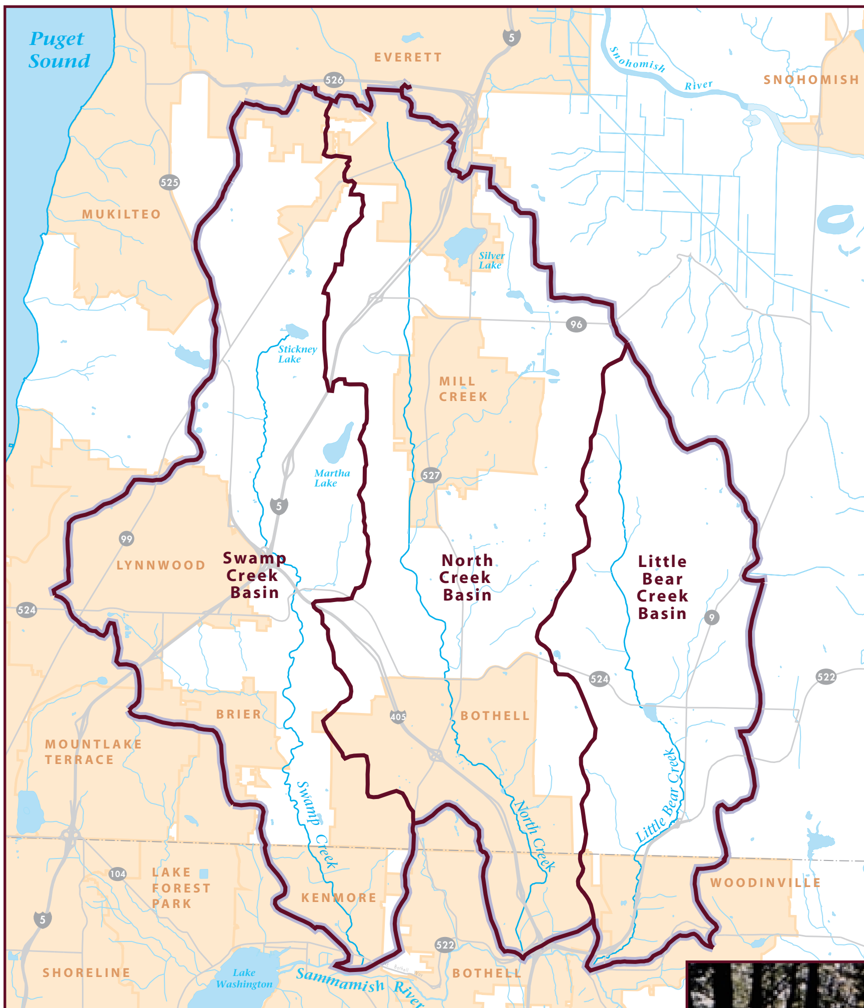
# Habitat Inventory and Assessment of Three Sammamish River Tributaries:

# North, Swamp and Little Bear Creeks




**May 2001**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**KING COUNTY**

# 1999 Habitat Inventory and Assessment of Three Tributaries to the Sammamish River:

# North, Swamp, and Little Bear Creeks

**May 2001**

Report to:

King County Department of Natural Resources
Wastewater Treatment Division

King County Department of Natural Resources
Water and Land Resources Division

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# EXECUTIVE SUMMARY

Declining stocks of native salmon, increasing urbanization, and the listing of the Puget Sound chinook ESU as threatened under the Endangered Species Act have intensified interest in assessing instream habitat conditions in King County streams. Little current information about the habitat condition of the larger northernmost tributaries to the Sammamish River (i.e. Swamp Creek, North Creek, and Little Bear Creek) is available. These streams are the three major northern tributaries of the Sammamish River, which drains into Lake Washington, and ultimately into Puget Sound. Approximately 95 percent of the combined area of the three watersheds are within Snohomish County, with the lower portion of each sub-basin located in King County.

From August to November of 1999, King County conducted habitat assessments on these three streams using methods derived from standard assessment protocols. Based on knowledge of stream location and condition and a review of aerial photographs, King County defined the preliminary assessment areas and divided each creek into 11-15 segments that were similar in channel morphology and surrounding land use characteristics (Appendix A and Maps 1-3). The goals of the habitat assessment project for the north Lake Washington tributaries were threefold: (1) characterize the habitat quality, primarily for salmonids; (2) establish a baseline for future evaluation of trends in habitat quality and watershed function; and (3) inform the process of prioritizing areas for restoration and preservation.

The results of the habitat assessments indicate that channel and habitat structure of a number of the segments in all three streams are frequently degraded relative to values from published “properly functioning conditions” conditions for the Puget Sound or the Pacific Northwest region. For example, bankfull width to depth ratios are often larger than prescribed 'properly functioning conditions' ratios, suggesting that channel dynamics are unstable. Pool habitat frequencies are lower than standards and of low quality in most segments. This decreased slow water “rearing” habitat may limit juvenile carrying capacity as well as hinder upstream migration by adult salmon.

These data suggest that processes creating natural habitat structure may be changed from natural conditions. Analysis of basin land cover reveals less forested and increasingly impervious cover, as well as a significant loss of wetlands, which has been shown to alter the basin hydrologic regime. This change in basin hydrology leads to destabilization of channel morphology. Riparian vegetation also seldom resembled natural conditions and was nearly completely depleted of sources of high quality, coniferous large woody debris (LWD). Dominant riparian vegetation included landscaping, shrubs, and deciduous forest. LWD frequencies were low in most segments of all three streams. The low amounts of instream LWD may be partially responsible for the low pool frequency. LWD frequency was closely related to pool frequency in most segments of Swamp, North and Little Bear creeks, as it is in undisturbed streams of the Pacific Northwest.

These data are important baseline information for any restoration projects that might occur in the basins, as well as for monitoring changes in habitat quality. Data contained herein may be used for a limiting factor analysis for the threatened chinook salmon as well as other salmonid species in these basins. The data collected may also be analyzed at a finer spatial scale to inform project planning at more localized sites or among basins for regional project planning. Land use planning, transportation planning, and stormwater management planning in these basins can also benefit by using this data. WRIA 8 reconnaissance assessments and watershed planning for salmonid species recovery have utilized these data and will likely continue to do so.

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# INTRODUCTION

Over the past century, the historic range of Pacific salmon in the Pacific Northwest (PNW) has been reduced by nearly 50 percent (Nehlsen et al. 1991). The resulting reduction in salmonid abundance and diversity has led to the listing of several salmon stocks in the PNW under the Federal Endangered Species Act (ESA). There is no single cause for this decline, but significant contributors are human impacts on the aquatic ecosystems that support salmon populations (NRC 1996). Activities such as timber harvest, mining, agriculture, grazing, dams, fishing, hatcheries, and urbanization have all contributed to the “salmon problem.” Urbanization (residential, commercial, and industrial) has been especially hard on small streams in the lowland ecoregions of the PNW (May et al. 1997). These small streams provide critical habitat for all freshwater life stages of salmonids (Williams et al. 1975). Salmon spawning in the three major tributaries to the Sammamish River, Swamp, North, and Little Bear creeks is much reduced from historic levels (Schultz and Students 1935, Ostergaard 1998); (Table 1).

**Table 1. Current anadromous salmonid distribution in Swamp, North and Little Bear creeks (Williams et al. 1975, modified from May et al. 1997).**

| Stream | Coho | Chinook | Sockeye | Chum | Pink |
|---|---|---|---|---|---|
| Swamp | X | X | X | | |
| North | X | X | X | | |
| Little Bear | X | X | X | | |

Stream habitat loss and degradation are often cited as important limiting factors to salmon (Salo and Cundy 1987, Groot and Margolis 1991, Nehlsen et al. 1991, NRC 1996, Myers et al. 1998). High-quality rearing habitat is critical for the survival of juvenile salmonids from emergence to smolt migration. Adequate total pool area and residual depth along with sufficient cover are necessary for successful juvenile salmonid rearing (Konopacky 1984, Bjorn and Reiser 1991). Juvenile chinook, for example, utilize high-quality pools (good cover and relatively deep) when they are in transition from emergence to smoltification (Bjorn and Reiser 1991). Salmonids often shift their habitat preferences seasonally, primarily due to changes in flow and usable stream area. For example, juvenile coho prefer off-channel, backwater, or wetland/ beaver ponds during the winter, and show a preference for main-channel pools formed by large woody debris in the summer months (Nawa et al. 1990, Nickelson et al. 1992, Peterson et al. 1992). In addition, adult chinook require deep staging pools for their upstream migration (Giger 1973).

Anthropogenic activities in the watershed can have detrimental effects on salmonid spawning habitat (Bisson et al. 1992). Some studies indicate that the optimum pool to riffle ratio for salmonid production and over-winter survival is approximately 1:1 (Nickelson et al. 1992). On the other hand, Montgomery et al. (1999) found that chinook and coho redd frequency increased with decreasing pool spacing (i.e. increasing pool frequency) in tributaries to the Skagit River. Streambed substrate is also critical to spawning success, incubation, and survival to emergence for salmonids. Each salmonid species has a specific preference for spawning habitat conditions (Kondolf and Wolman 1993), but all salmonids require spawning gravels that are highly permeable and relatively free of fine sediment (McNeil 1966, Chapman 1988, Crisp and Carling 1989). The substrate also provides benthic habitat for macroinvertebrates, freshwater mussels, and bottom-dwelling fish such as sculpin. Increased over-land flow (including runoff)—and stream bank erosion caused by anthropogenic activities in the watershed—contribute to sediment deposition in the interstitial spaces of spawning gravels. This sediment suffocates biota reliant on well-oxygenated intragravel flow (Hartman and Brown 1987).

Large woody debris (LWD) performs numerous instream functions contributing to the formation of high quality aquatic habitat. LWD is a key component for maintaining a high degree of habitat complexity or spatial heterogeneity in streams (Maser et al. 1988). LWD maintains the hydraulic stability of critical instream habitat features, especially pools (Bilby and Ward 1991). LWD dissipates hydraulic energy during peak flows, providing high-flow refuge for salmonids (Bilby 1984). In addition, LWD stabilizes streambeds by minimizing scour and provides excellent cover and habitat diversity (Harmon et al. 1986) for salmonids. With the loss of LWD in the channel, stream morphology shifts away from the characteristic pool-riffle habitat to a more simplified, glide-dominant channel form, with a subsequent decrease in available rearing (pool) habitat.

Riparian forests play a critical role in the control of stream channel morphology because they stabilize the active floodplain and are the primary source of LWD. These "biophysical" interactions are particularly important to PNW stream ecosystems (Rot 1995). Riparian forest composition can determine the longevity and function of LWD in the channel. LWD derived from conifers, especially western red cedar (*Thuja plicata)* tends to be larger than that from deciduous species, thus reducing the chance of being washed downstream. LWD from conifers are also significantly more resistant to decay. This increased resistance results increased longevity of instream structural components (Harmon et al. 1986).

The most commonly recognized functions of the riparian corridor include (Gregory et al. 1991, Naiman and Bilby 1998, Naiman et al. 2000)

- Provide canopy-cover shade necessary to maintain cool stream temperatures required by salmonids and other aquatic biota. The optimal temperature range for most salmonid species is 10-14$^{o}$ C but can vary depending on species and life history stage (Bjorn and Reiser 1991, NOAA 1996).
- Provide organic debris, leaf litter, and other allochthonous inputs that are a critical component of many stream food webs.
- Stabilize streambanks, minimize streambank erosion, and reduce the occurrence of landslides, but still provide stream gravel recruitment.
- Reduction of fine sediment input into the stream system through floodplain sediment retention and vegetative filtering.
- Filter and vegetative uptake of nutrients and pollutants from groundwater and stormwater runoff.
- Provide recruitment of large woody debris (LWD) into the stream channel.
- Provide critical wildlife habitat including migration corridors, feeding and watering habitat, and refuge areas during upland disturbance events.

A large proportion of coniferous species, a wide buffer, and few breaks in the riparian corridor indicate high riparian integrity (May and Horner 2000).

Modifications to natural land cover and the drainage network that result from urbanization also change the hydrologic regime of the basin surfaces (Horner and May 1999) (Figure 1 and Figure 2). Under natural land-cover conditions found in the PNW, stormwater runoff is produced only during very large storm events (Booth 1991). As impervious surface area increases with urbanization, the sub-surface dominated hydrologic regime shifts to one dominated by surface runoff. Urban development also adds numerous artificial channels to the natural stream system. The most common of these artificial channels are road-crossings (along with roadside drainage-ditches) that act as conduits for surface runoff and stormwater outfalls. Little or no infiltration or storage is associated with these artificial stormwater routing systems and as a result the runoff volume is dramatically increased.

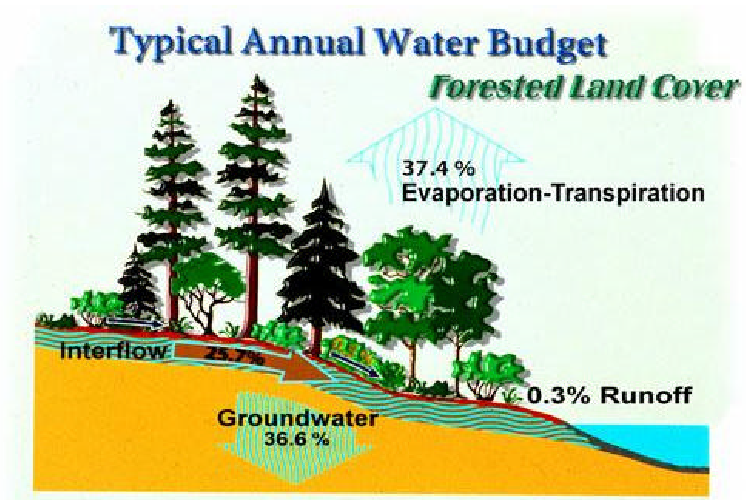


**Figure 1. Typical annual water budget in watersheds with forested land cover.**

The stream habitat assessments implemented by King County in 1999 and described within this report attempted to quantify the instream, riparian and watershed conditions that contribute to high quality aquatic habitat. Stream habitat evaluation is a core element of several recently implemented regional programs. Specifically, King County is in the process of siting a new wastewater treatment facility, which requires a Habitat Conservation Plan (HCP). Watershed and stream habitat characteristics, along with a variety of other information, will be used to select the most appropriate site for the treatment plant and if necessary to identify mitigation opportunities. In addition, the Water Resource Inventory Area 8 (WRIA 8, Greater Lake Washington Watershed) technical committee is compiling stream habitat information as part of the WRIA planning process. This compilation and assessment will result in identification of areas that require stream habitat restoration and preservation. Finally, the Sammamish River Ecosystem Restoration Study (216 Program) is a cooperative program between the Army Corps of Engineers and King County created to enhance habitat in the Sammamish River and its tributaries. The stream habitat assessment discussed in this report is intended to provide information about North, Swamp, and Little Bear creeks to benefit these and other projects and also supports other land use planning and Sensitive Areas regulation.

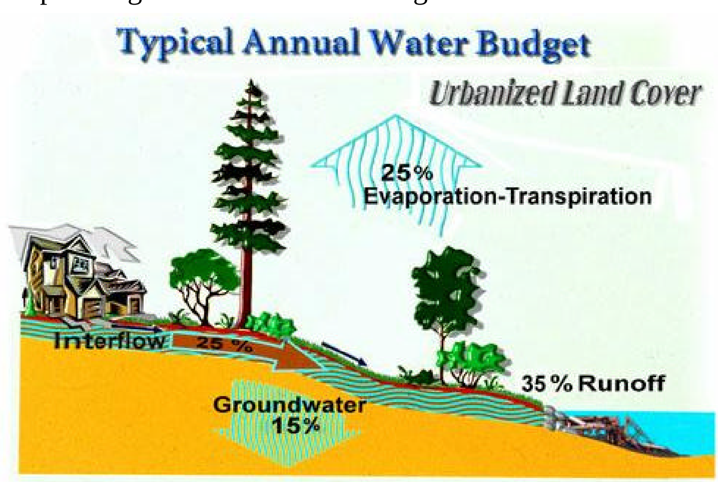


**Figure 2. Typical annual water budget in an urbanized watershed.**

Little current information about the habitat condition of the larger, northernmost tributaries to the Sammamish River (i.e., Swamp Creek, North Creek, and Little Bear Creek) is available; stream assessments have not been conducted since 1995. Approximately 25 percent of the perennial segments of these three streams were evaluated as part of dissertation and continuing research by May et al. (1997) using methods similar to those used in the assessments described in this report. Continued development, restoration efforts, and large storms may have changed conditions since the 1995 assessments (May et al. 1997).

From August to November of 1999, King County, in cooperation with Snohomish County, conducted habitat assessments of these three streams using the methods described herein. The goal of the habitat assessment project for the north Lake Washington tributaries was threefold: (1) characterize the streams in terms of the habitat quality for aquatic organisms; (2) identify areas of priority for restoration and preservation; and (3) establish a baseline for future evaluation of trends in habitat quality and watershed function. This report describes how King County characterized the streams and established baseline data for future monitoring projects and identification of priority restoration areas.

# ASSESSED STREAMS

The instream habitat and basin conditions of Swamp, North, and Little Bear creeks were assessed and the data collected are evaluated in this report. The combined area of the three watersheds is 44,600 acres with North Creek comprising the largest area at 19,000 acres, followed by Swamp Creek at 16,000 acres, and Little Bear Creek at 9,600 acres. The climate and rainfall patterns in Snohomish County are typical of the Puget Sound Lowland Ecoregion, with about 75 percent of the annual precipitation falling during the winter rainy season from October through April. Most precipitation is in the form of rain, with little if any snowfall.

