting Habitat Factors

While the causes of declining salmonid populations can be attributed to many factors, this report focuses on human-controlled modification or destruction of saltwater nearshore and freshwater habitats and the changes to ecological processes that effect those habitats in WRIA 8.

II. Watershed Overview

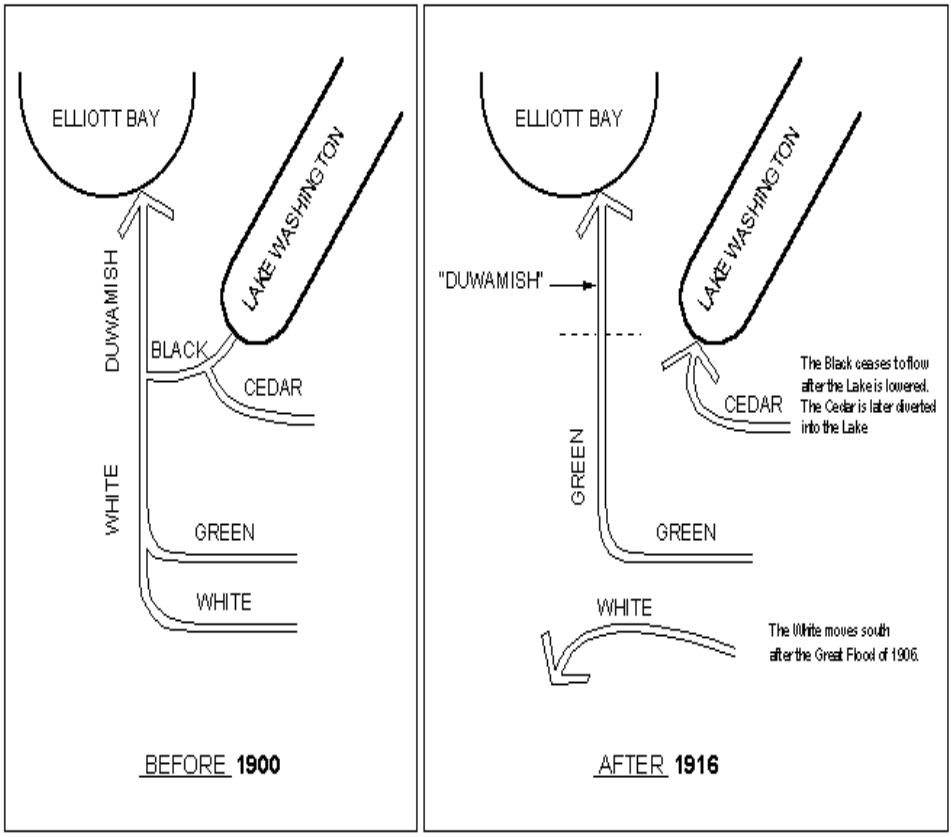
Physical Description

Out of the 692 square miles in WRIA 8, 607 are in the Cedar - Sammamish watershed, which contains two major river systems, the Cedar and the Sammamish, and three large lakes, Union, Washington and Sammamish. The remainder of the WRIA consists of numerous small watersheds that drain directly to Puget Sound between Elliott Bay and Mukilteo. Lake Washington is the second largest natural lake in the state, with about 80 miles of shoreline (including about 30 miles along the shore of Mercer Island) and a surface area of about 35.6 square miles. Arguably, Lake Washington has the most highly altered watershed on the West Coast. Despite such heavy alteration, it continues to support numerous salmon runs.

WRIA 8 is located predominantly within the borders of King County, but 15 percent of it extends northward into Snohomish County. To the west it is bounded by Puget Sound, while to the east the headwaters of the Cedar River reach the crest of the Cascade Range near Stampede Pass. The northern and southern boundaries follow hilltops, ridges and plateaus that define the drainage divides between the Snohomish/Snoqualmie (WRIA 7) and Green/Duwamish (WRIA 9) watersheds, respectively.

The Lake Washington watershed has been dramatically altered in the 150 years since the first Euro-American settlers arrived in the Seattle area. This started with heavy logging of old growth forest in the 19th Century. It expanded at the turn of the 20th Century, when Seattle tapped the Cedar River as its main source of water supply. A major alteration of the watershed occurred in the decade of 1910-20, when the Lake Washington Ship Canal and Hiram M. Chittenden Locks were completed (Figure 1). The ecological consequences of this last alteration were profound: the outlet of Lake Washington was redirected from its south end, at the Black River; the new outlet at the Locks and Salmon Bay had almost no features of a natural estuary and presented migrating salmonids an abrupt transition from freshwater to saltwater (and saltwater to freshwater); and the level of Lake Washington was dropped about nine feet, which drained wetlands along much of its shoreline and dramatically changed the confluences with its tributaries. In a separate but related action in the same decade, the Cedar River was redirected from its normal connection with the Black River, which had fed the Duwamish, and was channelized to flow into Lake Washington, with the initial hope of creating a major freshwater industrial port at Renton. The lowering the water surface level of Lake Washington also lowered the water surface of Lake Sammamish and drained the vast wetland complex that had made up the Sammamish River Corridor between the two lakes. This provided the basis for a major expansion of farming in that corridor, which led to channelization of the Sammamish River in the early 1920's to nearly its present course. Thus, by the 1920's the general hydrogeography of the present watershed was established.