The geology and soil structure of the Sammamish Basin has been determined largely by the most recent glacial period (Vashon period) about 15,000 years ago. The three watersheds have their headwaters at about 500 ft elevation on the Snohomish “bench” area of glacial till and outwash soils. All three mainstems have low to moderate gradients (0-4%) as they flow from north to south into the Sammamish River Slough, an area that was once an extensive wetland. The basins are dominated by Alderwood till and Everett outwash type soils (May 1996).

The area was once almost completely forested with Douglas-fir (*Pseudotsuga menziesii*), western red cedar (*Thuja plicata*), western hemlock (*Tsuga heterophylla*), and red alder (*Alnus rubra*). Repeated logging cycles beginning in the late-1800s, followed by residential and commercial development, especially since the mid-1960s, has reduced the forested land to a fraction of the original area.

## Swamp Creek

The Swamp Creek watershed is located immediately to the west of North Creek. The mainstem Swamp Creek is approximately 18 km long with a gradient that ranges from 0-2 percent. The headwaters are located in the Paine Field and West Casino Road area of South Everett, above the intersection of State Route 99 and Airport Road. Extensive wetlands once dominated the headwaters of Swamp Creek. The upper reaches still have some large good-quality wetlands and high-quality salmonid spawning and rearing habitat, as well as one of the largest populations of freshwater mussels found in the Puget Sound Lowlands (PSL). The upper middle reaches of Swamp Creek run primarily through an area of low to moderate density suburban residential land use. In some places, the forested riparian zone is fairly wide and contains mostly mixed coniferous and deciduous forest with few road crossings.

Adjacent to the City of Brier, Swamp Creek picks up flow from its largest tributary stream, Scriber Creek. The Scriber Creek sub-basin is intensely urbanized and composed of portions of the cities of Lynnwood and Mountlake Terrace, including Alderwood Mall and a large section of the Highway 99 commercial corridor. Downstream of the Scriber confluence, Swamp Creek flows through a predominantly low-density suburban residential area. In these middle segments, large areas of forest are still common and the riparian corridor is largely intact and is of good quality. The lower segments of the creek located in King County flow through residential and commercial developments associated with the Kenmore/Bothell areas. The mainstem of Swamp Creek drains into the Sammamish River just upstream of its outlet into Lake Washington.

## North Creek

North Creek is located between the Little Bear and Swamp Creek watersheds, running north to south from its headwaters in the city of Everett to its mouth near Bothell. The mainstem is approximately 16 km long with a gradient that ranges from 0-2 percent. The headwaters of North Creek are in a heavily developed section of Everett dominated by commercial and multi-family residential development. This relatively flat area was originally dominated by forested and open-water wetlands, but is now the site of Everett Mall. The middle upper mainstem includes reaches with intact mature coniferous riparian forest, an extensive unfragmented forested wetland and open wetlands as well as bermed, channelized reaches. The City of Mill Creek, located in this section of stream is a rapidly growing community that includes large-scale planned residential communities and a large shopping center and business complex at the intersection of 164th St. SE and State Route 527.

Land use in the lower middle reaches is mostly rural residential and contains mostly intact mixed riparian forest. Below the Silver/Tambark confluence near Maltby Road, North Creek flows through an area of mostly open wetlands and then into the City of Bothell and the Canyon Park Commercial/Industrial Park. The stream is channelized through most of this segment, and the riparian zone is poor. This area has been used extensively by spawning sockeye and kokanee since the 1960's (J. Mattila, pers. comm.). Downstream of 228th Street SW in Bothell, the stream flows parallel to Interstate 405 through a mostly rural residential sub-basin until crossing into King County. The remaining segment of the stream runs through a major industrial park built on land previously converted from wetland to agriculture, before draining into the Sammamish River near Bothell.

## Little Bear Creek

Little Bear Creek has its headwaters in an area south of Seattle Hill Road. The mainstem length is approximately 12 km and the average gradient is about 0.8 percent. This area was originally dominated by forested wetlands but is currently undergoing conversion to residential development. The stream still has a large amount of riparian wetlands with several active beaver ponds. The land-use in the upper basin is primarily rural with numerous horse farms throughout the sub-basin. The upper mainstem of the creek has a predominantly young, deciduous riparian forest with several riparian wetlands. Below Maltby Road, land use is predominantly suburban with the riparian zone narrow and broken throughout. The lower mainstem of the stream runs parallel to State Route 522, a major four-lane commuter highway. The creek is heavily impacted with a poor quality riparian corridor and extensive suburban development. The lower portion of the creek runs through the commercial portion of downtown Woodinville before flowing into the Sammamish River

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# METHODS

Stream habitat assessment methods for Pacific Northwest streams abound (Overton et al. 1997, Barbour et al. 1999, Pleus and Bullchild 1999). Many agencies in the region have developed their own suites of channel features and channel feature definitions for the assessments. The habitat assessment protocol used here differs from others in that it incorporates a variety of methods used by local agencies. We have attempted to take into account the utility of each of these protocols as evaluated by Scholz and Booth (1998). In particular, methods were borrowed from 1) the Timber, Fish, and Wildlife (TFW) Ambient Monitoring Manual and a suite of other state, federal, and local protocols 2) a successful basin reconnaissance level assessment conducted by Entranco et al. (1994) that identified and prioritized reaches for restoration and preservation in the Big Bear Creek watershed. Agency, tribe, and university experts also reviewed these methods prior to implementation.

## Basin Conditions

Instream habitat is affected by conditions in the entire watershed (May et al. 1997). To examine watershed characteristics that may be contributing to habitat quality of each segment, segment sub-basins were delineated beginning at the most downstream end of the segment, including the total catchment area draining into that segment. King County GIS technicians determined sub-basin conditions for each segment using data sources listed in Table 2. Sub-basin area, percent forested vegetation (mixed, early, middle, and late coniferous forest and total), total stream length, total road length, road density, number of road stream crossings, and density of stream crossings were determined. Some of the data noted in the Table 2 must be considered approximate, because the source data coverage is incomplete, especially for Snohomish County. This applies to a majority of the data, as large portions of each watershed lie in Snohomish County. After GIS-extracted road crossing data were examined for errors, it was determined that a visual count of the crossings using 1996 orthographic photos of the basins would be more accurate. The resolution of the orthographic photos often made delineation of residential or small private roads impossible, so these data should also be considered a best conservative estimate.

**Table 2. Basin conditions source data.**

| Basin Parameter | Source | Comments |
|---|---|---|
| Area | 7.5 minute USGS digital quads. | The area of the catchment draining into the downstream most point of the segment. |
| Segment length (km) | King County GIS Hydro layers. | The length of the stream segment: Snohomish County coverage incomplete. |
| Percent forest vegetation | King County classification of a 1995 LandSat image. | Classification done by Chris Pyle, King County, using GIS. |
| Total stream length (km) within the sub-basin | King County GIS Hydro layer. | The hydro layer is not complete, especially in Snohomish County, so the total stream length is probably greater than reported. |
| Roads (km), Road density (km/km$^2$), | King County GIS Roads and Hydro layer. | Errors exist because of incomplete road and stream coverage data. A King County GIS analyst corrected obvious errors. |
| Road crossings (#/km) | King County 1996 NIES ortho-photographs. | Road Crossings data were calculated from visual analysis of orthographic photographs of the streams. |

Two important basin condition parameters, total impervious area (TIA), and total wetland area were not included in this assessment. The most recent classified Landsat image (1995) from which TIA for these basins can be calculated is now outdated and not useful for analysis of these rapidly urbanizing basins. Because road density, however, is highly correlated with TIA (May et al. 1997), road density will be used in place of TIA for this analysis. Total wetland area data are also not included in the analysis of natural cover types within the basin because of missing data in the applicable King County GIS data layers and the lack of data for the Snohomish County portion of the assessment.

# Field Methods

The mainstems and major tributaries of North, Swamp, and Little Bear creeks were assessed from their mouths at the confluence of the Sammamish River to the upper reaches of each stream located in Snohomish County. Based on knowledge of channel types, stream location, ease of future identification of the segment start and endpoints, condition and a review of aerial photographs, King County defined the preliminary assessment areas and divided each creek into 11-15 segments that were similar in channel morphology and land use characteristics (Appendix A and Maps1-3). Although stream reach morphology was not the only criteria used to define segments, start and endpoints of the Swamp Creek segments fall at the SSHIAP segment breaks, which are defined using gradient and confinement categories. In addition, the start and endpoints of North and Little Bear creeks often coincided with SSHIAP segment breaks. It should be noted that SSHIAP does not use land-use as a criterion for segment delineation as this survey did. Generally, assessments were conducted to the upper reaches of the mainstems in Snohomish County and included tributaries until low flows prevented accurate and consistent instream habitat feature identification. Areas classified as wetlands, where water depth was greater than 1.5 meters, dry channels, or where property owners restricted access were not assessed.

## *Reach Characterization*

Change in land use, riparian condition, and stream morphological character were used to define reach breaks segment. Riparian condition, land use, bank condition, and bankfull width and depth were measured and noted in homogeneous reaches (approximately 50 to 300 m in length). Location of fences and other property boundary markers were also noted. The following subsections (riparian condition and bank condition) provide descriptions of the measurements conducted in each reach.

### *Riparian Condition*

Riparian vegetation composition was visually estimated for each channel reach. Dominant and subdominant riparian vegetation categories were described for the right and left banks using the following categories:

- Forest (greater than 20 ft in height): coniferous, deciduous, or mixed
- Shrubs and/or vines
- Tall herbaceous (e.g. unmowed field)
- Short herbaceous (e.g., mowed grass, pasture)
- Impervious: buildings, roads, asphalt, etc.
- Residential landscaped (mowed lawn with ornamental shrubs/trees)

Percent shade was estimated from the center of the channel in each reach. Five cover categories were used to provide an index of riparian cover.

- 0-5%
- 6-25%
- 26-75%
- 76-95%
- 96-100%

Presence of invasive plant species was also noted.

### *Bank Condition*

Streambank condition was estimated for each designated reach using the method described by Booth (1994). Categories included:

- **Stable**: vegetated or low bars to level of low flow
- **Low Scour**: steep, raw banks only below bankfull level
- **Full Scour**: steep, raw banks above bankfull level
- **Armored**: artificial bank protection of any kind

## *Habitat Inventory*

The habitat assessment included in-channel assessments of habitat units and an inventory of large woody debris. A complete description of the stream assessment protocol used is located in Appendix B. Data were also collected on reach characteristics; these measurements included bankfull width and depth, riparian vegetation, percent shade, and bank stability.

### *Instream measurements*

Assessments were conducted in an upstream direction during low flow conditions from late August to early November. Habitat units were categorized as pools, riffles, or glides. Categories were kept simple to avoid compounding errors resulting from observer differences. The length, mean thalweg depth, wetted width, depth, as well as the residual pool depth (Figure 4), the deepest point of pool (A) minus the depth at the hydraulic control (B), were measured. Habitat units were defined as:

**Pool**: Slow water, length and width at least 1/2 the bankfull channel width and 10 cm minimum residual pool depth. Subcategories define the general type of pool, and include: scour (lateral, channel, channel confluence, plunge), dam, and backwater as defined by Overton et al. (Overton et al. 1997).

**Riffle**: Swiftly flowing, turbulent water; some partially exposed substrate; substrate cobble and/or boulder dominated (McCain et al. 1990).

**Glide**: Wide, uniform channel volume, low to moderate water velocity, little surface agitation. Anything not qualifying as pool or riffle.

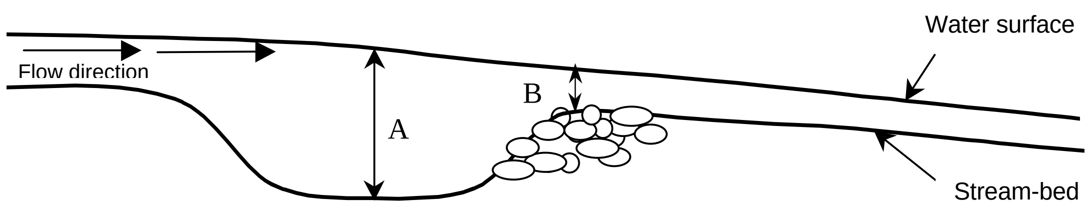


**Figure 3. Measuring residual pool depth. The deepest point of the pool (A) minus the depth at the hydraulic control of the pool (B) is the residual pool depth. The hydraulic control has been described as, where the last trickle of water would run out if the water were "turned off**."

A Pool Quality Index score (PQI) (Appendix B) was determined for each pool in the field using a rating system adopted from Platts et al. (1983). Pools received a higher rating if they were large in relation to the size of the channel, deep, and had good cover for fish. Riffle quality was assessed in the field using a riffle quality index (RQI) developed by King County staff and Chris May (UW). Riffle quality ratings were based on substrate composition, degree of embeddedness, and proximity of pools or wetlands.

### *Large Woody Debris*

Large woody debris was defined as logs at least 2 m (6 ft) long and at least 15 cm (6 in) diameter (Peterson et al. 1992) or rootwads of any size. Each piece of LWD was measured, and the stream reach and the zone it occupied were noted. Data recorded were diameter and length estimated to nearest 0.05 meter, whether the piece was coniferous or deciduous, and whether the LWD had a pool-forming function. Zones were defined as:

- **1**: within the wetted area of the stream
- **2**: not in water, but protruding below bankfull
- **3**: spanning the channel, not protruding below bankfull

### *Tributaries, Wetlands, Side Channels, and Pipes*

Tributaries, wetlands, and side channels entering or adjacent to the stream, and location, size, and function of pipes were noted. Notes were taken to further describe the habitat quality, species identification, and presence of fish and wildlife. In addition, any obvious problems or concerns such as point of discharge or withdrawal for each reach were also described. Opportunity and/or need for protection or restoration project were also noted.

### *Biology*

Presence of juvenile and/or adult fish, freshwater mussels, amphibians and other biota was noted. Juvenile salmonids, however, were not usually identified to species, although an approximation or impression of numbers or abundance was recorded. These observations were reported; however, the reader should take into account that these are notes only based on "field notes" and represent a brief "snapshot" in time and not a formal assessment of fish abundance. In addition, it should be noted that lack of an observation does not imply absence of a species from these sites.

### *Photographs*

Photographs depicting the general nature of each characterized reach or notable features were taken as the field staff proceeded upstream. Representative photos will be included in this report to illustrate typical reaches receiving low, medium-low, medium-high, and high habitat quality ratings.

# Analysis

After summarizing the instream and riparian data of each segment the values were compared to published values representing natural conditions or values that were determined to be indicative of naturally functioning conditions. In addition, a "Habitat Quality Index" (HQI) was developed in an effort to integrate several quantitative parameters to evaluate overall stream habitat quality. Stream channels dominated by wetland reaches were not evaluated in this assessment because the wetland channels were often too deep to assess, and assessed reaches could not be appropriately evaluated using the targets and standards applied to stream-type channel reaches. Wetlands have ecological significance to streams and their biota, but have different habitat/ physical characteristics than stream ecosystems.

### *Matrix of Pathways and Indicators*

In an effort to identify parameters indicative of ecosystem processes functioning in a manner that will maintain stable and healthy streams (for anadromous salmonid populations), NMFS (1996) developed the "Matrix of Pathways and Indicators" as an evaluation tool (Appendix C). This matrix presents a number of environmental parameters important to production and survival of anadromous fishes and sets three condition levels for each parameter: (1) properly functioning, (2) at risk, and (3) not properly functioning. This matrix was also adopted by the WRIA 8 technical committee as a tool for evaluating stream conditions within the Puget Sound Lowland (PSL) Ecoregion. If the data collected in these assessments could be compared with the NMFS matrix parameters, the results were presented with the matrix "properly functioning conditions" thresholds.

### *Riparian Condition*

Riparian vegetation, bank condition, and canopy cover were summarized over the length of each stream segment. Weighted means of these reach scale data were calculated by summing together reach length represented by a parameter category then dividing the total length by the total number of meters assessed in the segment. Right and left bank data were combined to determine the percentages of the segment falling into each data category.

### *Instream Habitat Parameters*

Three instream habitat parameters were measured during the assessments: riffles, pools, and LWD. The means for each parameter were calculated for each segment and compared to published values from natural conditions. The methodology for evaluating these parameters is outlined below.

#### *Riffle Habitat*

Riffle habitat in each stream segment was quantified by calculating the surface area of wetted stream channel classified as riffles. The percentage total stream habitat classified as riffle habitat was also calculated. Generally, an equal proportion of pool and riffle habitat is considered optimum, thus the riffle fraction should be 40 to 60 percent (Peterson et al. 1992).

#### *Pool Habitat*

Pool habitat in each stream was quantified by calculating the surface area of wetted stream channel classified as pools. The percentage of total stream habitat classified as pool habitat was also calculated. Target conditions for pool frequency have been established by a number of authors. Peterson et al. (1992) suggest that pools should comprise 50 percent by area in streams with a less than 3 percent gradient. Greater than 55 percent by surface area has also been recommended for streams with a 0-2 percent gradient (Washington Department of Fish and Wildlife and Western Washington Treaty Tribes 1997, Washington Forest Practices Board 1997). The NMFS Matrix of Pathways and Indicators (1996) suggests that 30 pools/km for streams 6 m wide and 35 pools/km for streams 7.6 m wide indicate "properly functioning conditions."