Figure 1. Configuration of the Duwamish drainage prior to 1900 and after 1916 (Source: Dunne and Dietrich 1978)



In the ensuing years, the most important cause of physical change to the watershed has been the expansion of urban and suburban development. In particular, this has altered the hydrology of the watershed; both through changes in land cover and through increased water withdrawals. Changes in land cover due to urbanization have been extensively shown to relate to degradations in salmon habitat, mostly due to changes in flows but also because of degraded riparian areas. The removal of forest cover for urban and suburban development dramatically increases the size and frequency of high flows from stormwater in lowland creeks. It typically reduces low flows in the summer and early fall, because cleared land and impervious surfaces dramatically reduces groundwater recharge. As to increased water withdrawals, through the 1940s these were primarily from Seattle's Cedar River Watershed, but total withdrawals from the watershed have been relatively stable since then, as Seattle and the region have developed other supplies. Major groundwater withdrawals in the watershed since then have been from below the lower Cedar River, lower Issaquah Creek, lower Bear Creek and Rock Creek (a tributary to the Cedar River). Following significant floods in the 1950s, countywide flood control efforts in the 1960s led to a dramatic expansion of levees on

the Cedar River and local sponsorship of major dredging and levee construction on the Sammamish River by the Corps of Engineers. This in turn supported the greater development of the floodplains of both rivers. Meanwhile, expanding urbanization led to heavy residential development of the shorelines of Lake Washington and Lake Sammamish. Residential development has also expanded along the bluffs above Puget Sound and along parts of its shoreline. The marine nearshore of WRIA 8 was even more dramatically affected by the construction of a railroad line along most of its length early in the 20th Century. Bulkheads and other protections for the railroad line and developments have significantly curtailed natural, beach-forming ecological processes along the Puget Sound nearshore.

Beside these changes in physical habitat, the introduction of non-native fauna and flora have significantly changed the biology of the Lake Washington ecosystem. There have been upwards of 40 non-native fish introduced into the watershed. Some of these introduced species did not persist and today, there are 24 known non-native fish species in the watershed, including notably smallmouth and largemouth bass, which can be significant predators of juvenile salmonids. Sockeye salmon in the lake system are believed to be primarily the descendants of fry transplanted from Baker Lake in the 1930s. Since juvenile sockeye require a lake for a year or more of rearing, the Cedar River supported few if any sockeye prior to its connection with Lake Washington (in years of heavy floods, the historic Cedar River flowed into Lake Washington for short periods of time, but the connection was not lasting nor regular). However, the Cedar did support runs of pink and chum salmon prior to being redirected into Lake Washington; these are now extinct. As to non-native flora, Eurasian watermilfoil now dominates much of the shorelines of Lakes Washington and Sammamish. Himalayan blackberry is common in riparian areas throughout the watershed, and Japanese knotweed and reed canary grass are spreading.

The Cedar - Sammamish Watershed is comprised of two major physiographic areas. The eastern portion of the watershed (about 14% of its total area) lies in the Cascade Range while the western portion (the remaining 86%) occupies the Puget Sound Lowland. Largely because of its elevation, the eastern portion (the upper Cedar River and parts of upper Issaquah Creek) receives much more precipitation, up to 102 inches annually, compared to an average of 38 inches in the western portion. The three basins in the watershed with the largest salmonid populations--the Cedar River, Bear Creek and Issaquah Creek--are distinctly different based on geology, hydrology and topography. Only the Cedar River, which originates in relatively high mountain country in the Cascade Range, develops a large annual snowpack. Issaquah Creek originates at the foot of the Cascades, in bedrock hills that are too low to hold snow for sustained spring or summer runoff. Bear Creek is entirely a lowland stream system, originating in a large area of forests and wetlands in south Snohomish and north King counties. Beside the Cedar River, all of the watershed streams must rely primarily on groundwater to sustain baseflows in the summer and early fall.

The division of the watershed by its topography and its three major lakes gives it ecological complexities not found in watersheds based on major river systems. Stream habitat issues for salmon in the Cedar River, Issaquah Creek and Bear Creek are largely unique to each system; actions to address them can be largely independent of one another. The geographic distribution of these systems, and the physical differences between them, has helped create

genetic differences among their salmon populations. All of these differences contribute to the likelihood that recovery goals for salmon in the watershed will be based not just on production, but also on distribution and genetic diversity within the watershed. The lakes have their own complex ecologies, which are not especially well understood but which make salmonids from the Cedar - Sammamish Watershed unusual within Puget Sound. Native salmon from Bear Creek and other tributaries of the original Cedar - Sammamish Watershed basin would have co-evolved with lake habitats. However, the native salmon of the Cedar River would have evolved primarily in stream conditions. The effect of native salmon from the Cedar River migrating and rearing in Lake Washington rather than in the historic Cedar, Black and Green/Duwamish river complex is not known.

WRIA 8 has the largest human population in the state, with approximately 1.4 million people, more than twice the human population of any other WRIA despite its being geographically smaller than most. Based on projections by the Puget Sound Regional Council, this population is expected to increase more than 10 percent in each of the next two decades, bringing it to more than 1.7 million in 2020.

Most of WRIA 8 lies within the Urban Growth Area boundaries. However, nearly all of its most productive salmon spawning habitats are not within that area. Beside the lower Cedar River and Bear and Issaquah creeks, only Little Bear and May creeks have upper basins that are largely outside of the urban area. The official life of the current boundary of the Urban Growth Area in King County is through 2014. A long-term challenge for salmon recovery throughout Puget Sound is to preserve and enhance habitat in the face of effects of increasing human population pressures.

To help us better understand the Cedar - Sammamish Watershed and WRIA 8, we have divided it into ten geographic areas as shown in the corresponding map (Map 1):

- Tributaries draining directly to Puget Sound;
- Nearshore (marine waters and habitats);
- Hiram M. Chittenden Locks and Salmon Bay
- Lake Union
- Lake Washington
- Lake Washington tributaries (except the Cedar River)
- Cedar River
- Sammamish River and its tributaries
- Lake Sammamish
- Lake Sammamish tributaries

These divisions make sense because of natural and/or anthropogenic landscape features. However, they are all linked together as part of the larger ecosystem and by the processes necessary to support naturally produced salmonids.

Land Uses and History

Land uses differ considerably across the watershed and there are few watersheds in the Puget Sound basin that matches the extremes evident in WRIA 8. In the upper Cedar River, land is devoted almost entirely to preservation of forests. A mix of residential, commercial forestry generally characterizes the smaller streams, and agricultural land uses. Residential, industrial, and commercial uses prevail in the lower reaches of virtually all the streams. The Puget Sound drainages are primarily residential in nature.

These land uses have emerged over the last 150 years, which have seen a number of other fundamental changes to the WRIA. Some of these major changes include:

- 1840's and 1850's European settlement begins
- 1880-1910 Logging across much of the watershed
- 1901 City of Seattle begins water diversions out of Cedar River
- 1916 Cedar River diverted into Lake Washington, Hiram M. Chittenden Locks finished changing the outlet of Lake Washington to Salmon Bay
- 1945-2000 Residential, commercial, and industrial uses replacing largely farmlands and forests in western half of WRIA

CURRENT FISH STATUS

Chinook, sockeye, coho, kokanee, steelhead, rainbow and coastal cutthroat trout as well as native char (Bull trout), and one non-native salmonid (Atlantic salmon) have been recently found in the Cedar – Sammamish Watershed. Additionally, at least 40 non-native fish species (of which approximately 24 persist) have been introduced into the Lake Washington watershed creating numerous new trophic interactions with the native species.

Chinook

The Cedar - Sammamish Watershed supported an average yearly total run (fish returning to the river and those caught in the fisheries) of about of approximately 9,600 adult chinook salmon (hatchery and naturally produced) during the period 1968-1997. However, in the past nine years the naturally produced run size has averaged less than 550 adult fish. Returns of naturally produced chinook to the Cedar – Sammamish Watershed have experienced the same decline that has occurred in many of the other Puget Sound drainage basins. Research is needed to better understand the contribution of hatchery "strays" to the naturally produced "wild" chinook stocks in the Cedar - Sammamish Watershed.

Coho

Coho escapement estimates for the tributaries of Lakes Washington and Sammamish from 1980 to 1999 averaged 8,058 and ranged from 399 to 20,002. However, escapement estimates are not always indicative overall habitat productivity because they do not necessarily reflect the harvest of Cedar - Sammamish Watershed basin origin subadult and adult coho.

The Cedar River coho stock was identified as unique based on its spawn timing and its geographic isolation. However, the status of this stock appears to be on a downward trend in escapement. Between 1980 and 1999 the average escapement was 3,710. While there has been insufficient or no escapement data collected in four of the ensuing 10 years, the most recent two years indicate extremely poor returns. Since 1991, where data is available, the average coho escapement has been 697 fish.

Winter Steelhead

The Cedar - Sammamish Watershed winter steelhead stock has been characterized as "Depressed". This winter steelhead population began a steady decrease in the mid-1980's, similar to those of many other regional stream systems. Recently, escapement estimates of this stock has shown a slight upward trend but preliminary numbers from the 2000/01 run year indicate a poor return.

Sockeye

The Cedar River sockeye salmon stock makes up the largest production unit of the aggregate Lake Washington sockeye salmon run. The long-term trend for this stock is negative and the stock status is depressed. Lake Washington tributary sockeye spawners make up the second production unit of this stock and the long-term status is also depressed. The smallest production unit of this sockeye stock is Lake Washington beach spawners and the status of this stock is also depressed. This last stock has seen a larger decrease in percentage of population that the first two and the reasons are unclear. It has been hypothesized that the construction of docks and/or the introduction and explosive distribution of Eurasian watermilfoil may be partially to blame.

Kokanee

Cedar - Sammamish Watershed kokanee (*O. nerka*), the resident form of sockeye salmon, have been separated into two distinct stocks based on a number of key characteristics, the most important being run timing and unique genetic traits (Young et. al. 2001). The early run stock of kokanee that return to Issaquah Creek are considered native to the Lake Sammamish drainage.

Another stock of kokanee salmon enters east and south Lake Sammamish tributaries (e.g.: Laughing Jacobs, Ebright and Lewis creeks) from October through early January. These adult kokanee are morphologically distinct from the kokanee mentioned above with a heavy spotting pattern along their entire dorsal surface and both caudal lobes along with varying degrees of red coloration laterally.

Finally, what has been thought to be a separate kokanee stock present in Bear Creek (sometimes referred to as Big Bear Creek) and Swamp Creek is now believed to be genetically closer to sockeye salmon and has been called a residualized sockeye stock (Young et al 2001). However, if the definition of a kokanee is landlocked or residualized sockeye then this stock would be managed as a kokanee stock

Rainbow Trout

The rainbow trout found in Lake Washington are believed to be from one of two origins. They are growing juvenile steelhead trout that will ultimately smolt and migrate to the marine waters of Puget Sound and beyond or the from non-native stocks of hatchery origin rainbow trout reared fish released into WRIA 8 and intended for a "put-grow and take" or "put and take" recreational fisheries. The hatchery produced fish are not believed to be a self-sustaining population as there is no evidence of natural reproduction and the recreational harvest is quite high.

Coastal Cutthroat Trout

Assessing populations of coastal cutthroat trout in the Cedar - Sammamish Watershed Basin is particularly difficult. Ludwa et al. (1997) estimated the abundance of coastal cutthroat trout in McAleer Creek at 8 fish per 50 meters of stream. In that same study, the number of coastal cutthroat trout in Lyons Creek was estimated at 30 fish per 50 meters of stream. Scott et al. (1986) examined Kelsey Creek in 1979 and found 4 to 5 fish per 50 meters but that was increased to 23 fish per 50 meters in 1996 (Ludwa et al 1997).

Data for trends in coastal cutthroat trout abundance in Cedar - Sammamish Basin streams is not available at the time of this report. With a paucity of specific coastal cutthroat data, it is not within the scope of this report to determine population abundance for these fish. However, observations by local fisheries biologist indicate that coastal cutthroat populations in the Cedar Lake Sammamish Basin are increasing.