#### *LWD Frequency and Size*

LWD frequency was compared to published frequency ranges in natural forested systems of the pacific northwest. The low end of the natural range in several studies was 150 pieces/km (a range of 150-460 in Murphy (1989), a range of 150-400 in Ralph et al. (1994), and 140-670 for streams of similar size and gradient in Beechie and Sibley (1997). Especially large pieces of LWD initiate the formation of stable woody debris jams (Naiman et al. 2000). The Matrix of Pathways and Indicators suggests 50 pieces/ km that are at least 60 cm wide by 15 m long indicate "properly functioning conditions." Although NMFS did not categorize this size class as "key pieces," the large size range is comparable to the Washington State Forest Practices Board's Watershed Analysis Manual (1997) and WDFW's Wild Salmonid Policy (1997) key piece size standard of 0.55m diameter and 10 meters in length for streams with a 6-10 meter bankfull width. TFW key piece criteria is based on a volume calculation that allows variable diameters and lengths (Schuett-Hames et al. 1999a). The frequency of all wood that met minimum diameter criteria of at least 50 cm was calculated, and no minimum length requirement was used for comparison with the NMFS frequency standards (NOAA 1996). Pool forming LWD and the zone LWD occupied within the channel were also collected, but not included in this report. The species composition of the LWD was included only in the wood quality index (WQI) metric within the habitat quality index (HQI) described below.

## *Habitat Quality Index*

A multi-metric index, the Habitat Quality Index (HQI) was developed during this study, to assess the overall condition of the habitat in each stream segment. The HQI incorporates eight metrics important to salmonid production in third order streams to score a assessment segment with a single number representing the overall habitat quality of that reach (Peterson et al. 1992, NOAA 1996, May et al. 1997, Barbour et al. 1999). Each of the individual metric scores was calculated from quantitative assessment data. The metrics in our index include:

- Pool frequency (# pools/ km stream)
- Percent pool habitat
- Weighted Pool Quality Index (PQI, modified from Platts et al. 1983).
- Percent riffle habitat
- Weighted riffle quality index (incorporating embeddedness, cover, and substrate size)
- LWD frequency (# pieces/ km stream)
- LWD volume ($m^3$/ km stream)
- Wood quality index (incorporating frequency of coniferous pieces, and pieces with diameters greater than 0.5 m)

In order to develop a scoring scale that represents the possible range of metric values in King County, instream habitat data from 74 Puget Sound Lowland (PSL) streams that represented streams with a range of urbanization impacts (May et al. 1997) was reviewed. These data were collected using protocols comparable to the methods used by King County and is a large data set for similar individual metrics. The data distribution for each metric was determined by examining the quartile distribution of the PSL data set. Using this distribution and comparing the ranges of values for each metric to published values for natural conditions for similar sites, and the NMFS' properly functioning conditions matrix (NOAA 1996), the upper and lower quartiles of the values for each metric were identified to describe high and low quality conditions, respectively.

The possible range of scores (either 1-3-5 or 1-4-7 for low, medium, and high values) for each metric was assigned based upon ecological function and our confidence in the quality of the data. The low, medium and high categories correspond with the NMFS' properly functioning conditions table when possible (i.e. not properly functioning, at risk and properly functioning). The higher possible maximum score (7) was assigned to pool, riffle, and LWD measures because these metrics were more quantitative, and more confidence was held in these data because they could be compared to published data for "natural conditions. " The lower metric score ranges were used for the three quality indices. A score was applied to each metric based upon quartile values of the May et.al (1997) stream data (Table 3). Those values for each metric falling into the lowest or highest quartiles were given low and high scores, respectively, and the middle 50 percent of the values were given the medium score. In defining our "best" conditions we acknowledge that all of the PSL watersheds likely have been influenced by the legacy of logging, agriculture, and stream cleaning, and that adequate reference values are difficult, if not impossible to determine.

Using techniques similar to the benthic index of biotic integrity (B-IBI) (Karr and Chu 1999), metric scores were then summed to determine an overall HQI score for each segment. Possible scores range from 8 (lowest quality) to 50 (highest quality). Ratings categories of low, medium, and high were again determined from the quartile distribution of HQI scores calculated from the May et al. (1997) 74-stream data set. Since many of the segments fell into the "medium quality habitat" category, medium-high and medium-low categories were defined using the middle two quartiles of the reference stream HQI scores to give the results better resolution. Assessed segments with summed

HQI scores ranging from 8 to 23 were rated “low-quality” habitat, 24 to 31 were rated “medium-low”, 32 to 36 were rated “medium-high”, and segments with scores from 37 to 50 were rated “high-quality” habitat. It should be noted that this HQI rating system is newly developed and should be tested in other streams before being accepted for general use. It is desirable from a watershed management perspective to have a simple, standardized method of rating and ranking stream segments.

**Table 3. Habitat Quality Index metrics.**

| Parameter | Range of Values for Metric Scores | | | HQI Metric Scores | | |
|---|---|---|---|---|---|---|
| | 1st Quartile | Middle 2 Quartiles | 4th Quartile | Low | Medium | High |
| Pool Frequency (# pools/km) | <20 | 20-34 | >34* | 1 | 4 | 7 |
| Percent Pool habitat | <12 | 12-39 | >39* | 1 | 4 | 7 |
| Weighted PQI (freq. X score) | <31 | 31-149 | >149 | 1 | 3 | 5 |
| Percent Riffle Habitat | <14* | 14-44* | >44* | 1 | 4 | 7 |
| Weighted RQI (% area X score) | <339 | 339-1563 | >1563 | 1 | 3 | 5 |
| LWD Frequency (# LWD/km) | <51 | 51-166 | >166 | 1 | 4 | 7 |
| LWD Volume ($m^3$/stream km) | <39 | 39-267 | >267 | 1 | 4 | 7 |
| Weighted Wood Quality Index (# * (%conif. + % >= 0.5 diameter)) | <27 | 27-158 | >159 | 1 | 3 | 5 |

*These scores are adjusted from the reference site quartile ranges to reflect ecologically meaningful numbers or to comport with NMFS properly functioning conditions numbers (NOAA 1996).

## *Quality Control*

Two training sessions were held to prepare staff for the field assessment season and assure accurate and precise data. A classroom session was held to discuss assessment protocols and the specific objectives of the habitat assessment. A second session was held in the field to provide field staff with hands-on training in the use of the protocols and to provide field staff with the opportunity to identify any questions or concerns with the methodology prior to the actual assessment of the three northern tributaries to the Sammamish River.

After two weeks of data collection, the consistency between three field crews was assessed. Each field crew assessed the same reach independently. The data collected from this replicate reach were analyzed, and adjustments were made to minimize observer discrepancies. All data collected in the “QC reach” assessments were analyzed in the same manner as the actual assessment data.

# Map 1. Swamp Creek Map (Click for PDF)

# Map 2. North Creek Map (Click for PDF)

# Map 3. Little Bear Creek Map (Click for PDF)

# RESULTS

Data from basin condition analyses and habitat assessments are summarized for each stream segment (Table 4). Data highlights are presented in bulleted lists, and readers will find additional, more detailed data in the Appendices.

## Data Summary

To adequately characterize stream segments of uniform gradient, confinement and landuse it is necessary to assess an “adequate reach” length of representative instream conditions for each segment (May 1996). Great care was taken during pre-survey reconnaissance to ensure representative reaches were selected for the assessment. For this study, an average of 48.2 percent of each Swamp Creek segment was assessed, an average of 63 percent of each North Creek segment was assessed, and an average of 66 percent of each Little Bear Creek segment was assessed. This met the preliminary goal of approximately 50% established early in the study.

The percent of each segment sub-basin that is forested includes all three forest type categories, the majority of which in all cases was deciduous forest. Little Bear Creek segment basins had the greatest percentage of forest cover, ranging from 31 to 37 percent. North and Swamp Creek basin forest cover ranged from 9 percent in the uppermost North Creek segment located in Everett, to 23 percent in the upper Swamp Creek basins. Riparian forest cover, estimated visually from the stream channel, ranged from 0 to 100 percent in the three stream corridors. Instream LWD abundance was related to the percentage of riparian corridor that was forested (Figure 24). The frequency of LWD in nearly all of the segments was below natural frequencies of 150 pieces/ km (Murphy and Koski 1989, Ralph et al. 1994).

Good pool habitat provides refuge from higher energy habitat (e.g. riffles) in the stream for rearing juvenile salmonids and for adult salmonids migrating upstream. Good quality riffle habitat provides substrate for spawning. The frequency of pool habitat in all three streams was lower than values suggested by NMFS’ 'properly functioning conditions,' which is 30/km for Swamp and Little Bear creeks and 35/ km for North Creek (NOAA 1996). A suggested optimal ratio of pool to riffle habitat is 1:1 (Peterson et al. 1992), suggesting that 40-60% by area for each habitat type is the target condition. Each stream has several segments with 40-60% pool or riffle habitat, but never both. Only the three uppermost segments of North Creek, where the percentage of forested riparian vegetation was 56 to 90 percent, were categorized as “high quality”.

## Swamp Creek

The Swamp Creek habitat assessment began at the mouth of Swamp Creek and ended 380 meters north of 164th St. SE in Snohomish County and included 344 continuous meters of Scriber Creek beginning at its confluence with Swamp Creek (Map 1, Appendix A). We assessed more than the 25 percent of the total segment length suggested by May et al. (1997) as the minimum amount needed to represent the stream segment. An average of 48.2 percent of each segment (range: 15.1-100 percent) was assessed on Swamp Creek. Only segments 1 and 11 on the mainstem and segment 6 on Scriber Creek fell under this 25 percent minimum (Appendix J). It was not possible to assess the large, deep wetlands in the upstream reaches of segment 1 and downstream reaches of 11. Approximately half of the 0.9 km that is not part of the wetland complex in segment 1B was assessed. We assessed 0.35 km of a total 2.0 km in segment 11A, and 0.47 km of 3.5 km of 11B. The 11B assessment was terminated when low water prevented identification of habitat units. The assessments of segments 6 and 11 should only be considered representative of 4 times the length of the assessed reaches, this would mean 25% of the reach was assessed. Segment 11A assessments are representative only of the accessible habitat—not the wetlands that were too deep to assess. These reaches were labeled wetland channels and the habitat quality of these reaches was not evaluated in the assessments. All of the comparisons and comparative statements mentioned in the results text are between segments in the Swamp Creek basin.

**Table 4. Selected data summary table of Swamp, North and Little Bear creeks.**[1]

| | | Basin | Riparian | LWD | Habitat Units | | | |
|---|---|---|---|---|---|---|---|---|
| **Stream** | **Segment** | **% Forested** | **% Forested** | **LWD freq.#/km** | **Pool freq. #/km** | **Pool habitat %** | **Riffle habitat %** | **HQI Score** |
| **Swamp Creek** | **1A*** | 19* | 37 | 25.0 | 2.8 | 27 | 0 | 11 |
| | **1B*** | -- | 77 | 132.0 | 52.8 | 69 | 9 | 26 |
| | **2** | 19 | 17 | 7.2 | 10.9 | 17 | 36 | 20 |
| | **3** | 19 | 52 | 75.3 | 26.3 | 59 | 27 | 34 |
| | **4** | 18 | 54 | 38.9 | 23.9 | 40 | 38 | 26 |
| | **5** | 18 | 60 | 41.0 | 22.6 | 31 | 48 | 26 |
| | **6** | 8 | 70 | 34.9 | 32.0 | 28 | 46 | 29 |
| | **7** | 22 | 42 | 122.8 | 44.3 | 31 | 38 | 36 |
| | **8** | 22 | 64 | 118.0 | 26.8 | 29 | 17 | 33 |
| | **9** | 22 | 0 | 57.4 | 25.1 | 30 | 6 | 21 |
| | **10** | 23 | 92 | 93.6 | 18.4 | 30 | 7 | 23 |
| | **11A*** | 23* | 75 | 57.5 | 43.1 | 54 | 0 | 22 |
| | **11B*** | -- | 100 | 46.8 | 34.0 | 34 | 18 | 23 |
| **North Creek** | **1** | 19 | 0 | 2.8 | 2.8 | 0 | 0 | 15 |
| | **2** | 20 | 5 | 2.4 | 52.8 | 15 | 9 | 16 |
| | **3** | 20 | 24 | 18.6 | 10.9 | 30 | 36 | 20 |
| | **4** | 19 | 45 | 38.8 | 26.4 | 41 | 27 | 23 |
| | **5** | 19 | 38 | 55.3 | 24.0 | 23 | 38 | 25 |
| | **6** | 18 | 44 | 95.5 | 30.4 | 25 | 44 | 28 |
| | **8** | 19 | 56 | 161.0 | 32.0 | 27 | 46 | 30 |
| | **9** | 17 | 41 | 47.2 | 33.3 | 28 | 42 | 15 |
| | **10A*** | 17* | 73 | 66.8 | 26.8 | 27 | 17 | 31 |
| | **10B*** | -- | 56 | 132.9 | 25.1 | 24 | 6 | 26 |
| | **11** | 16 | 56 | 169.6 | 18.4 | 45 | 7 | 42 |
| | **12** | 15 | 81 | 232.9 | 43.1 | 46 | 0 | 39 |
| | **13** | 10 | 90 | 256.8 | 34.0 | 46 | 18 | 37 |
| **Little Bear Creek** | **1** | 32 | 33 | 21.2 | 9.4 | 14 | 43 | 18 |
| | **2** | 32 | 77 | 71.8 | 17.5 | 25 | 37 | 31 |
| | **3** | 33 | 72 | 119 | 21.9 | 50 | 20 | 31 |
| | **4** | 34 | 88 | 64.7 | 26.5 | 49 | 10 | 27 |
| | **5** | 34 | 43 | 88.5 | 28.4 | 47 | 4 | 26 |
| | **6** | 36 | 0 | 45 | 15.0 | 26 | 18 | 18 |
| | **7** | 36 | 12 | 101 | 20.2 | 27 | 25 | 28 |
| | **9** | 36 | 41 | 86.1 | 16.2 | 30 | 18 | 28 |
| | **10** | 35 | 100 | 48.2 | 5.1 | 2 | 9 | 10 |
| | **11** | 37 | 100 | 82.6 | 12.4 | 10 | 39 | 25 |
| | **12** | 37 | ** | ** | ** | ** | ** | 23** |
| | **13** | 37 | 100 | 123 | 20.0 | 19 | 7 | 18 |
| | **14** | 36 | 86 | 236 | 2.7 | 2 | 1 | 19 |

**Segment 12 was evaluated without measurements, and determined to be equally similar to the previous and following segments

[1] Data presented in table 4 are also presented and discussed in more detail elsewhere in the report. See results section for each stream (pages 18-49), and appendices.

## Basin Land-use and Riparian Integrity

The percentage of the Swamp Creek basin that remains forested is below 20%, very little of which includes coniferous species (Appendix D). Landscaped areas, herbaceous vegetation, shrubs, various exotics, and minimal natural riparian forest characterize the riparian zones of most assessed segments (Appendix E; see pie charts on Maps 3-5). Areas where natural forest cover remain are typically dominated by deciduous species including red alder, willow, and big-leaf maple. Mature, coniferous-dominated forest corridors still occur in isolated areas in these urbanizing watersheds.

### Basin Land-use

- Road density in the sub-basins ranged from 6.9 $km/km^2$ to 8.06 $km/km^2$ on the mainstem (segments 11 and 10, respectively; Appendix D).
- Road density in the Scriber Creek sub-basin (segment 6) was highest (9.19 $km/km^2$).
- Swamp Creek segment sub-basins are only 17-25 percent forested–primarily by deciduous species.
- Sub-basins of mainstem segments 7-11 (upstream of Scriber Creek confluence) are greater than 20 percent forested.
- Segment 6 sub-basin (Scriber Creek tributary) is only 8.5 percent forested.

### Riparian Corridor Continuity

- Total number of road crossings was highest in segments 6 (Scriber Creek tributary) and 11 (5 and 10 crossings, respectively). These segments were also the longest evaluated in the Swamp Creek basin. Appendix D).
- Road crossing frequency was highest by a wide margin in segment 9.

### Riparian Vegetation

- All segments except 1A, 2, 7, and 9 contained at least 50 percent total forest cover within the riparian corridor (Appendix E).
- Only segments 7 and 10 included some reaches dominated by coniferous forest (7 and 46 percent of the assessed reaches, respectively).
- Residential landscaping or shrubs that often included the pervasive Himalayan blackberry (*Rubus discolor*) dominated the remaining riparian vegetation. Blackberry (*R. discolor* or *R. laciniatus*) was present in all segments, and dominant in many reaches. Reed Canary grass (*Phalaris arundinacae*) was also present in segments throughout the watershed, and Japanese knotweed (*Polygonum cuspidatum*) was present in the lower 5 segments (Appendix F).

### Canopy Cover

- All Swamp Creek reaches had less than 95 percent canopy cover (Appendix G).
- Segments with greater than 70 percent forest cover (segments 1B, 10, and 11B) consistently had greater than 50 percent of the stream segment categorized as 76-95 percent canopy cover.
- The upper five segments of Swamp Creek had the highest percentage of reaches with 25% or more shade.
- 1999 temperature data from Swamp Creek indicate there were numerous occasions from June through August where temperatures exceeded $14^0$C, the NMFS' (1996) "properly functioning conditions" limit for salmonids (Appendix H).

## Large Woody Debris

No segments of Swamp Creek contained LWD within the published natural frequency ranges of 150 to 670 pieces/km (Murphy and Koski 1989, Ralph et al. 1994, Beechie and Sibley 1997) (Figure 4). The highest LWD frequency was found in segment 1B, where channel gradient is lower and an extensive wetland above the assessed reaches may moderate high flows and decrease the likelihood of wood removal by high flows. Much of this LWD is likely transported from upstream reaches to this downstream low-gradient segment during high flow conditions. In addition, LWD recruitment potential within this segment was relatively high with 77 percent of the riparian zone in deciduous forest cover. The lowest LWD frequency occurred in segment 2 upstream, where riparian forest cover was also lowest (17 percent). A large percent of the riparian zone of segments 6 and 11B were also forested; however, LWD frequency remained low in these segments, a fact which underscores that multiple factors influence LWD abundance in streams. Numbers of large diameter pieces were low; however, the highest number of large diameter pieces was found in segments with some mixed or coniferous forested riparian zone. In summary:

- The highest frequencies of LWD was in segments 1B and 7 (121 and 122 pieces/km).
- Segments 7, 8, and 10 had relatively high LWD frequencies (80 to 122 pieces/km).
- Segments 1A, 2, 4, and 11A had low LWD frequencies (less than 40 pieces/km).
- The frequency of large pieces was below "properly functioning conditions" in all segments (Appendix I).
- The highest frequency of large diameter pieces (> 0.5m diameter, no min. length) was in segments 6, 8, and 10 (33, 36, and 32 pieces/km, respectively, Appendix I).

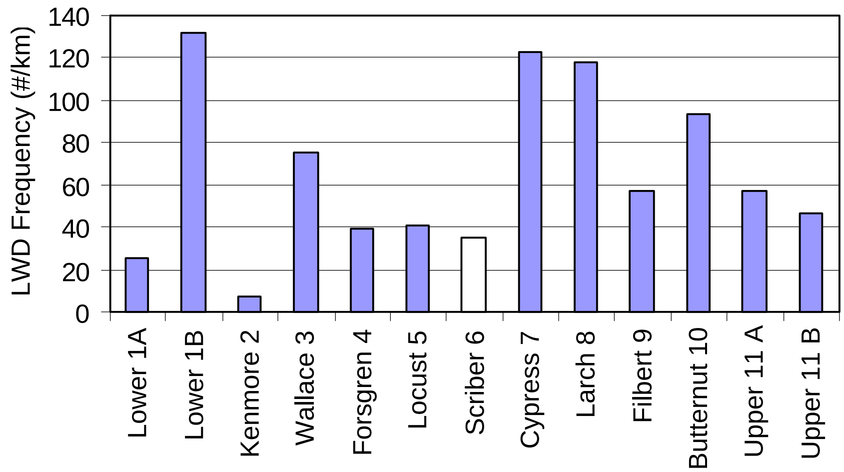


**Figure 4. LWD frequency in Swamp Creek segments. One hundred and fifty pieces per kilometer is the low end of naturally frequency ranges; no segments in Swamp Creek were in this range (Murphy and Koski 1989, Ralph et al. 1994, Beechie and Sibley 1997). The hatched bar represents a tributary segment.**

## *Channel Morphology*

Comparisons of bankfull width to depth ratios (BFW: BFD ratios) can indicate shifts in channel stability in response to disturbance (Rosgen 1996). Increased discharge increases streambank erosion rates and causes channel widening and increased BFW: BFD ratios. The "properly functioning conditions" suggests a BFW to BFD ratio of 10 is indicative of a stable, properly functioning channel, a value of 10-12 indicates an "at risk" channel, and ratios greater than 12 suggest that conditions are not properly functioning.

### *Bankfull Width*

- The mean bankfull width of Swamp Creek was 8.1 meters and generally decreased in an upstream direction (Appendix J).
- The bankfull width of the tributary stream, Scriber Creek (segment 6), was 7 meters.

- One measurement of bankfull width in Segment 11B was particularly wide (20 meters), a width that indicates the infrequent occurrence of a well defined channel and increased floodplain connectivity in this segment. This lack of definition of the channel caused an increase in the mean BFW of this upstream-most assessed segment.

### *Bankfull Width to Depth Ratios*

- Only segments 8 and 11A had BFW: BFD ratios less than 10 (9.1 and 8, respectively; Figure 5).
- BFW:BFD ratios of segments 5, 7, and 9 were between 10 and 12.
- BFW:BFD ratios of all other segments were greater than 12.

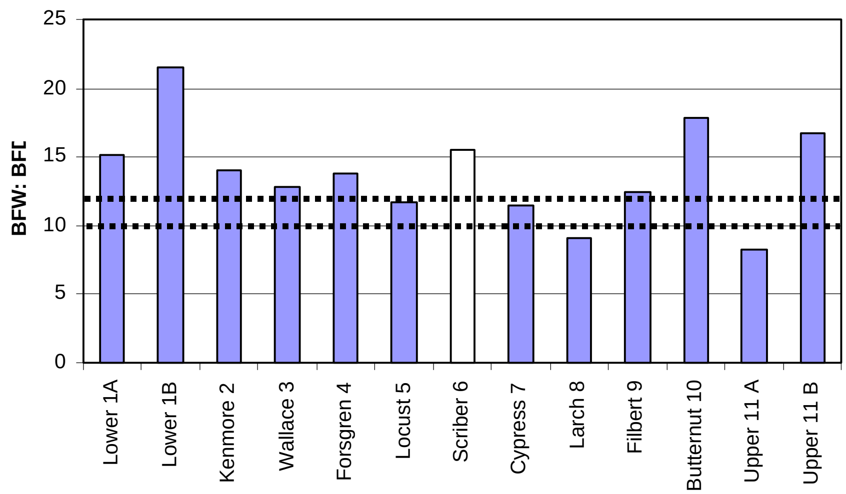


**Figure 5. Bankfull width to depth ratios for Swamp Creek segments. Values below 10 are suggested by the NMFS Matrix of Pathways and Indicators as indicative of properly functioning conditions, between 10 and 12 the stream is "at risk," and above 12 conditions are not properly functioning (NOAA 1996). The hatched bar represents a tributary segment.**

## *Streambank Stability*

Streambank stability was generally poor throughout Swamp Creek. Streambank stability ratings in many segments were related of the riparian corridor condition and position in the watershed. Segments in the upper reaches of the watershed tended to have more stable streambanks than the middle and lower reaches (Appendix K).

- The lower 6 segments had the highest percentage of reaches rated "armored" or "full scour."
- Forty percent or greater of the upper segments 7-11 were rated "stable", with the exception of segment 10, which had banks that were rated 79 percent low scour and 17 percent full scour.

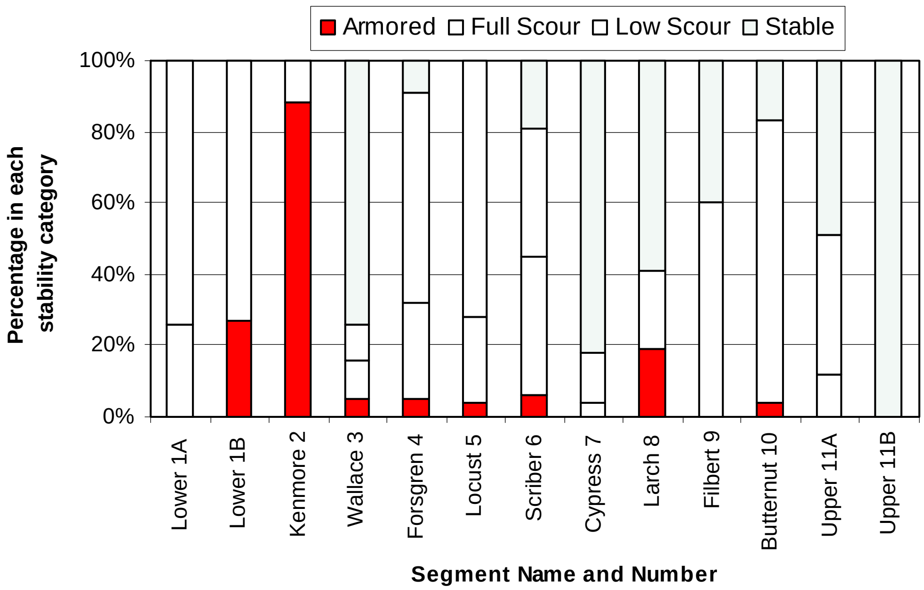


**Figure 6. Streambank stability ratings of Swamp Creek segments. A higher percentage of streambanks were rated armored and high scour in the lower segments.**

### *Riffle Habitat*

Generally, a balance between pool and riffle habitat is considered optimal fish habitat, with each component comprising 40-60 percent of the total stream habitat (Peterson et al. 1992). The amount of spawning (riffle) habitat was much lower than “optimal” in most stream segments evaluated (Figure 7). Riffle quality was generally lowest toward the mouth of the creek and highest in the upper four segments. In summary:

- The percentage of riffle habitat was greater than 40 percent only in the middle segments 5 and 6.
- There were no riffles in the lowest reaches of Swamp Creek (segment 1A), or the upper segment 11A.
- The percentage of riffle habitat was less than 20 percent in segments 1, 8, 9, 10, and 11.

Riffle quality index (RQI) scores indicate the quality of spawning habitat in each riffle. High quality riffles have clean substrate and abundant cover. Mean RQI scores on Swamp Creek segments with more than one riffle were lowest in segments 2 and 4 (2.4 and 2.3, respectively) and highest in the upper segments 10 and 11B (both 4.2).

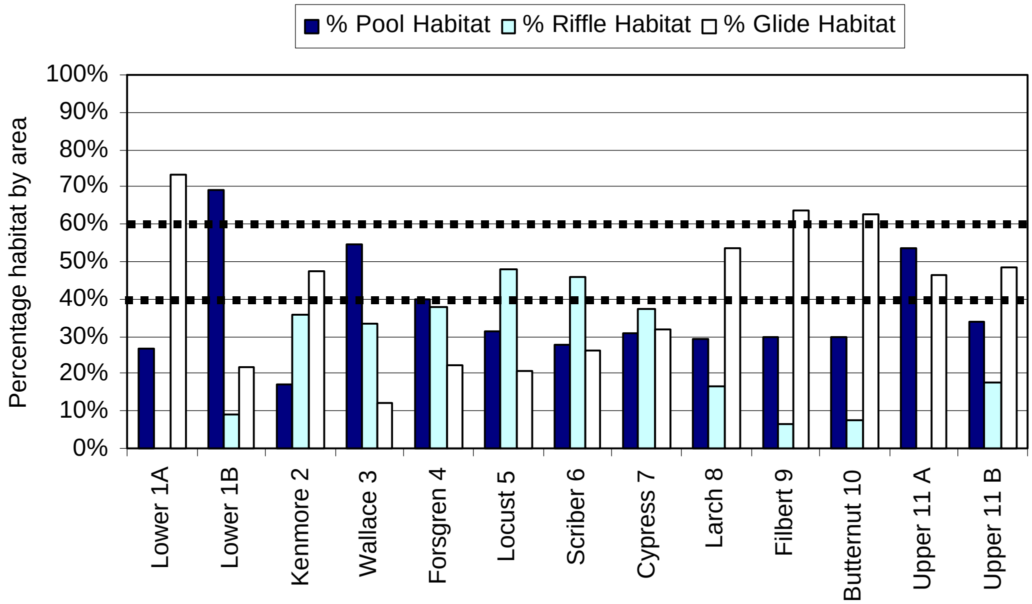


**Figure 7. The percent habitat composition by area of Swamp Creek segments. Optimal habitat distribution is 1:1 pool to riffle ratio; the percentage of each should be between 40 and 60 percent (Peterson et al. 1992). The percent pool habitat by area decreased from the mouth of Swamp Creek to the middle segments and increased slightly in segments 11A.and 11B.**

## *Pool Habitat*

Only four Swamp Creek segments (1B, 3, 4, and 11A) were close to resembling natural conditions: they approach 40 percent pool habitat by area. (Figure 4, Appendix J). NMFS' matrix suggests 30 pools/km indicate properly functioning conditions. In summary:

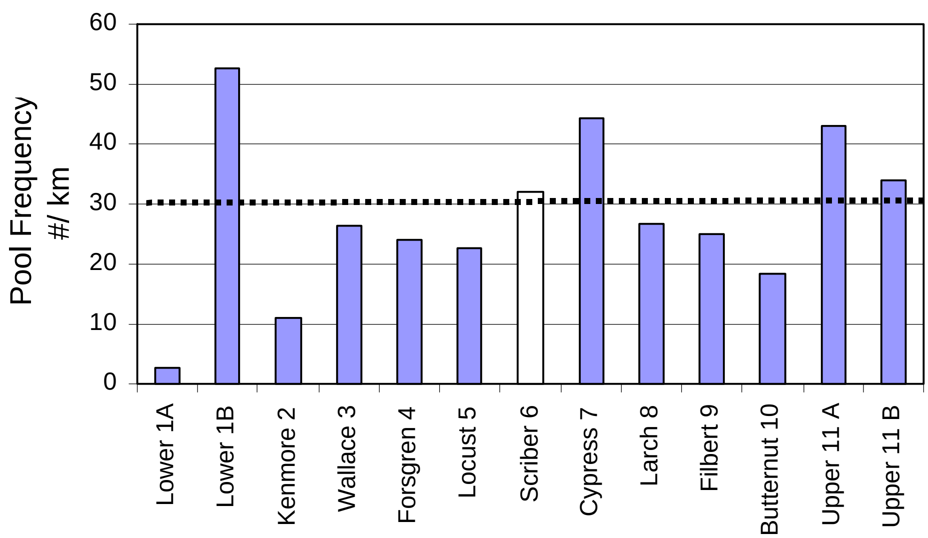


**Figure 8. Pool frequency in Swamp Creek segments. Four segments meet the NMFS Matrix of Pathways and Indicators target of 30 pools/ km (NOAA 1996). The hatched bar represents a tributary segment.**

- Segments 1B, 3, and 11A had greater than 50 percent pool habitat by surface area.

- Segment 4 had 40 percent pool habitat by surface area.
- Segments 1B, 6, 7, 11A, and 11B had greater than 30 pools per stream kilometer (Figure 8).

Mean PQI scores were in the middle of the optimal range, a finding that indicates that many pools had adequate cover such as LWD or undercut banks. In summary:

- Pool quality was highest in the lower segments 1A, 1B, and 3 (5.0, 4.0, and 4.0, respectively), where the deepest pools were located.
- PQI scores were lowest in the Scriber Creek tributary (Segment 6) and mainstem Swamp Creek segments 2 (3.0, and 3.3, respectively).

## Glide Habitat

Glides are intermediate habitat units that have characteristics of both pools and riffles but provide little of the functional capabilities of either. Although relatively deep and slow during baseflow conditions like pools, glides provide little refuge during peak-flows. Glides are also usually slow water habitat where finer sediment predominate, making them poor spawning habitat. There was a general shift in habitat dominance from a balanced pool-riffle morphology to a glide-dominant habitat structure in Swamp Creek. This is typical of urban streams in the PSL (May et al. 1997). All segments, except segments 1B, 3, and 5 had greater than 25 percent glide habitat by surface area (Figure 7).

## Habitat Quality Index

The habitat quality of the assessed segments of Swamp Creek was evaluated using the Habitat Quality Index (HQI). The summed score of eight metrics determined the final HQI score. Swamp Creek HQI scores fell primarily in the low and medium low habitat quality categories, although three segments were rated medium-high. Score for segments in the middle stream reaches tended to be higher quality than the upper and lower segments, because of increased habitat complexity. Scores ranged from 11 in segment 1A to 36 in segment 7.

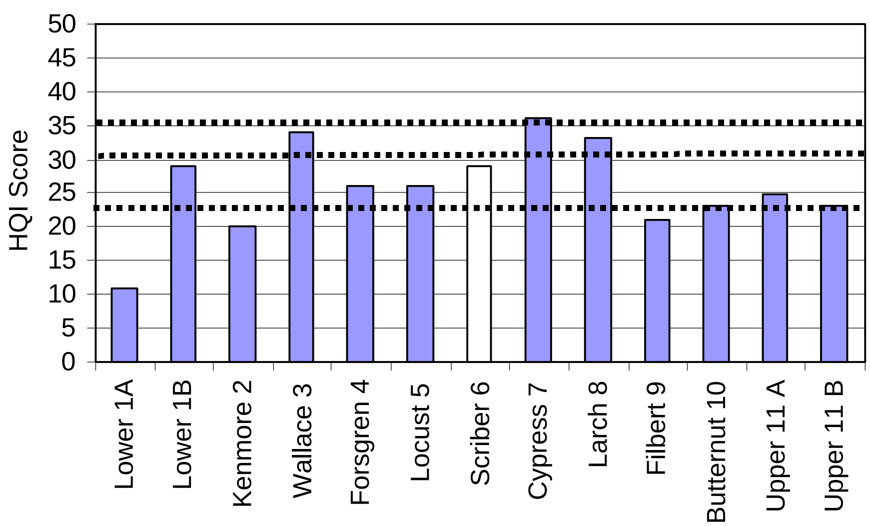


**Figure 9. Swamp Creek HQI Score distribution. Segments with scores below 23 were rated low, 24-31 were rated medium low, 32-36 were rated medium high, and those with scores above 36 were rated high quality. The hatched bar represents a tributary segment.**

### *Segments 1A, 1B, and 2*

HQI scores for lower Swamp Creek segments were low and medium low due to a lack of instream habitat complexity (Table 5; Map 4). Low pool frequency, lack of riffle habitat, and little LWD in segments 1A and 2 indicate that these segments lack suitable spawning and rearing habitat for salmonids. The non-wetland portion of segment 1B was rated medium-low because of slightly greater frequencies of pools and LWD. Pool frequencies in these three segments correspond with LWD frequencies (Figure 24). The greater amount of LWD in segment 1B also corresponds with a higher percentage of forested reaches in the riparian zone of this segment. The riffle quality metric score was low in segment 1A, but increased to the highest possible metric score in Segment 2 (scores: 1 and 5, respectively). Streambank stability ratings for these lower segments of Swamp Creek were also generally poor.