NMFS found the scarcity of available information made a risk assessment extremely difficult for coastal cutthroat trout. In their final conclusion a majority of the Biological Review Team (BRT) members believed the Puget Sound ESU coastal cutthroat is not presently in danger of extinction, nor is it likely to become so in the foreseeable future. A minority believed that the ESU is likely to become endangered in the foreseeable future (Johnson 1999).

Native Char (Bull Trout)

The stock status for bull trout in the basin is unknown. Information on the presence, abundance, distribution, utilization and life history of bull trout in the Cedar - Sammamish Watershed Basin is either unavailable or extremely limited. There are reproducing populations of native char in the upper Cedar River subbasin, principally associated with Chester Morse Lake. Reproducing populations of char in the lower Cedar River, Lake Washington or Lake Sammamish or their tributaries have not been confirmed.

Presently, only one life history form, adfluvial, of bull trout is known to be present in Chester Morse Reservoir. Resident forms may be present in the upper headwaters of the Cedar or Rex Rivers or within some of their tributaries. Quantitative information concerning life history and abundance of these fish in WRIA 8 is sparse. Redd counts conducted during the from 1992 to 2000 inclusive range from 6 to 236 (Kurko pers comm) but viewing conditions during some years likely caused an underestimation of the actual number of redds.

III. Individual Sub-Watershed Synopsis

a. Streams Draining Directly to Puget Sound

Primary designated land uses: residential, commercial, and industrial

Recently documented salmonid species present: chinook (rare), coho (sparse), chum (sparse) and coastal cutthroat trout.

A number of independent streams in WRIA 8 drain directly into Puget Sound. Among the largest are Pipers Creek, Boeing Creek and Picnic Point Creek. All have correspondingly small drainage basins, are heavily impacted by urbanization and no longer function properly in supporting naturally reproducing salmonid populations.

Limiting Habitat Factors and Impacts:

Urban, commercial and industrial use that are:

- Creating fish passage barriers;
- Altered stream hydrology;
- Reduction in channel complexity;
- Reduction in LWD recruitment; and
- Generally non-functional riparian habitats

b. Marine Nearshore

Primary designated land uses: railroad, residential, commercial and industrial

Recently documented salmonid species present: All species of juvenile and adult anadromous salmonids (chinook, coho, sockeye, winter steelhead, and coastal cutthroat trout) from WRIA 8 utilize this subarea. Anadromous salmonids and additional anadromous salmonid species (e.g.: chum and pink) from other WRIAs also utilize this subarea. .

The Marine Nearshore (Nearshore) is, by definition those habitats that lie between the lower limit of the photic zone (approximately at minus 30 meters MLLW) and the upland–aquatic interface. It provides a critical link in the life history of all anadromous salmonids for physiological transition, feeding, refuge and as a migration route to and from the ocean. Most anadromous salmonid species utilize the Nearshore for juvenile rearing.

The overwhelming majority of the marine shoreline of WRIA 8 has been adversely impacted by the placement of a railroad line along 87% of the shoreline. This eliminated the supply of beach sediments that were the source of most of the sands and gravels to the beaches. The placement of the railroad line also eliminated the marine riparian vegetation that would have historically been present. These impacts not only adversely impact anadromous salmonids originating from WRIA 8 but other WRIAs as well that utilize the shorelines for support during migration.

All migratory juvenile anadromous salmonids are dependent on healthy and functioning estuarine and nearshore environments. Some species, such as chinook and chum salmon, are more dependent on healthy estuarine habitats for physiological transition and rearing prior to their ocean migration. Nearshore habitats also produce important prey items for anadromous salmonids including vertebrate and invertebrate species utilized by juveniles and forage fish (e.g.: herring, sandlance, and surf smelt) utilized by subadult and adult salmonids.

Limiting Habitat Factors and Impacts:

Industrial, urban, and commercial use that are:

- Interrupting ecosystem processes such as beach sediment recruitment;
- Alterations to water quality;
- Reduction in LWD recruitment; and
- Generally non-functional riparian habitats.

c. Hiram M. Chittenden Locks and Salmon Bay

Primary designated land uses: commercial and recreational boat traffic and surface water elevation (level) control structure for Lakes Union and Washington

Recently documented salmonid species present: chinook, coho, sockeye, steelhead, chum, pink salmon and coastal cutthroat trout.

Physical Changes: In 1916 the Ship Canal was completed, resulting in the rerouting of the outlet of Cedar - Sammamish Watershed from the Black River through the Lake Washington Ship Canal (Ship Canal) and the Hiram M. Chittenden Locks (Locks). One of the results of this project was the lowering of the surface of Lake Washington an average of 9 feet. The completion resulted in moving the estuary outlet for Lake Washington from the Duwamish River to the Ship Canal and into Salmon Bay.

The Locks were constructed as a navigation project, with a small and large lock, to provide commercial boat traffic from the marine waters of Puget Sound to the protected freshwater waters of the Ship Canal and Salmon Bay. The original project purpose and design did not include specific features to pass downstream migrating salmon and steelhead smolts.

The physical separation of the freshwater in Lake Washington and the marine waters of Puget Sound has resulted in one of the most modified estuary systems on the West Coast of North America.

Historically, Salmon Bay was a long, shallow, tidally inundated, saltwater bay that opened to Puget Sound and had tidal elevations equal with Puget Sound. At low tide, it was practically dry, the water level dropping as much as 20 feet (6.1 m) between extreme high and low tides (Williams 2000), but averaging 8 foot (2.4 m) fluctuations between high and low tide. Salmon Bay connected to Shilshole Bay through, The Narrows, where the Locks were

eventually placed. Early maps indicate a small stream (Ross Creek) drained from Lake Union into Salmon Bay. In the late 1800's, this original stream had been dredged, straightened and widened to allow for the transport of logs between Salmon Bay and Lake Union. With completion of the Lake Washington Ship Canal, the Fremont Cut, and Salmon Bay waterway, a navigable connection between Lake Union and Salmon Bay was established.