**Table 5. HQI metric scores and ratings Swamp Creek segments 1-2.**

| Segment description | Pool Freq. | % Pool Area | Weigh. PQI | % Riffle Area | Weigh. RQI | LWD Freq. | LWD Vol. | Weigh. WQI | Total HQI Score | Habitat Quality Rating |
|---|---|---|---|---|---|---|---|---|---|---|
| 1A (Lower) | 1 | 4 | 1 | 1 | 1 | 1 | 1 | 1 | ***11*** | Low |
| 1B (Lower) | 7 | 7 | 5 | 1 | 3 | 4 | 1 | 1 | ***29*** | Med. Low |
| 2 (Kenmore) | 1 | 4 | 3 | 4 | 5 | 1 | 1 | 1 | ***20*** | Low |
| **Possible Metric and HQI Scores** | ***1-4-7*** | ***1-4-7*** | ***1-3-5*** | ***1-4-7*** | ***1-3-5*** | ***1-4-7*** | ***1-4-7*** | ***1-3-5*** | ***9-50*** | |

## *Segments 3, 4, and 5*

An overview of the metrics and habitat scores for segments 3-5 is outlined below in Table 6. HQI ratings of the lower middle segments of Swamp Creek range from medium-low to medium-high (Table 6). Medium low scores are due to moderate numbers of pools and riffles, and relatively low quantity and low quality LWD. The medium-high rating reflects the higher frequency and volume of LWD in segment 3. All three of these segments have higher quality riffles than downstream segments. LWD frequency shows little correlation with riparian forest cover in these segments. Fifty-one to 56 percent of the reaches were forested with deciduous trees (Appendix E), but LWD frequency and volume were only medium to low.

**Table 6. HQI metric scores and ratings of Swamp Creek segments 3, 4, and 5.**

| Segment description | Pool Freq. | % Pool Area | Weigh. PQI | % Riffle Area | Weigh. RQI | LWD Freq. | LWD Vol. | Weigh. WQI | Total HQI Score | Habitat Quality Rating |
|---|---|---|---|---|---|---|---|---|---|---|
| 3 (Wallace) | 4 | 7 | 3 | 4 | 5 | 4 | 4 | 3 | ***34*** | Med. High |
| 4 (Forsgren) | 4 | 7 | 3 | 4 | 5 | 1 | 1 | 1 | ***26*** | Med. Low |
| 5 (Locust) | 4 | 4 | 3 | 7 | 5 | 1 | 1 | 1 | ***26*** | Med. Low |
| **Possible Metric and HQI Scores** | ***1-4-7*** | ***1-4-7*** | ***1-3-5*** | ***1-4-7*** | ***1-3-5*** | ***1-4-7*** | ***1-4-7*** | ***1-3-5*** | ***9-50*** | |

## *Segments 6-8*

An overview of the metrics and habitat scores for segments 6-8 is outlined below in Table 7. The habitat of the upper middle segments of mainstem Swamp Creek were rated medium-high quality. Scriber Creek tributary habitat was rated medium-low. All three segments contained moderate habitat complexity with moderate amounts of pool and riffle habitat. Riparian integrity, as characterized by a coniferous dominated, wide, and continuous riparian corridor, was higher in segments 7 and 8 than other areas. LWD occurred in moderate amounts in mainstem segments, and wood quality was moderate to high. Riparian vegetation within these segments had a higher coniferous component, which may be responsible for the higher LWD metric scores compared to downstream segments. Lack of LWD recruitment from the riparian zone, loss of LWD during high flows, and/ or removal of

LWD by adjacent landowners may be the cause of lower quantities of LWD in stream segments. Scriber Creek, segment 6, had low LWD frequencies despite abundant riparian forest cover, which suggests typical urban loss mechanisms may be operating.

**Table 7. HQI metric scores and ratings of Swamp Creek segments 6-8.**

| Segment description | Pool Freq. | % Pool Area | Weigh. PQI | % Riffle Area | Weigh. RQI | LWD Freq. | LWD Vol. | Weigh. WQI | Total HQI Score | Rating |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 (Scriber) | 4 | 4 | 3 | 7 | 5 | 1 | 4 | 1 | ***29*** | Med. Low |
| 7 (Cypress) | 7 | 4 | 5 | 4 | 5 | 4 | 4 | 3 | ***36*** | Med. High |
| 8 (Larch) | 4 | 4 | 3 | 4 | 5 | 4 | 4 | 5 | ***33*** | Med. High |
| **Possible Metric and HQI Scores** | *1-4-7* | *1-4-7* | *1-3-5* | *1-4-7* | *1-3-5* | *1-4-7* | *1-4-7* | *1-3-5* | *9-50* | |

### *Segments 9-11B*

An overview of the metrics and habitat scores for segments 9-11B is outlined below in Table 8. Habitat within the upper segments of Swamp Creek was rated as low and medium low quality, although the segments rated low had scores in the uppermost end of the low quality category. Few riffles in any of the segments, as well as fewer pools in segment 10, reflect a decrease in habitat complexity in these upper segments. Pool frequency remained low although segment 10 had the highest riparian coniferous component (46 percent) and a higher WQI score, which suggests a higher percentage of coniferous LWD and large pieces.

**Table 8. HQI metric scores and ratings of Swamp Creek segments 9-11B.**

| Segment description | Pool Freq. | % Pool Area | Weigh. PQI | % Riffle Area | Weigh. RQI | LWD Freq. | LWD Vol. | Weigh. WQI | Total HQI Score | Rating |
|---|---|---|---|---|---|---|---|---|---|---|
| 9 (Filbert) | 4 | 4 | 3 | 1 | 3 | 4 | 1 | 1 | ***21*** | Low |
| 10 (Butternut) | 1 | 4 | 3 | 1 | 3 | 4 | 4 | 3 | ***23*** | Low |
| 11 A (Upper) | 7 | 7 | 3 | 1 | 1 | 4 | 1 | 1 | ***25*** | Med. Low |
| 11 B (Upper) | 4 | 4 | 3 | 4 | 5 | 1 | 1 | 1 | ***23*** | Med. Low |
| **Possible Metric and HQI Scores** | *1-4-7* | *1-4-7* | *1-3-5* | *1-4-7* | *1-3-5* | *1-4-7* | *1-4-7* | *1-3-5* | *9-50* | |

## *Biology*

Chinook redds were not found in Swamp Creek during the 1999 King County assessment (Mavros et al. 2000); however, juvenile salmonids, including coho and cutthroat, were observed in many segments during these habitat assessments. Coho, sockeye and kokanee were spotted in Swamp Creek reaches in 1997 by volunteer salmon watchers (Vanderhoof et al. 2000). Fewer observations were made in 1998 and 1999 by volunteers, and no spawning salmonids were observed. In 1999 coho (*Oncorhynchus kisutch*) and cutthroat trout (*O. clarki*) were observed spawning in segment 10 and 11, and area not covered by volunteer data (Mattila 1999). Freshwater mussels (*Unionid ssp.*) were observed in segments 8, 10, and 11B, with especially large numbers occurring in segment 10, which is directly below a large wetland.

## Map 4. Swamp Creek Segments 1-5 (Click for PDF)

## Map 5. Swamp Creek Segments 6-8 (Click for PDF)

# Map 6. Swamp Creek Segments 9-11 (Click for PDF)

# North Creek

North Creek was assessed from its mouth at the confluence of the Sammamish River through the McCollum Park segment near 128th St. SE in Snohomish County (Appendix A). Penny Creek tributary was assessed from its confluence with North Creek up to the Mill Creek Country Club golf course. The results of the Penny Creek assessment only apply to reaches below the golf course (Map 9). More than the recommended 25% of each segment determined necessary to be representative of a segment (May et al. 1997). An average of 63% of the segments were assessed (range: 28-100%, Appendix J). Data collected in 1995 (May et al. 1997) were used for the Silver Creek and Tambark Creek tributaries.

## *Riparian Integrity*

Forest cover is decreased basin-wide relative to natural land cover conditions, and mature forest cover is nearly completely absent (Appendix D). Landscaped areas, herbaceous vegetation, shrubs, various exotics, and minimal natural riparian forest characterized the riparian zones of most assessed segments (Appendix E, and map 7,8 and 9 pie charts). Those areas where natural riparian forest still exists are dominated by deciduous species including red alder, willow, and big-leaf maple. The riparian corridor of only the upper most segment of the mainstem in McCollum Park is still predominantly coniferous forest.

Canopy cover data generally corresponds with riparian cover composition. Where forest was the dominant riparian vegetation (greater than 50 percent) shade was never lower than 25 percent (Appendix G). The following provides an overview of the riparian features in this area.

### Basin Land-use

- Total forest cover was 15 to 20 percent in the segment sub-basins 1-12 and 9.5 percent in the uppermost most segment sub-basin 13.
- Deciduous forest dominated the basin forest cover of all segments,
- Mixed forest cover ranged from 6.0 percent in the Silver/ Tambark Tributary sub-basin (segment 7) to 2.6 percent in segment the 13 sub-basin.
- Road density ranged from 7.4 $km/km^2$ in the lower (1-4) segment sub-basins to 9.4 $km/km^2$ and higher in the upper (13-15) segment sub-basins (Appendix D).
- Road density was highest (9.8 $km/km^2$) in segment 14 where the city of Everett dominates the sub-basin.

### Riparian Corridor Continuity

- Road crossings were highest in mainstem segments 3 and 5 (5 and 4 respectively).

### Riparian Vegetation

- The percentage of riparian forest cover generally increased in an upstream direction, from 0 percent in segment 1 to 43 percent in segment 8, and 90 percent in segment 13.
- Segments 10B and 12 had a small mixed forest component (21 and 31 percent, respectively).
- Only segment 13 had significant reaches of the riparian zone (57 percent) where coniferous forest was the dominant vegetation.
- Blackberry (*R. discolor* or *R. lacinatus*) was present in all segments, and dominant in many segments. Reed Canary grass (*Phalaris arundinacae*) was also present in all but segments 12 and 13 (Appendix F).

### Canopy Cover

- Canopy cover generally increased as percent riparian forest cover increased.

- Canopy cover was highest in segments 12 and 13 where riparian vegetation was greater than 80 percent forested.
- Segments with under 50 percent forest cover in the riparian zone generally had some reaches with little or no shade, and no reaches with greater than 75 percent shade.
- Temperature data were not available for North Creek.

## *Large Woody Debris*

As other studies have found, LWD recruitment seemed to be, at least partially dependent on the presence of a natural, relatively intact riparian zone (May et al. 1997, Horner and May 2000, Naiman et al. 2000, Rot et al. 2000). The two segments with the highest percentage of forested riparian cover (12 and 13) also had the highest frequency of LWD (Figure 23). Two other segments with greater than 50 percent forest cover in the riparian zone also had LWD frequencies in the natural range. Large diameter pieces are present in low numbers in most segments of North Creek; however no segments fell within published natural ranges (Appendix I).

- Four segments (i.e. 8, 11-13) had LWD frequencies above the natural range (i.e. greater than 150 pieces/km, Figure 10).
- Only segments 11 and 13 have LWD frequencies greater than 50 pieces/ km where wood is greater than or equal to 0.5 meters in diameter.

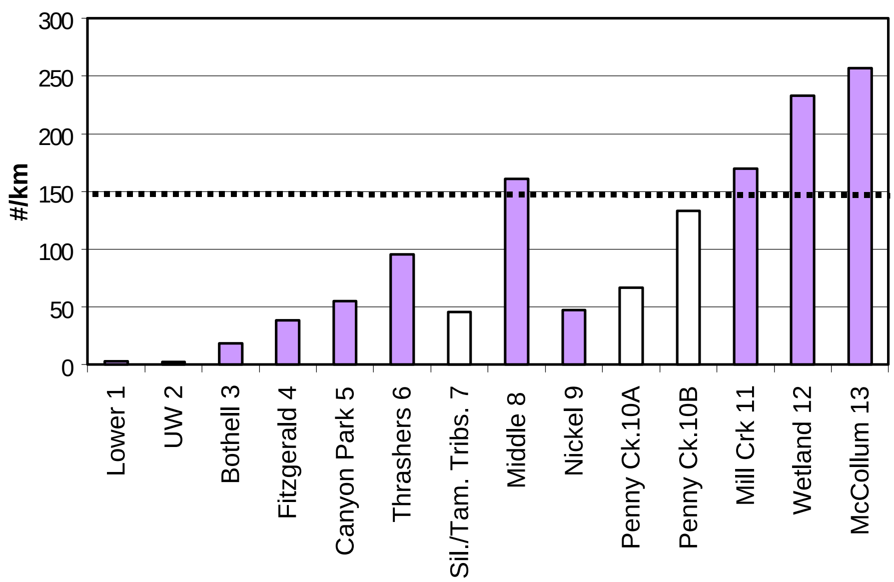


**Figure 10. LWD frequency in North Creek segments. One hundred and fifty pieces per kilometer is the low end of naturally frequency ranges, only the upper segments in North Creek were in this range (Murphy and Koski 1989, Ralph et al. 1994, Beechie and Sibley 1997). The hatched bars represent tributary segments.**

## *Channel Morphology*

Comparison of bankfull width to depth ratios (BFW:BFD ratios) can indicate shifts in channel stability in response to disturbance (Rosgen 1996). Increased discharge typically results in increased streambank erosion and causes channel widening and increased BFW:BFD ratios. The matrix of properly functioning conditions suggests that a BFW to BFD ratio of 10 is indicative of a stable, properly functioning channel, a value of 10-12 indicates an “at risk” channel, and ratios greater than 12 suggest conditions are not properly functioning (NOAA 1996). The following provides an overview of the channel morphology features.

### *Bankfull Width*

- The BFW of mainstem North Creek was 7.5 meters.
- BFW was narrowest (6.8 meters) in the two most downstream segments (i.e. 1 and 2) where the stream is channelized and has a low gradient.
- The mean bankfull width of Penny Creek was 4.3 meters.

### *Bankfull Width to Depth Ratios*

- The BFW:BFD ratios of seven segments were less than 10 (Figure 11).
- The segment 11 BFW:BFD ratio was between 10 and 12.
- Four segments had BFW: BFD ratios greater than 12.

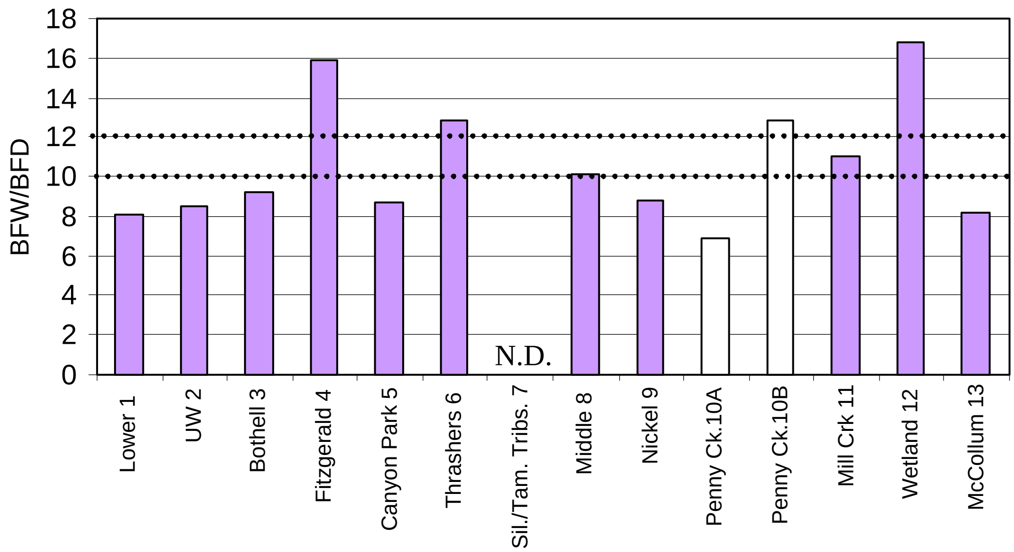


**Figure 11. Bankfull width to depth ratios for North Creek segments. Values below 10 are suggested by the NMFS Matrix of Pathways as indicative of 'properly functioning conditions', between 10 and 12 the stream is "at risk", and above 12 conditions are not properly functioning (NOAA 1996). The hatched bars represent tributary segments. N.D. = Tributary not done.**

## ***Streambank Stability***

Streambank stability of North Creek segments was associated with riparian condition, gradient and position within the stream continuum. Lower gradient segments and those with highest percent of reaches with forest cover had the most stable banks. The banks of the lower middle segments had the most armoring. Stability generally decreased as one moved upstream to the middle segments and increased again as riparian forest cover increased (Appendix K).

- Ninety eight to 100 percent of reaches in segments 1-3 had stable streambanks.
- No reaches in segment 13 were armored or rated 'full scour'.
- Upper Penny Creek (segment 10B), and segment 11 had no reaches with streambanks classified as stable.
- Percent armoring was highest on segments 4, 5 and 12 of the mainstem (32 percent, 15 percent and 15 percent, respectively).

A high percentage of tributary segments 7 and 10A were also armored (33 and 18 percent, respectively).

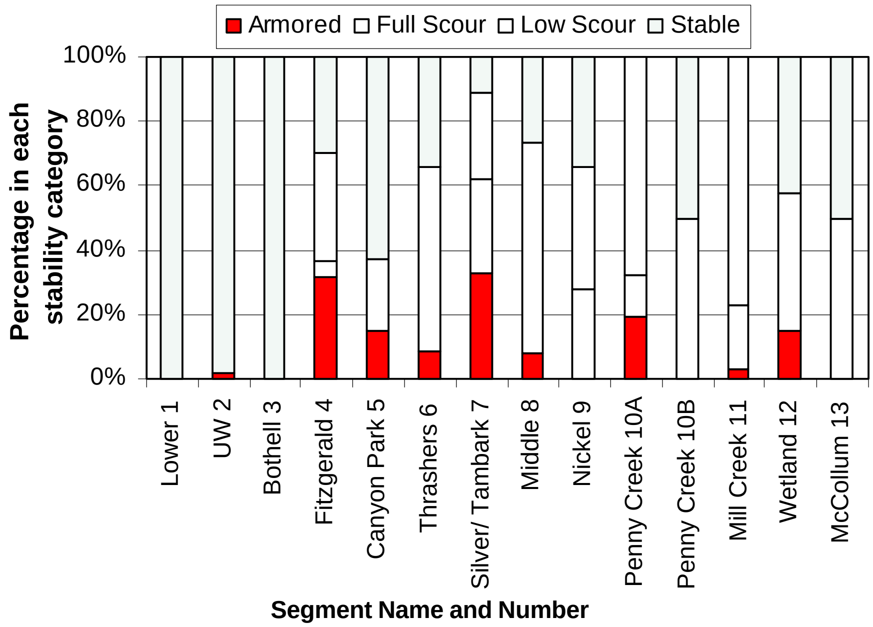


**Figure 12. Streambank stability of North Creek segments. The three downstream-most segments had the largest percentage of stable banks.**

## *Riffle Habitat*

Spawning habitat (riffles) in all segments of the North Creek mainstem is below the optimum quantitative range of 40-60 percent (Figure 13). There is no apparent upstream to downstream trend in the quantity of riffle habitat. The riffle quality was generally low in the lower stream segments and moderate in the remaining segments (Appendix L). The lower segments are lower gradient response reaches where sediment is more likely to aggrade and fill substrate interstices, resulting in a lower RQI. The highest quality riffles were in the upper reaches of the creek.

- No segments had riffles comprising more than 50 percent of the total stream habitat.
- Only lower Penny Creek Tributary segment (10A) contained more than 40 percent of the habitat classified as riffles.
- The percentage of riffle habitat was between 20 to 40 percent in four segments (3, 4, 6, and 8) of the lower two thirds of North Creek.
- The percentage of riffle habitat was very low, between 10 to 20 percent, in seven segments (1, 2, 5, 9, 10B 12, and13) of North Creek.

Riffles received high riffle quality index (RQI) scores if substrate was free of fine sediment, was not embedded, and good quality cover was present.

- The lowest mean riffle quality score was in Segment 2 (RQI score: 1.3).
- The segments in the lower third of North Creek (Segments 1-5) had low mean riffle quality ratings (RQI scores less than 3).

- The highest quality riffles were found in the upper segments 11 and 12 (RQI scores 3.9 and 4.0, respectively).

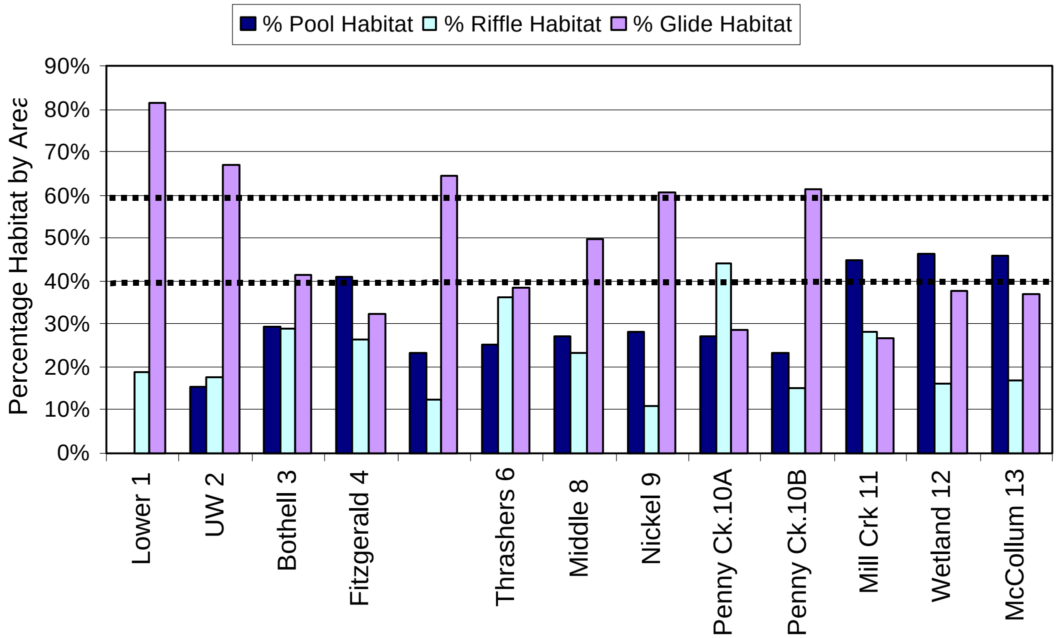


**Figure 13. Percentage habitat composition of North Creek segments. Optimal pool to riffle habitat ratio is 1:1; the percentage of each should be between 40 and 60 percent (Peterson et al. 1992). Only four segment had more than 40 percent pool habitat by area, and only one had greater than 40 percent riffle habitat by area.**

## *Pool Habitat*

The distribution of pool habitat in North Creek generally correlated with the abundance of LWD and intact riparian forest (Figure 24). Pool habitat area just above 40 percent in only one lower segment (4) and the three uppermost assessed segments (11, 12, and 13) (Figure 13) where LWD frequency also met NMFS' target conditions (NOAA 1996). Likewise, pool frequencies only approached the NMFS' properly functioning conditions standards (35 pools/ km) only in the upper reaches of the mainstem, and in lower portions of Penny Creek (Figure 14).

- Mainstem segments 11, and 12 and lower Penny Creek tributary, (10A) had pool frequencies above 30/km.
- No segments had total pool area making up more than 50 percent of the total stream habitat.
- Percentage of pool habitat was above 40 percent in four segments (4, 11-13).
- All other segments had between 10-30 percent pool habitat by area.

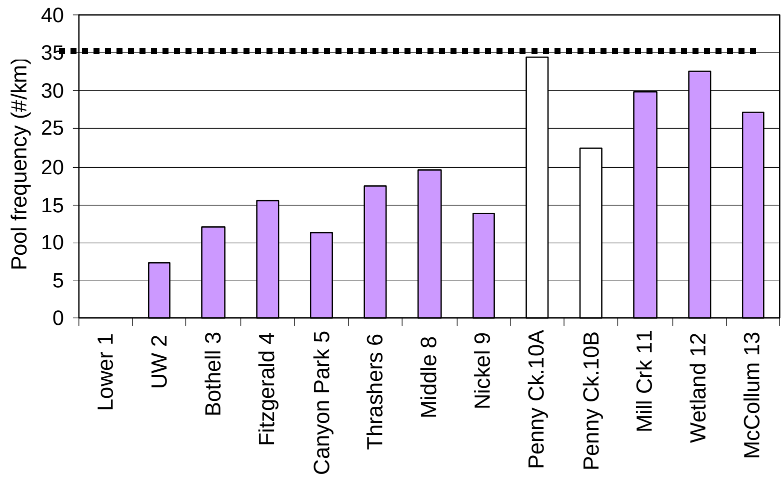


**Figure 14. Pool frequency in North Creek segments. Three segments meet the NMFS' Matrix of Pathways and Indicators properly functioning conditions standard for a stream of this width, which is 35 pools/km. The hatched bars represent tributary segments.**

Pool quality was highest in the lower–middle segments where mean pool depths were greater, and also high in upper segments where LWD frequency was high.

- Segments 3-5 had the highest quality pools (4.4-4.5), in addition to the highest percentage of deep pools (Appendix L).
- Pools in segments 11 and 12 were also of high quality (4.0), and LWD frequencies were high.
- Pools in all other segments received moderate quality scores (3-3.8).

## Glide Habitat

Glides are intermediate habitat units that have characteristics of both pools and riffles but provide little of the functional capabilities of either. Although relatively deep and slow during baseflow conditions like pools, glides provide little refuge cover during peak-flows. Glides are also usually slow water habitats where finer sediments predominate, making them poor spawning habitat. All segments, except segment 3, had greater than 25 percent glide habitat by surface area. A shift from balanced pool-riffle channel morphology to one dominated by glides is typical of urban streams in the PSL (May et al. 1997).

- Glides made up 50 percent or more of the instream habitat in six segments (Segments 1, 2, 5, 8, 9, 10B) (Figure 13).
- Glides made up at least 25 percent of the instream habitat in all segments.

## HQI Scores

The habitat quality of eight North Creek assessment segments was evaluated using the Habitat Quality Index (HQI). As previously discussed in the Methods Section, the summed score of seven metrics determined the final HQI score. HQI scores for North Creek segments are summarized in Figure 15 below, and in general increased as one moved upstream. Scores ranged from 15 to 42 in segments 1 and 9, and 11 respectively (Appendix M). A general overview of the HQI scores is presented below.

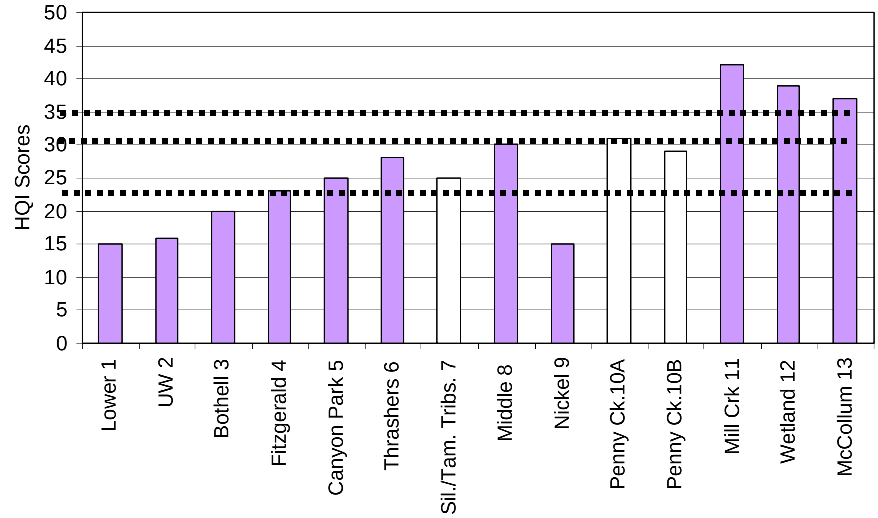


**Figure 15. North Creek HQI score distribution. Segments with scores below 23 were rated low, 24-31 were rated medium low, 32-36 were rated medium high, and those with scores above 36 were rated high quality. Hatched bars represent tributary segments.**

## *Segments 1-5*

A summary of the HQI scores for North Creek segments 1-5 are presented in Table 9. HQI scores for the lowest four North Creek segments were low due to limited instream habitat complexity (Table 9, Map 7). Pool frequencies were low in segments 1-4, and percent pool habitat by area varied from low to high (segments 1 and 4, respectively). These four low quality segments had moderate amounts of riffle habitat and moderate riffle quality scores. Low scores for wood quantity and quality in these four most downstream segments correspond with low pool frequency are partially responsible for the reduction in habitat complexity. In addition these segments had generally poor riparian zones (low percentages of forest cover). Metric scores indicate habitat complexity and habitat quality was not significantly higher in Segment 5, rated Medium-Low, however the quantity and quality of LWD was higher, in part due to the presence of a restoration within this segment that included addition of LWD.

**Table 9. HQI Scores and metric scores for North Creek segments 1-5.**

| Segment description | Pool Freq. | % Pool Area | Weigh. PQI | % Riffle Area | Weigh. RQI | LWD Freq. | LWD Vol. | Weigh. WQI | Total HQI Score | Habitat Quality Rating |
|---|---|---|---|---|---|---|---|---|---|---|
| **Lower 1** | 1 | 1 | 1 | 4 | 5 | 1 | 1 | 1 | ***15*** | Low |
| **UW 2** | 1 | 4 | 1 | 4 | 3 | 1 | 1 | 1 | ***16*** | Low |
| **Bothell 3** | 1 | 4 | 3 | 4 | 5 | 1 | 1 | 1 | ***20*** | Low |
| **Fitzgerald 4** | 1 | 7 | 3 | 4 | 5 | 1 | 1 | 1 | ***23*** | Low |
| **Canyon Park 5** | 1 | 4 | 3 | 1 | 5 | 4 | 4 | 3 | ***25*** | Med. Low |
| **Possible Metric and HQI Scores** | ***1-4-7*** | ***1-4-7*** | ***1-3-5*** | ***1-4-7*** | ***1-3-5*** | ***1-4-7*** | ***1-4-7*** | ***1-3-5*** | ***9-50*** | |

## *Segments 6-9*

Habitat in the middle mainstem North Creek segments (numbers 6-9) were rated medium–low to low quality due to lack of habitat complexity and low LWD frequencies (See Map 8, Table 10). Adjacent segments 6 and 8 had low pool frequencies (segment 7 is a tributary segment) that were moderate quality. LWD frequency and quality was better in middle reaches, where at least 40 percent of the segment was dominated by riparian forest cover that included coniferous species. Spawning habitat quality was generally high, although riffle frequencies were lower than optimum. Segment 9 metric and HQI scores indicate stream habitat was mostly low quality in terms of channel complexity or LWD quality and quantity. Channelized reaches, half of which flow through a reed canary grass wetland with no forest cover, dominate this segment. Wetlands within this segment may, however, provide important hydrological buffering and refuge functions for this stream. Silver and Tambark tributaries had moderate habitat complexity, moderate quality pools and poor quality riffles. Large woody debris frequency and quality were also low in these tributaries.

**Table 10. HQI and metric scores for North Creek segments 6-9.**

| Segment description | Pool Freq. | % Pool Area | Weigh. PQI | % Riffle Area | Weigh. RQI | LWD Freq. | LWD Vol. | Weigh. WQI | Total HQI Score | Habitat Quality Rating |
|---|---|---|---|---|---|---|---|---|---|---|
| **Thrashers 6** | 1 | 4 | 3 | 4 | 5 | 4 | 4 | 3 | ***28*** | Med. Low |
| **Silver/Tam. 7*** | 7 | 4 | 3 | 4 | 1 | 1 | 4 | 1 | ***25*** | Med. Low |
| **Middle 8** | 1 | 4 | 3 | 4 | 5 | 4 | 4 | 5 | ***30*** | Med. Low |
| **Nickel 9** | 1 | 4 | 3 | 1 | 3 | 1 | 1 | 1 | ***15*** | Low |
| **Possible Metric and HQI Scores** | ***1-4-7*** | ***1-4-7*** | ***1-3-5*** | ***1-4-7*** | ***1-3-5*** | ***1-4-7*** | ***1-4-7*** | ***1-3-5*** | ***9-50*** | |

*Tributary stream, data for metric scoring from (May et a1. 1997).

## *Segments 10-13*

Habitat quality in segments 10-13 is summarized in Table 11. In general, high habitat complexity, and riffle habitat quality in addition to increased frequency and quality of LWD in the three upstream most segments (numbers 10-13) assessed resulted in relatively high HQI scores and habitat quality ratings (See North creek segment 10-13 map, Table 11). Pool frequency was moderate, and the percentage of pool area was high. A moderate percentage of the stream habitat consisted of riffles. Riffles in segments 11 and 12 were rated high quality. LWD frequency and quality was also high in segments 11-13. At least 56 percent of the reaches in these segments were dominated by a forested riparian corridor, which in segments 10B, 12 and 13 included least some coniferous component (See Map 9 pie charts; Appendix E). Penny Creek tributary habitat was rated medium-high and medium-low due to moderate scores for nearly all metrics. Even though a significant portion (greater than 65 percent) of the riparian zone of each Penny Creek segment was forested (with a coniferous component in segment 10A), LWD frequency and quality scores remained moderate. High flows, evidenced by low streambank stability ratings, may explain this in large part. The higher pool frequency in lower Penny Creek The highest HQI scores were found in segments (11-13) that are isolated from surrounding development by a wide riparian corridor and wetland area. In addition few breaks in the riparian corridor occur in the stream corridor of these high-scoring segments.