Currently, the mile-long Salmon Bay waterway between the Locks and Shilshole Bay serves as the "estuarine" area with the Locks creating for migrating adult and juvenile salmon an abrupt transition between fresh and marine waters. This area is not an estuary formed by river action and associated deposition, but was historically influenced by tidal action up to the Fremont Cut. As a result, this area lacks the diversity of habitats and brackish water refuges characteristic of other (unaltered) river estuaries and over 1,300 acres of shallow water and wetland habitat were lost from the implementation of the Locks and Ship Canal.

Limiting Habitat Factors and Impacts:

The Locks are a unique feature that:

- Caused fish passage delays and mortalities;
- Created a highly altered estuary;
- Thru dredging, filling and bank hardening created a loss of over 1,300 acres of shallow water and wetland habitats;
- Simplified the remaining channel; and
- Adversely impacted water quality.

d. Lake Union and Ship Canal

Primary designated land uses: commercial and recreational boat traffic, water dependent industrial and commercial use with upland areas primarily in residential, commercial and industrial uses.

Recently documented salmonid species present: chinook, coho, sockeye, steelhead, rainbow and coastal cutthroat trout.

Physical Changes: The construction of the Lake Washington Ship Canal (completed in 1916) created a connection between Lake Washington, Lake Union, and Puget Sound where previously there had been none. Lake Union and what is now known as Portage Bay were originally separated from Lake Washington and Union Bay by a natural ridge. Historically, Lake Union is believed to have been a separate drainage basin fed by underground springs and intermittent creeks. By 1885, a narrow canal, which served as a log chute, had been excavated between Lake Washington and Lake Union. As part of construction of the Ship Canal, a minimum 100 foot-wide navigable passage was constructed between the two lakes and between Lake Union and the original Salmon Bay.

The overwater coverage, bulkheads, and shoreline armoring associated with land uses is extensive. As a result, there is relatively little shallow water habitat (natural or altered) along

the Lake Union shorelines. Portage Bay, however, has retained shallow water habitat. The south side of Portage Bay, portions of the Gas Works Park shoreline, and small areas at the south end of Lake Union are the only areas that have retained any seemingly natural shoreline characteristics.

Limiting Habitat Factors and Impacts:

Lake Union and the Ship Canal are unique features in WRIA 8 that:

- Degraded water quality through an increase in water temperature;
- The riparian shoreline of Lake Union is highly altered from its historic state;
- Historic practices and discharges into Lake Union and the Lake Washington Ship Canal have contributed to the contamination of bottom sediments;
- Thru dredging, filing and bank hardening simplified the historic channel;
- Thru dredging, filling and bank hardening simplified the historic stream channel; and
- Non-functional riparian habitats.

e. Lake Washington

Primary designated land uses: recreational boat traffic, water dependent commercial use, shorelines primarily single and multi family residential structures with upland areas primarily in residential, commercial and industrial uses.

Recently documented salmonid species present: chinook, coho, sockeye, kokanee, steelhead, rainbow and coastal cutthroat trout.

Physical Changes: Lake Washington is the second largest natural lake in Washington State with a surface area of 22,138 acres. The lake drains to Puget Sound via the Lake Washington Ship Canal, an artificial waterway 8.6 miles long. The main inflow to the system is the Cedar River, which contributes about 55 percent of the mean annual inflow. The Sammamish River contributes approximately 27 percent of the surface flow to the lake.

Lake Washington has experienced a series of physical and limnological changes that began in 1916 when the natural outlet of the lake, the Black River, was blocked, and the outlet was changed to the Ballard Locks. At the same time, the Cedar River was redirected to increase the amount of flow into Lake Washington. These actions lowered the lake's level by about 10 feet, exposed 5.4 km2 of previously shallow water habitat, reduced the lake's surface area 7.0 percent, decreased the shoreline length by about 12.8 percent, and eliminated much of the lake's wetlands. Historically, the lake level varied by up to 6.5 feet during flood events. Currently the level of Lake Washington is not allowed to fluctuate more than 2 feet.

The shoreline of the lake has been extensively altered. Historically, more commercial development was located on the lakeshore, but as the population in the watershed has grown, the demand for residential waterfront property increased significantly. The majority of the shoreline is now urban, residential, with the exception of a few commercial and industrial developments. Thirteen incorporated cities now border the lake.

As the watershed has developed, dredging, filling, bulkheading, and the construction of piers, docks, and floats have occurred in shoreline areas. An estimated 82 percent of the Lake Washington shoreline has been bulkheaded. There is 33.2 miles of Lake Washington shoreline within the Seattle city limits of which 31.5 miles (or 95 percent) was classified as unretained (i.e., not hardened) in 1999 (Weitkamp et al. 2000). Overall, 70.65 percent of the Lake Washington shoreline is retained by either rip-rap or bulkheads, while 29.35 percent of the shoreline is unretained and is either beach, naturally vegetated, or landscaped.

In 1999, there were an estimated 2,737 piers and docks along the shore of the lake that collectively covered about 4 percent of the lake's surface within 100 feet of shore (Toft in prep). This estimate did not include marinas, moored vessels, commercial developments and bridges. This represents an overall frequency of 36 docks per mile. In 1942 there were an estimated 1,122 docks (Hockett 1976). The 1999 counts represent an increase of 1615 docks from 1942. The annual percent increase in new docks has been steadily decreasing from 5.7 % in the 1940's, to 1.8 % in the 1960's and 0.5 % during the 1990's. The annual percent of recreational docks has been increasing at about the same rate as the total dock count but the annual percent increase of large marina dock complexes increased during the late 1970's and 1908's, leading to a doubling in the number since 1960 to an overall count of 111 (Toft in prep). These figures do not account for increases or decreases in the size of the docks.

Much of the large woody debris that was likely associated with the lake's shore has been eliminated. The only "natural" shoreline remaining in Lake Washington is in the vicinity of St. Edwards Park, which represents less then 5 percent of the lake's shoreline. A recent survey of the lake's shoreline under the City of Seattle's jurisdiction indicated that "natural vegetation" was present along only 22 percent of the northern shoreline and 11 percent of the southern shoreline.

The limnological characteristics of Lake Washington have undergone dramatic changes during the last 50 years. Except for combined sewer overflows, sewage effluent was completely diverted from the lake by 1968 and the lake subsequently reverted to a mesotrophic state. The major sources of phosphorus inputs to the lake are now from tributary streams. As a result of the diversion of sewage, several major changes in the zooplankton community occurred. Most notably, beginning in 1976, *Daphnia* became the dominant pelagic zooplankton taxa.

Cleanup of the lake resulted from the formation of METRO in the 1950's, which rerouted sewage discharges to Puget Sound. The cleanup of Lake Washington due to the rerouting of sewage effluent provides one of the best examples anywhere of a successful, large-scale, regional restoration program.

In addition to changes in the lake's littoral zone and limnology, exotic plants and animals (i.e., non-native) have impacted the Lake Washington ecosystem. Twenty-four non-native fish species have been identified in Lake Washington. Some of these species are known to prey on juvenile salmon (e.g., smallmouth bass) while others are potential competitors with juvenile salmonids for food.

Nine introduced, non-native plant species are currently present in Cedar - Sammamish Watershed. Certainly one of the most visible, and also likely the most significant is Eurasian watermilfoil, an exotic aquatic plant, which was introduced into Lake Washington in the 1970's.

Limiting Habitat Factors and Impacts on Lake Washington:

- The riparian shoreline of Lake Washington is highly altered from its historic state. Current and future land use practices all but eliminate the possibility of the shoreline to function as a natural shoreline to benefit salmonids;
- Introduced plant and animal species have altered trophic interactions between native animal species;
- The known historic practices and discharges into Lake Washington have contributed to the contamination of bottom sediments at specific locations;
- The presence of extensive numbers of docks, piers and bulkheads have highly altered the shoreline; and
- Riparian habitats are generally non-functional.

f. Lake Washington tributaries (except the Cedar River)

Primary designated land uses: primarily residential, commercial and industrial.

Recently documented salmonid species present: chinook, coho, sockeye, kokanee, steelhead, rainbow and coastal cutthroat trout.

The tributaries of Lake Washington are among some of the most altered hydrological streams in the Puget Sound Region. They low gradient streams, have a hydrology pattern generally dependent on rainfall and groundwater and not snowpack, and exist in heavily urbanized settings and are subjected to the adverse habitat impacts that accompany this setting. These drainage basins generally have high levels of impervious surfaces, altered hydrologic regimes, loss of floodplain connectivity, poor riparian conditions and water quality problems.

Limiting Habitat Factors and Impacts on Lake Washington tributaries

Land use practices have resulted in:

- Numerous known and unknown blockages;
- Pool habitat is limited with very few deep pools, off-channel habitat, instream complexity, riparian cover and refugia habitat is lacking and little LWD is available;
- The hydrologic connectivity to the floodplain has been degraded due to streambank hardening;
- The riparian buffers typically are inadequate and often fragmented;
- Changes to the natural hydrologic regime; and
- There are high levels of impervious surfaces.

g. Cedar River (lower and upper) and its tributaries

Primary designated land uses: In the lower Cedar River reaches a combination of industrial, commercial, residential use transitioning into agricultural and forestry as one moves upstream outside of urban growth boundaries. In the upper Cedar River the predominant land use is transitioning from commercial forestry to preservation of forests inside the City of Seattle municipal watershed.

Recently documented salmonid species present: chinook, coho, sockeye, kokanee, steelhead, rainbow and coastal cutthroat trout. In the upper watershed native char (Bull trout) have been documented.

The lower Cedar River tributaries are low to moderate gradient streams, have their origins in rain-on-rain elevations, and exist in urbanized settings with the adverse habitat impacts that accompany this setting. The downstream reaches generally have high levels of impervious surfaces, altered hydrologic regimes, loss of floodplain connectivity, poor riparian conditions and water quality problems. As one moves upstream, habitat conditions show improvement but in many instances do not meet many of the criteria necessary for properly functioning habitats important for salmonid survival. The Cedar River is also the largest (by volume) input of water into Lake Washington.

The City of Seattle began to divert water out of the upper Cedar River in 1901 and access for anadromous fish has been denied since that time. The reintroduction of anadromous fish is scheduled to occur by 2003(?). Land use of the upper watershed has historically been a mixture of commercial timber harvest and preservation for the City of Seattle water supply. In 1995 the City of Seattle, who owns 99.4% of the upper watershed, placed a moratorium on timber harvest and in its place initiated an emphasis on protection and restoration of lands in the watershed.

Limiting Habitat Factors and Impacts on Lake Washington tributaries

Land use practices have resulted in lower Cedar River and its tributaries:

- Numerous known and unknown blockages;
- Bank hardening features (e.g.: levees) that have caused scouring, reduced side channel and off-channel habitats;
- Pool habitat is limited with very few deep pools, instream complexity, and refugia habitat is lacking and little LWD is available;
- The hydrologic connectivity to the floodplain has been degraded due to streambank hardening;
- A reduction in forest cover and increasing impervious surfaces;
- Rechanneling of specific stream reaches that limits lateral stream migration to facilitate roads and protect property;
- The riparian buffers typically are inadequate and often fragmented; and
- Some streams have high levels of impervious surfaces.