**Table 11. HQI metrics and scores for North Creek segments 10-13.**

| Segment description | Pool Freq. | % Pool Area | Weigh. PQI | % Riffle Area | Weigh. RQI | LWD Freq. | LWD Vol. | Weigh. WQI | Total HQI Score | Habitat Quality Rating |
|---|---|---|---|---|---|---|---|---|---|---|
| **Penny Ck. 10A** | 7 | 4 | 3 | 4 | 5 | 4 | 4 | 3 | ***34*** | Med. High |
| **Penny Ck. 10B** | 4 | 4 | 3 | 4 | 3 | 4 | 4 | 3 | ***29*** | Med. Low |
| **Mill Ck 11** | 4 | 7 | 3 | 4 | 5 | 7 | 7 | 5 | ***42*** | High |
| **Wetland 12** | 4 | 7 | 3 | 4 | 5 | 7 | 4 | 5 | ***39*** | High |
| **McCollum 13** | 4 | 7 | 3 | 4 | 3 | 7 | 4 | 5 | ***37*** | High |
| **Possible Metric and HQI Scores** | ***1-4-7*** | ***1-4-7*** | ***1-3-5*** | ***1-4-7*** | ***1-3-5*** | ***1-4-7*** | ***1-4-7*** | ***1-3-5*** | ***9-50*** | |

### *Biology*

During the assessment, juvenile salmonids were frequently observed in all habitat unit types in mainstem North Creek segments 6 and 8, which are adjacent to each other (see Map 7Map 8). The only two chinook redds sighted during the 1999 King County spawning surveys were located in segment 8 (Map 7, Map 8). Freshwater mussel beds (*Unionid spp.)* are also located in scattered sites in segments 8, 12, and 13.

# Map 7. North Creek Segments 1-5 (Click for PDF)

## Map 8. North Creek Segments 6-9 (Click for PDF)

## Map 9. North Creek Segments 10-13 (Click for PDF)

# Little Bear Creek

The mainstem of Little Bear Creek from its confluence with the Sammamish River to 180th St. SE in Snohomish County and 371 meters of Great Dane tributary were assessed (Appendix A). An average of 66 percent of the 14 segments identified were assessed, ranging from 0 percent to 100 percent (0 percent: segments 12 and 100%: segments 1, 3, 4, and 6) (Appendix J). Field technicians conducted a reconnaissance of segment 12, and determined that the previously assessed segments 11 and 13 were representative of the instream and riparian habitat found in segment 12. As such, habitat quality of segment 12 was estimated from data collected from segments 11 and 13. Eight percent of segment 10 (Great Dane tributary) was assessed until water depths became too low to make accurate habitat measurements. Results of the Great Dane Creek portion of this assessment should be assumed to represent only four times the assessed amount of this tributary (1.6 km). The total length of Great Dane Creek is approximately 3.5 km.

## *Riparian Integrity*

Sub-basin forest cover was much reduced from pre-settlement conditions; no mature forest cover was present. Where forest cover was present, nearly half of it was deciduous, primarily dominated by red alder (*Alnus rubra*) and big-leaf maple (*Acer macrophyllum*) (Appendix D). The remaining forest cover was composed of mixed deciduous and coniferous species with only a small percentage of area in early and middle seral stages of coniferous forest succession. Portions of the riparian zone throughout the stream length were dominated by mixed forest, with moderate percentages (15-33 percent) in the lowest four segments, then decreasing in the middle reaches of the stream, and increasing as one moved upstream from segment 6 (Map 10, and 11, Appendix E). Canopy cover generally corresponded with riparian forest quantities; segments with at least 50 percent of the reaches forested, had fewer reaches in low shade categories (Appendix G). The following provides a summary of the habitat conditions in this sub-basin.

### *Basin Land-use*

Total sub-basin forest cover ranged from 31.7 percent in segment 1, to 37.1 percent in segment 14. When mixed and coniferous forest cover is combined, segments 1 and 2 had the lowest percent cover (13.5), while segment 8 contained the greatest percentage cover (16.4).

Road density was similar throughout the segment sub-basins. Road density in the sub-basins ranged from 5.1 to 5.9 km/km$^2$ (Appendix D).

### *Riparian Corridor Continuity*

Number of road crossings of the stream within the segment was highest in the two downstream most segments (3 in segments 1 and 2) and in the longest most upstream segment (~6 in segment 14). Number of road crossings was lowest in the lower–middle segments, 3, 4 and 5 (1 crossing each), and the upper segments 11 and 12 (1 and 0 crossings, respectively).

### *Riparian Vegetation*

Riparian forest cover ranged from 33 percent in segment 1, to 72-88 percent in he lower segments 2-4, to 0-43 percent in middle segments 5-9, then to 86-100 percent forested in upper segments (10-14) of the stream.

The riparian buffers associated with segments 2-4 were at least 70 percent forested, with 15-40 percent containing mixed and/or coniferous cover.

Segments 5-9 had less than 40 percent forested riparian cover, while the remaining riparian vegetation included shrubs, tall herbaceous species and vegetation associated with landscaped, residential property.

One hundred percent of the riparian zone associated with segments 10-13 was forested with a mix of deciduous and coniferous species.

The riparian zone of segment 14 contained approximately 86 percent deciduous forest.

Invasive plant species, including blackberry (*R. discolor*, *R. laciniatus*), reed canary grass (*P. arundinacaea*), and Japanese knotweed (*P. cuspidatum*), were present, but not dominant in the lower 9 segments of Little Bear Creek.

### *Canopy Cover*

Canopy cover generally increased as percent riparian forest cover increased.
Canopy cover was highest in segments 10 and 12 where riparian forest cover was 100 percent.
Canopy cover ratings for the other two segments (11 and 13) with 100 percent riparian forest cover were both within the 25-75 percent category.
Relatively large portions of the reaches in segments 1, 4, 5, and 9 did not contain shade (17-40 percent).
1999 temperature data from Little Bear Creek indicate that there were numerous occasions from June through August where temperatures exceeded $14^0$C, NMFS' (1996) "properly functioning conditions" limit for salmonids (Appendix H).

## Large Woody Debris

Quantities of LWD throughout Little Bear Creek were much below natural (Murphy and Koski 1989, Ralph et al. 1994, Beechie and Sibley 1997) levels. Only one segment had LWD frequencies within published natural ranges (Figure 16). Total quantity of LWD in the stream do not follow trends in riparian forest coverage (Figure 23). Frequencies of large LWD pieces are very low despite the presence of conifers within the riparian zone of most segments (Appendix I). Following is a summary of LWD quantity and quality in Little Bear Creek.

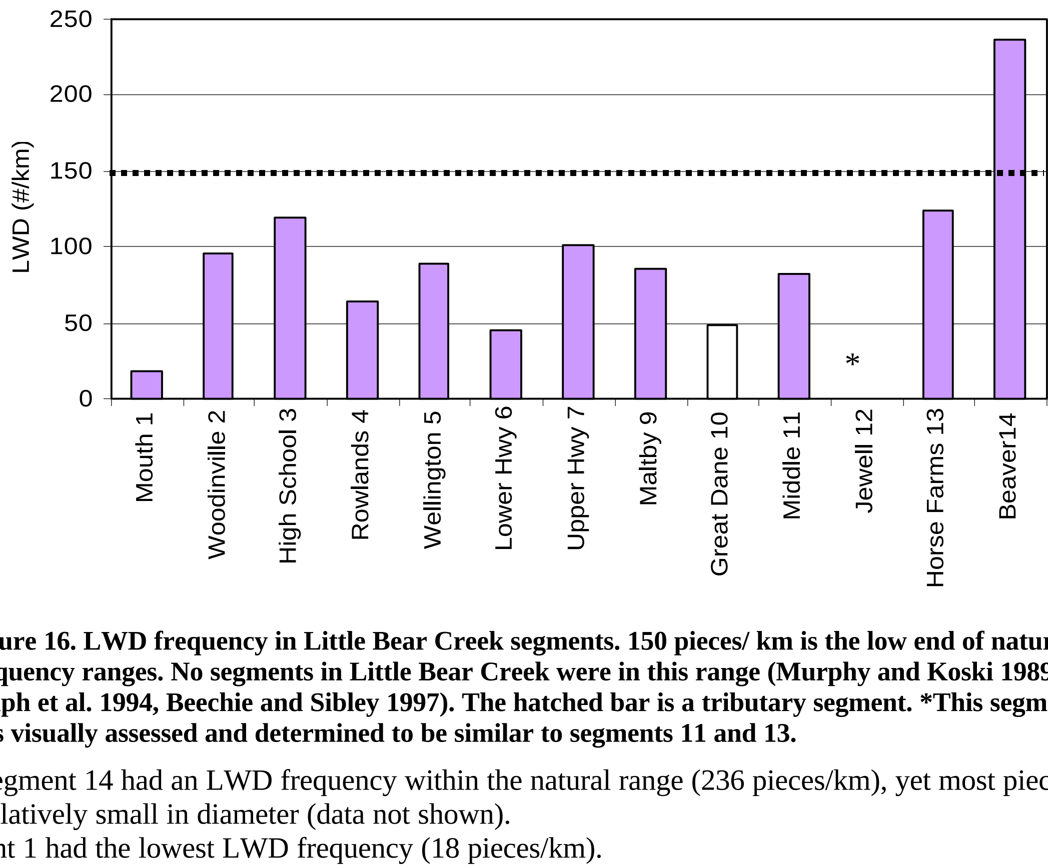


**Figure 16. LWD frequency in Little Bear Creek segments. 150 pieces/ km is the low end of natural frequency ranges. No segments in Little Bear Creek were in this range (Murphy and Koski 1989, Ralph et al. 1994, Beechie and Sibley 1997). The hatched bar is a tributary segment. *This segment was visually assessed and determined to be similar to segments 11 and 13.**

Only segment 14 had an LWD frequency within the natural range (236 pieces/km), yet most pieces were relatively small in diameter (data not shown).
Segment 1 had the lowest LWD frequency (18 pieces/km).
Segment 12 is predicted to have an LWD frequency between that of segments 11and 13.

## Channel Morphology

Comparisons of bankfull width to depth ratios (BFW: BFD ratios) can indicate shifts in channel stability in response to disturbance (Rosgen 1996). Increased discharge typically increases streambank erosion rates which results in channel widening and increased BFW: BFD ratios. The NMFS' matrix of properly functioning conditions suggests a BFW to BFD ratio of 10 is indicative of a stable, properly functioning channel. A ratio of 10-12 indicates an "at risk" channel, and ratios greater than 12 suggest conditions are not properly functioning (NOAA 1996).

### Bankfull Width

The mean bankfull width of Little Bear Creek was 5.6 meters.
The widest mean bankfull widths were 7.2 and 7.1 meters, on segments 3 and 5, respectively.
The narrowest mainstem segment mean bankfull width was 3.7 meters on segment 14.
The mean Great Dane tributary bankfull width was 3.3 meters.

### Bankfull Width to Depth Ratios

Only segment 7 had a mean BFW: BFD ratio greater than 10 (Figure 17).
BFW: BFD ratios ranged from 4.5 to 12.

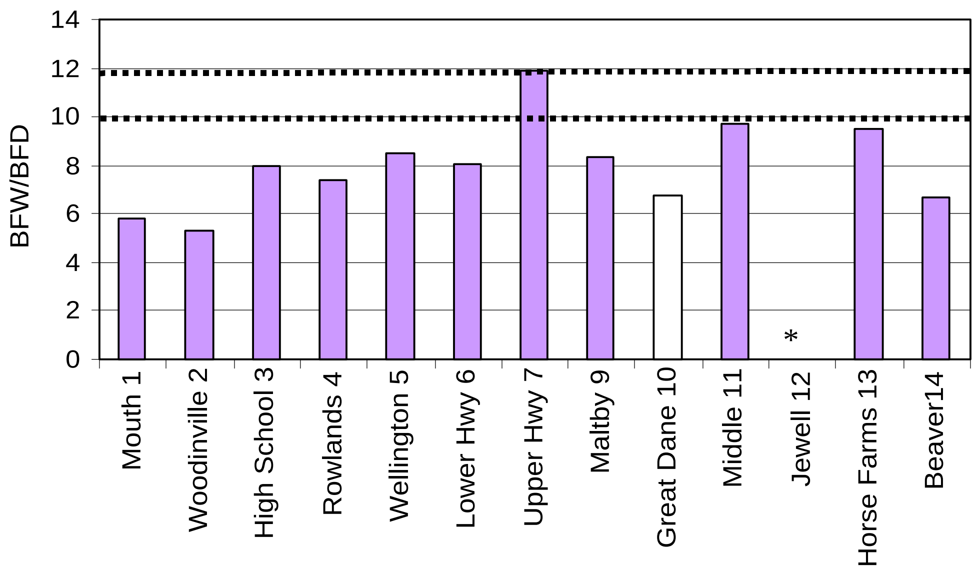


**Figure 17. Bankfull width to depth ratios of Little Bear Creek segments. Values below 10 are suggested by the NMFS Matrix of Pathways as indicative of 'properly functioning conditions', between 10 and 12 the stream is "at risk", and above 12 conditions are not properly functioning (NOAA 1996). The hatched bar represents a tributary segment. Segment 12 was visually assessed and determined to be similar to the adjacent segments 11 and 13.**

## Streambank Stability

Streambank stability ratings were related to the condition of the riparian corridor and relative location of the segment within the stream continuum. The most stable streambanks were located in the uppermost stream segments, which also had the highest percentage of riparian forest cover (Appendix K). One hundred percent of the reaches in segments 10-14 were rated stable, and riparian cover ranged from 100-86 percent.

- No reaches in the upper segments 7-14 were rated full scour.
- No reaches in the lower segments 1 and 4 were rated stable.
- Armoring was greatest in segments 1 and 7 (32 and 48 percent, respectively).

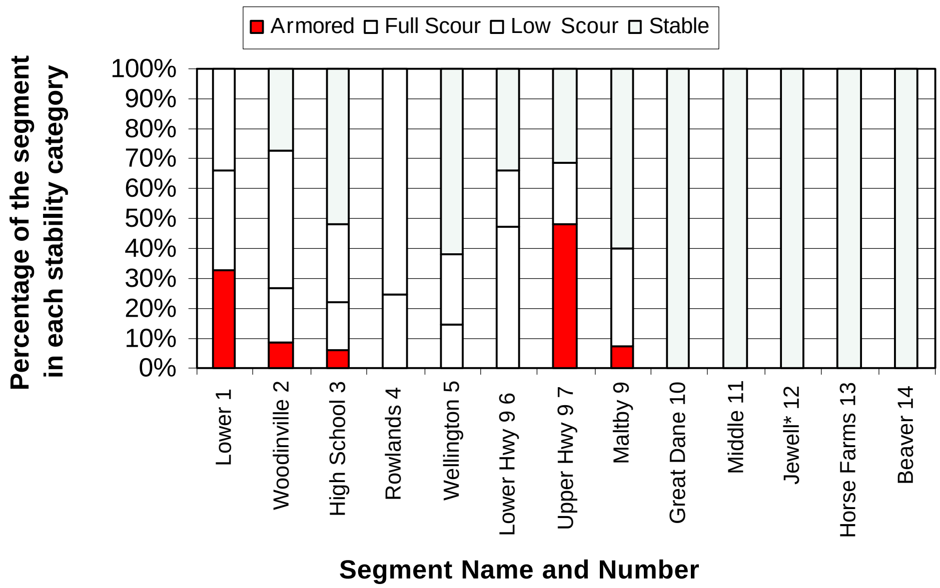


**Figure 18. Streambank stability ratings of Little Bear Creek segments. Upper segments had a higher percentage of streambanks rated stable. *Data from May et al. 1997**

## *Riffle Habitat*

Riffle habitat in this area below the optimum fraction of 40-60 percent in all but one stream segment (i.e. segment 1) (Figure 19). Percentage of riffle habitat by area generally decreased from the mouth of the stream to the middle–low gradient segments, then increased again in the upper stream reaches. The quality of these riffles was intermediate (Appendix L).

No segments contained riffles comprising more than 45 percent of the total stream habitat.
Only segment 1 had a percentage of riffle habitat within the natural range (40-60 percent); segment 11 was nearly within the natural range (42 and 39 percent, respectively).
The percentage of riffle habitat was 10 percent or less in segments 4, 5 and 13.
The highest quality riffles were in mainstem segments 5, 7 and Great Dane tributary segment 10 (3.8, 3.9, and 4.0, respectively).
The lowest quality riffles were in segments 4, 6, and 13 (2.5, 2.3 and 2.0, respectively).

## *Pool Habitat*

The percent of pool habitat by area was highest in the lower-middle segments and lowest in the upper segments (Figure 19). Percent pool habitat was within natural ranges only in the lower middle segments. No segments had pool frequencies of 30/ km or more, the value indicative of properly functioning conditions (NOAA 1996). Pool frequency trends did not appear to correspond with riparian zone integrity (Figure 25), however pool frequency was related to LWD frequency (Figure 24).

Pools made up between 45 and 50 percent of the stream habitat in segments, 3, 4 and 5.
Pools comprised 10 percent or less of the stream habitat in mainstem segments 11 and 14, and Great Dane tributary segment 10.