Land use practices have resulted in upper Cedar River and its tributaries:

Generally speaking, these lands are in a state of protection and in recovery from recent logging in some areas;
The Landsburg Diversion Dam is still a blockage to anadromous fish but anadromous fish are scheduled to be allowed upstream with the construction of passage facilities in 2003

h. Sammamish River and its tributaries

Primary designated land uses: Residential, open space and recreational areas, urban commercial, residential and agriculture.

Recently documented salmonid species present: chinook, coho, sockeye, kokanee, steelhead, rainbow and coastal cutthroat trout.

The Sammamish River corridor is a distinct, regional landscape feature, which originates at the north end of Lake Sammamish and ends at the river mouth at the northern tip of Lake Washington. The river itself drains a watershed of about 240 square miles, of which 97 square miles are in the Lake Sammamish basin, 50 are in the Bear Creek basin, 67 are in the combined basins of Little Bear, Swamp and North creeks, and the remaining 26 in small sidewall streams and the valley floor comprise this subarea. The current river channel is 13.8 miles long.

The Sammamish River corridor can be divided into two reaches, based on topography and, to a lesser extent, land use. The lower corridor extends from R.M. 4.5 to R.M. 0.0 on Lake Washington. It has a much narrower, topographically constrained drainage area, which includes the downtown cores of the cities of Bothell and Kenmore but also some open space areas. The lower reach includes two large salmon-bearing streams, Swamp Creek and North Creek. A major King County sewer line runs underneath the Sammamish River Trail, which is adjacent to most of the river. The sewer line and the trail create potential constraints for restoration projects on their side of the river (mostly the right bank). From the standpoint of planning, the trail is also important for the recreational use it receives and the public ownership it provides.

The upper river corridor extends from the head at river mile (R.M.) 13.8 north to R.M. 4.5 through a floodplain valley that is more than one-mile wide in places. Two salmon-bearing streams are located in the upper reach: Bear Creek and Little Bear Creek.
Prior to Euro-American settlement, the Sammamish River had a complex, highly sinuous, meandering channel and abundant "swampy" areas that were filled with peat and diatomaceous earth.

Prior to the lowering of Lake Washington, there was generally about an 8.4-foot elevation difference between Lake Sammamish and Lake Washington. The river lost most of this elevation in its upper reach; backwater effects from Lake Washington appear to have extended beyond the confluence with Little Bear Creek. This backwatered area included extensive forested wetlands, especially at the mouth of North Creek. The Sammamish River was historically approximately twice as long as it is today, and overflowed its banks regularly. Its

corridor was densely forested with cedar, hemlock and Douglas fir, with willows and deciduous vegetation dominating close to the river banks.

The river corridor was heavily logged from the 1870s through the early 20th Century, by which time it had been essentially cleared of its old growth forest. Farming was attempted in the floodplain, but became feasible on a much larger scale after the opening of the Chittenden Locks in 1916, which lowered Lake Washington about nine feet, effectively draining most of the sloughs and wetland habitats along much of the corridor, especially in the lower reach. Lake Sammamish was lowered by this action as well, which decreased the elevation difference between the lakes to approximately twelve feet, reducing the river current somewhat. Around this same time, farmers in the Sammamish Valley formed a drainage district, which began to straighten the upper reach of the river to improve farmlands. By the mid-1920s, the river had largely been placed in its current location, though not at its current depth. The lowering of the lake, the channelization of the river and the construction of drainage ditches in the river valley eliminated much of the complexity of the floodplain, including wetlands, side-channels and many spring-fed streams that had flowed into the river from neighboring hillsides. Beginning in 1962, the U.S. Army Corps of Engineers systematically dredged and channelized the mainstem Sammamish River into its current conformation, primarily as a flood control project to prevent flooding of adjacent farmland during high spring flows. This action deepened the river by five feet throughout the valley and hardened the river's banks throughout most of its length, dramatically decreasing its remaining connection with the floodplain and cutting off most of the smaller streams to the river as resulting in a loss of salmonid refugia and/or forage areas

The Bear Creek subbasin represents the most important salmonid bearing system in the Sammamish River geographic area. The Bear Creek drainage basin covers approximately 32,100 acres (50 square miles). Throughout the basin are more than 100 miles of streams, nine (9) lakes, and over 2000 acres of identified wetlands.

The basin landscape and hydrologic network of streams have changed markedly in the past 150 years from primarily forest to a mix of forest, grass, and impervious surfaces. The landscape of the Bear Creek basin in 1985 was a mix of forest (71 percent), grass (17 percent), wetland (9 percent), and effective impervious surfaces (3 percent) (King County, 1989). The Bear Creek Basin Plan completed in 1990 identified large portions of lower Bear, Evans, and Cottage Lake Creeks needing habitat restoration.

One of the unique resource areas in this subbasin is Cold Creek. This cold-water spring is 5 to 7° C colder than the remainder of Bear Creek stream water temperatures. Bear Creek acts to cool the summer and early fall water temperatures in the Sammamish River downstream of the confluence.

Limiting Habitat Factors and Impacts on Lake Washington tributaries

In the Sammamish River and its tributaries land use practices have resulted in:

- Numerous known and unknown blockages;

- Bank hardening features (e.g.: levees) that have caused scouring, reduced side channel and off-channel habitats;
- Pool habitat is limited with very few deep pools, instream complexity, and refugia habitat is lacking and little LWD is available;
- The hydrologic connectivity to the floodplain has been degraded due to streambank hardening;
- A reduction in forest cover and increasing impervious surfaces leading to hydrologic disruption to natural stream flows, increased sedimentation and decreased water quality;
- Rechanneling of specific stream reaches that limits lateral stream migration to facilitate roads and protect property;
- The riparian buffers often are inadequate and fragmented; and
- Some stream basins have high levels of impervious surfaces.

i. Lake Sammamish

Primary designated land uses: Residential, open space and recreational areas, urban commercial, residential and agriculture.

Recently documented salmonid species present: chinook, coho, sockeye, kokanee, steelhead, rainbow and coastal cutthroat trout.

Lake Sammamish is located approximately 16 kilometers east of Seattle and is situated within the northern end of the 223 km^2 Sammamish Watershed. The lake provides a wide range of recreational and natural resource opportunities. The majority of the shoreline is privately owned; with only a few public parks that are located on the lakeshore. Water quality plays a key role in the lake's ecological health.

Lake Sammamish is approximately 13 kilometers long and 2 kilometers wide with a surface area of 19.8 km^2, a maximum depth of 32 meters and a mean depth of 17.7 meters. The major tributary to the lake is Issaquah Creek, which enters at the south end and contributes approximately 70 percent of the surface flow (and phosphorus load). Tibbetts Creek to the south, and Pine Lake Creek to the east, contribute about 6 percent and 3 percent of the flow, respectively. Surface water discharge from Lake Sammamish is through the Sammamish River at the north end of the lake, where a flow control weir at Marymoor Park controls the discharge.

Limiting Habitat Factors and Impacts on Lake Sammamish

In Lake Sammamish anthropogenic factors that effect the natural production of salmonids include:

- Alteration of the type and abundance of salmonid predators in Lake Sammamish have been identified as a probable factor of decline;
- Select areas of the Lake Sammamish contain elevated concentrations of sediment-associated contaminants;

- Eurasian water milfoil locally degrades water quality by reducing dissolved oxygen levels below minimum requirements for salmonids. The invasive nature of Eurasian water milfoil has likely decreased the overall diversity of macrophytes throughout Lake Sammamish; and
- The riparian buffers often are inadequate and fragmented.

j. Lake Sammamish Tributaries

Primary designated land uses: Residential, open space and recreational areas, urban commercial, forestry, and agriculture.

Recently documented salmonid species present: chinook, coho, sockeye, kokanee, steelhead, rainbow and coastal cutthroat trout. A single observation of two bulltrout has also been reported.

The East Lake Sammamish Tributaries encompass approximately 16 square miles and contains six main streams and 40 inventoried wetlands. There is a total of 27 miles of streams, of which only 4 miles are accessible to anadromous fish. These streams are currently inaccessible to salmonids due to erosion, dredging and culvert blockages, as well as natural stream channel gradient. Historically, there were 8 to 10 more miles accessible to anadromous fish. Most streams are short and steep, running through incised ravines. The urbanization of the basin has resulted in a variety of hydrologic and physical changes within the stream channels. Increases in peak flows and duration of high flows has resulted in expanding channel size, increased bank erosion, and increases in sediment deposition disrupting the aquatic habitat.

The Issaquah Creek Basin encompasses approximately 61 square. The basin's headwaters flow from the steep slopes of Cougar, Squak, Tiger and Taylor Mountains. Elevations range from more than 3,000 feet at the peak of Tiger Mountain to near sea level at the mouth of Issaquah Creek. The basin includes Issaquah Creek and its tributaries Holder, Carey, Fifteenmile and McDonald Creeks and the North and East Forks of Issaquah Creek as well as Tibbetts Creek.

Data from 1995 indicates that more than 75 percent of the basin was forested, with the remainder in wetlands, pastures, urban (less than 10 percent), and cleared areas. Currently, 30 percent of the basin is zoned commercial forest production, 12 percent is within the urban growth boundary, and the remaining in rural zoning (58 percent). Over 40 percent of the lands are in public ownership. Population increases in the basin and resultant pressure to develop rural lands are expected to continue. The population of the Issaquah Creek Basin is projected to increase by 18 percent between the year 2000 and 2020.

The Lewis Creek Basin drains a 1,209-acre area originating from the north slopes of Cougar Mountain. Lewis Creek flows northeasterly approximately 1.5 miles before it empties into the southern end of Lake Sammamish. Lewis Creek has numerous branched tributaries, forming a highly dendritic hydrologic pattern. Lewis Creek and its main tributaries are high gradient and

active streams with high sediment transport capacities. A multispectral analysis conducted in 2000 shows the basin has approximately 28 percent impervious surfaces

Limiting Habitat Factors and Impacts on Lake Sammamish

In Lake Sammamish tributaries the anthropogenic factors that effect the natural production of salmonids include:

- Known and unknown blockages;
- In some basins high levels of impervious surfaces have resulted in changes to hydrology;
- LWD is generally lacking;
- The loss of channel complexity as expressed through off-channel rearing refugia is believed to limit natural production of some salmonid species; and
- The riparian buffers often are inadequate and fragmented.

iv. CONCLUSIONS

There are solutions to all of the problems outlined in this report. Levees can be set back and off-channel habitats recreated. Riparian buffers can be reestablished that meet the needs of salmonids and then the vegetation allowed to mature. As an interim measure LWD can strategically be added to create niche habitats required by adult and juvenile fish.

The most basic need, shared by all life stages of all salmonid species is **water**. Water is absolutely essential to the needs of salmonids in both quality, quantity, and timing. As these urbanized basins continue to experience development and additional water is demanded by human residents there will continue to evolve a classic conflict between the needs of the fish and those of the humans. Adequate base flows in the streams, rivers and lakes will need to be set aside to meet the needs of fish. In urbanized basins protection from extreme high flows may be as important to base flows. It is not so much that humans have concentrated themselves in these basins, but what we do to the land and the method by which water is released into the streams and rivers. Finally, good water quality must be maintained.

The Limiting Factors Report is a coordinated step toward salmonid recovery in WRIA 8. It provides much of the necessary groundwork for a comprehensive recovery and conservation planning effort. The information presented in this report is a start. As new information is brought forward or is developed any conservation and recovery effort should be modified as necessary.

What This Report is Not

This report should be considered a work-in-progress. It does not examine the roles of hatcheries or harvest management. These other two "H's" are inextricably linked, especially in basins like the Lake Washington Basin that are among the most heavily altered systems in Pacific Northwest.