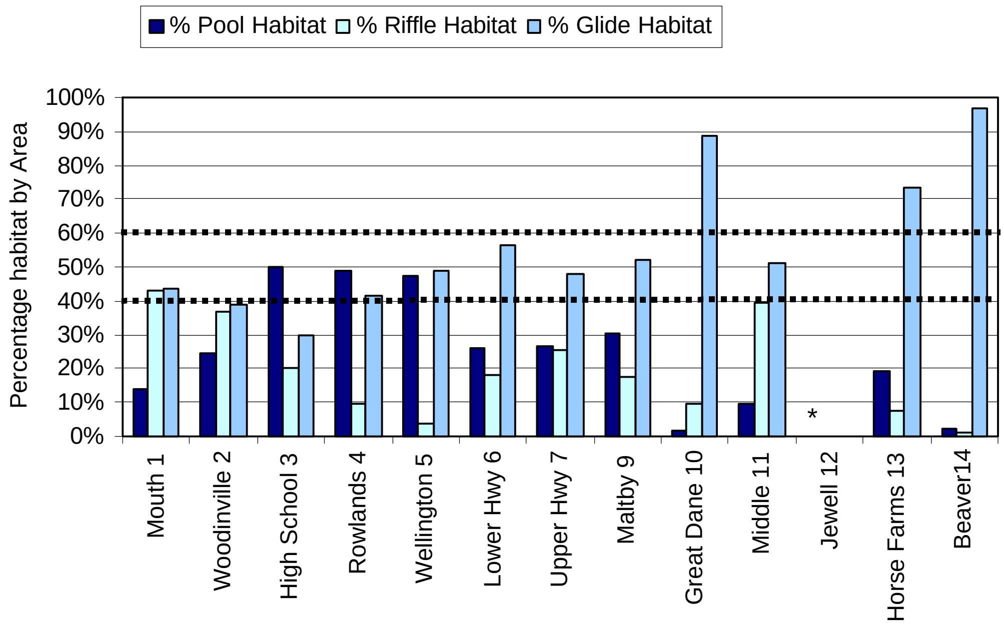


**Figure 19. Percent habitat composition by area in Little Bear Creek. Optimal pool to riffle habitat ratio is 1:1; the percentage of each should be between 40 and 60 percent (Peterson et al. 1992). Only four segments had more than 40 percent pool habitat by area, and only one had greater than 40 percent riffle habitat by area. * Segment 12 was visually assessed and estimated to be similar to the adjacent segments 11 and 13.**

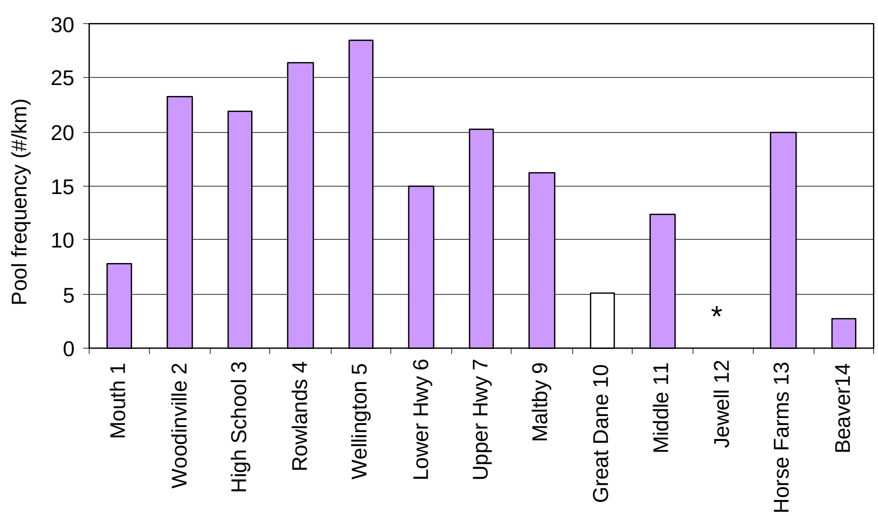


**Figure 20. Pool frequency in Little Bear Creek segments. No segments meet NMFS' Matrix of Pathways and Indicators properly functioning conditions standard of 35 pools/km. The hatched bar is a tributary segment. * Segment 12 was visually assessed and determined to be similar to the adjacent segments 11 and 13.**

Pool quality did not seem to correspond with LWD frequency or riparian forest integrity. Mean pool quality was highest in the middle segments (Appendix L).

Segment 3 had the highest mean pool quality (4.6)

The mean pool quality rating of middle segments (5-9) was high, between 4.2 and 4.4.

The mean pool quality in all other segments in the downstream most and upstream most segments ranged from 3.0-4.0.

## *Glide habitat*

Glides are intermediate habitat units that have characteristics of both pools and riffles but provide little of the functional capabilities of either. Although relatively deep and slow during baseflow conditions like pools, glides provide little cover refuge during peak-flows. Glides also tend to be slower water habitats where finer sediments predominate, making them poorer spawning habitat. All segments in this area had greater than 25 percent glide habitat by surface area.

Glide habitat made up more than 40 percent of the total habitat in 10 of the 12 segments assessed. Mainstem segments 13 and 14, and Great Dane tributary (segment 10) contained had greater than 70 percent glide habitat.
Segments 1 and 4 had the lowest percentage of glide habitat (35 and 30 percent, respectively).

## *HQI Scores*

HQI scores on Little Bear Creek ranged from 10 (Great Dane tributary) to 31 (Figure 21, Appendix M). All except one (segment 3) of the segments were rated low to medium-low habitat quality. Low scores for LWD metrics, low habitat complexity and the dominance of glide habitats in all segments contributed to the overall low HQI scores. Despite the presence of forested riparian buffers along many of the stream reaches, LWD quantities and pool frequencies remained relatively low in all segments, suggesting mechanisms of wood removal are operating other than absence of a recruitment source. In addition the dominance of deciduous forest in the riparian corridor may account for the low LWD quantity and quality. The following section provides an overview of the HQI scores for Little Bear Creek.

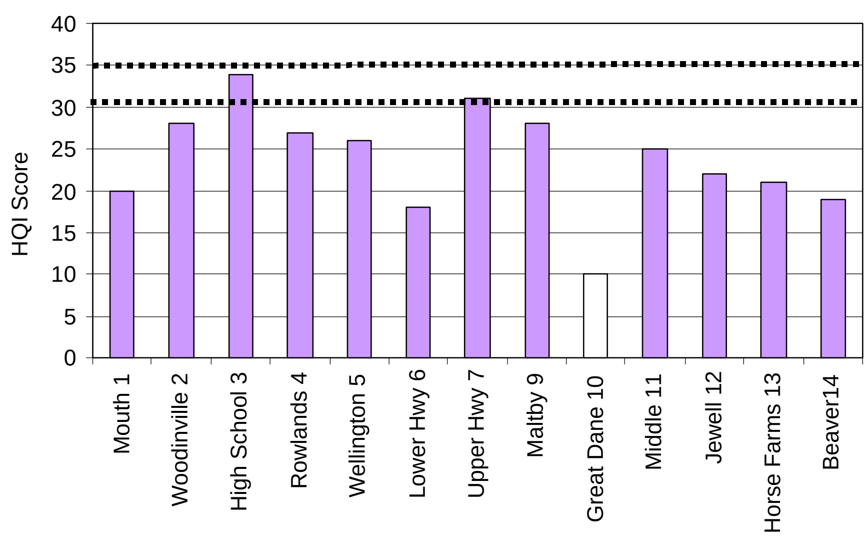


**Figure 21. Little Bear Creek HQI score distribution. Segments with scores below 23 were rated low, 24-31 were rated medium-low, 32-36 were rated medium-high, and those with scores above 36 were rated high quality. The hatched bar represents a tributary segment. Segment 12 was not done (N.D.) but was estimated to be similar to the adjacent segments 11 and 13.**

## *Segments 1-7*

HQI scores of segments 1, 2, 4-7 were low due to low instream habitat complexity, low quantity and quality of LWD (Table 12, Map 10). The two segments with the lowest scores (18) had low LWD frequency and volume, and few large and/or coniferous LWD pieces. All segments (3-5) with high percentages of pool habitat by area also had at least moderate amounts of wood. Higher LWD frequency, volume and quality scores in segments 2-4 correspond with increased riparian forest cover. Forests containing some coniferous species dominated the riparian zones of these lower–middle segments. Riffle frequency and quality were highest in segments 1-3 and lowest in segments 4-6.

**Table 12. HQI metric scores and quality ratings for segments 1-7.**

| Segment description | Pool Freq. | % Pool Area | Weigh. PQI | % Riffle Area | Weigh. RQI | LWD Freq. | LWD Vol. | Weigh. WQI | HQI Score | Rating |
|---|---|---|---|---|---|---|---|---|---|---|
| **1 (Mouth)** | 1 | 4 | 1 | 4 | 5 | 1 | 1 | 1 | ***18*** | Low |
| **2 (Woodinville)** | 4 | 4 | 3 | 4 | 5 | 4 | 4 | 3 | ***31*** | Med. Low |
| **3 (High School)** | 4 | 7 | 3 | 4 | 5 | 4 | 4 | 3 | ***34*** | Med. High |
| **4 (Rowlands)** | 4 | 7 | 3 | 1 | 3 | 4 | 4 | 1 | ***27*** | Med. Low |
| **5 (Wellington)** | 4 | 7 | 3 | 1 | 3 | 4 | 1 | 3 | ***26*** | Med. Low |
| **6 (Lower Hwy)** | 1 | 4 | 3 | 4 | 3 | 1 | 1 | 1 | ***18*** | Low |
| **7 (Upper Hwy)** | 4 | 4 | 3 | 4 | 5 | 4 | 4 | 3 | ***31*** | Med. Low |
| **Possible Metric and Total Scores** | ***1-4-7*** | ***1-4-7*** | ***1-3-5*** | ***1-4-7*** | ***1-3-5*** | ***1-4-7*** | ***1-4-7*** | ***1-3-5*** | ***9-50*** | |

## *Segments 8-14*

Mainstem and tributary segments in the upper reaches of Little Bear Creek generally had low instream habitat complexity and low to moderate amounts of LWD that lead to overall low habitat quality ratings (Table 13, Map 11). All segments scored low on the pool frequency metric, however segments 9 and 13 had moderate percentages of pool habitat by area. These two segments also contained moderate amounts of LWD. Two other segments (11 and 14) had moderate and high LWD frequencies, although this did not result in high pool quantities. The riparian integrity of segments 11-14 was high, with at least 85 percent forest cover; mixed forest dominates the riparian corridor of segments 11-13. However, low quantities of LWD were found in these segments, despite the presence of a well forested riparian zone. Riffle percentages and quality generally decreased in an upstream direction from segment 9 to segment 14. The tributary, Great Dane Creek, had very low habitat complexity and little instream LWD.

**Table 13. HQI metric scores and habitat quality ratings for segments 8-14.**

| Segment description | Pool Freq. | % Pool Area | Weigh. PQI | % Riffle Area | Weigh. RQI | LWD Freq. | LWD Vol. | Weigh. WQI | HQI Score | Rating |
|---|---|---|---|---|---|---|---|---|---|---|
| **9† (Maltby)** | 1 | 4 | 3 | 4 | 5 | 4 | 4 | 3 | ***28*** | Med. Low |
| **10* (Great Dane)** | 1 | 1 | 1 | 1 | 3 | 1 | 1 | 3 | ***10*** | Low |
| **11 (Middle)** | 1 | 1 | 3 | 4 | 5 | 4 | 4 | 3 | ***25*** | Med. Low |
| **12** (Jewell)** | | | | | | | | | ***22*** | Low |
| **13 (Horse Farms)** | 1 | 4 | 3 | 1 | 3 | 4 | 1 | 3 | ***18*** | Low |
| **14 (Beaver)** | 1 | 1 | 1 | 1 | 1 | 7 | 4 | 3 | ***19*** | Low |
| **Possible Metric and Total Scores** | ***1-4-7*** | ***1-4-7*** | ***1-3-5*** | ***1-4-7*** | ***1-3-5*** | ***1-4-7*** | ***1-4-7*** | ***1-3-5*** | ***9-50*** | |

† This HQI score applies only to the non-wetland reaches of the segment (approximately 2/3rds of the segment).
*Tributary
**Score estimated from representative reaches in segment 11 and 13.

### *Biology*

Juvenile coho and cutthroat were sighted throughout all of the segments. Sightings were especially frequent, mostly in the pools, of segments 3 and 4. Spawning sockeye and coho were also observed during the mid-September through early November habitat assessments of Little Bear Creek. Spawning sockeye were observed in segments 2 and 3, spawning kokanee were also spotted in segment 2. Later in the fall, adult coho were sighted in segments 3, 9, 11, and 14 and spawning behavior was noted in segment 9. One chinook redd was identified in segment 3 of Little Bear Creek during the 1999 King County WLRD spawning surveys; the only segment where both percent pool area *and* riffle quality were high.

Although the segment 3 habitat quality rating was only medium–low (the score was the highest possible in the medium low category), the only chinook redd observed in Little Bear Creek during the 1999 King County WLRD chinook spawning surveys occurred here.

Evidence of Beaver activity, including freshly gnawed branches and dam building were sighted in segments, 3, 5, 9, and 14. Freshwater mussel beds are located in the downstream reaches of segment 9.

# Map 10. Little Bear Creek Segments 1-7 (Click for PDF)

## Map 11. Little Bear Creek Segments 9-15 (Click for PDF)

# Combined data analysis

Examination of relationships between the larger combined data set collected from the three assessed streams, can reveal and confirm relationships between parameters and suggest possible causal relationships. The following provides an overview of this analysis.

Urbanizing streams tend to “over-widen” and incise as a result of more frequent bankfull flow conditions (Dunne and Leopold 1978). When BFW measurements are plotted against sub-basin area, regional curves can be developed showing the characteristic relationship for natural and urban streams. Using regional data complied by the University of Washington, Center for Urban Water Resources Management (Henshaw 1999), BFW measurements from the three assessed streams were compared to regional curves for low-urbanization and urbanized (high urbanization) streams (Figure 22). The data for North, Swamp, and Little Bear Creeks generally correspond with the regional data for urbanized streams, and confirm the conclusion that a modified hydrologic regime has negatively impacted stream channel morphology.

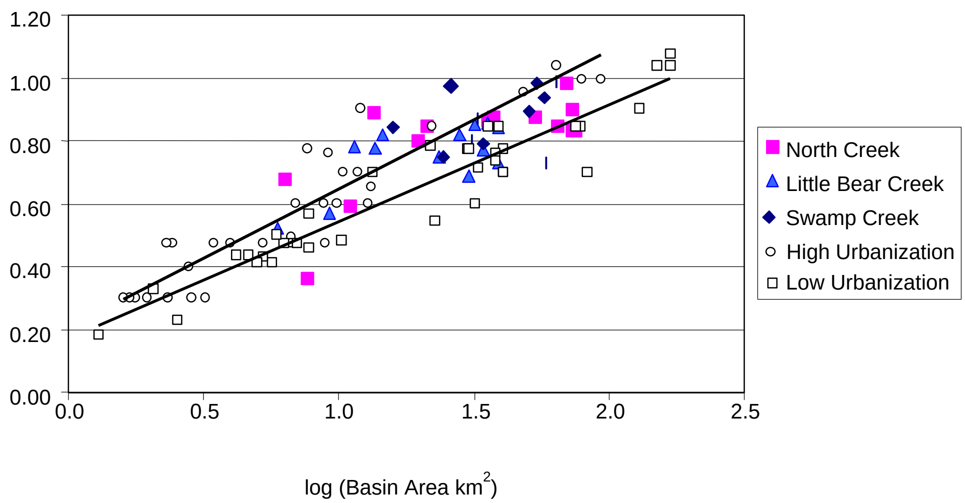


**Figure 22. The bankfull width of urbanized streams are larger relative to the basin size than streams with low levels of urbanization. The data from the three study streams: Swamp, North and Little Bear Creeks fall in the highly urbanized category (Henshaw 1999).**

Substantial frequency and volume of LWD were only found in assessed stream-segments that had a considerable forested component within their riparian zone, which may function as a source of LWD and a buffer to LWD removal by area residents. Having a fully forested riparian corridor did not, however, ensure natural levels of instream LWD (Figure 23). Isolated areas where mature, coniferous dominated forest corridors still occur in these urbanizing watersheds (see segment 10) of Swamp Creek, the upper mainstem segments (11-14) of Little Bear Creek, and segment 13 (McCollum) on the upper mainstem of North Creek). These areas in North and Swamp Creeks but not in Little Bear Creek, had relatively high LWD frequencies. High percentages of riparian forest cover do not necessarily guarantee high LWD frequencies due to multiple loss mechanisms and possible limiting recruitment potential.

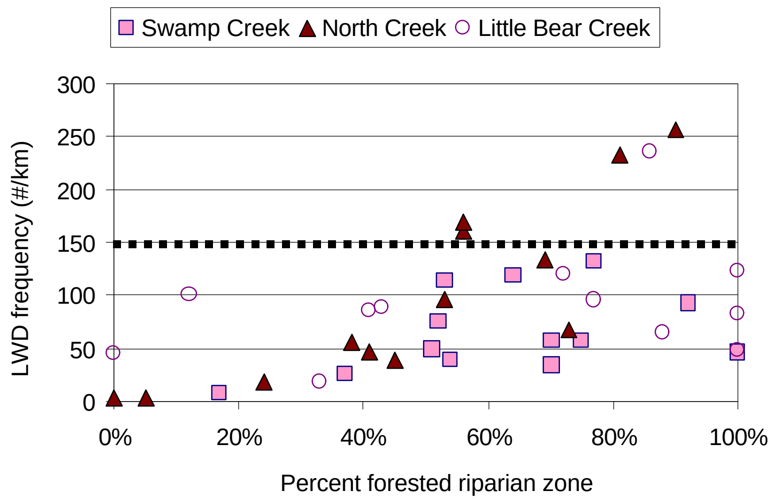


**Figure 23. LWD frequency and the percent of the riparian corridor that is forested. Instream large woody debris frequency is only high when a significant portion of the riparian zone is forested. $R^2$ =0.23, p < 0.01. Dashed line is the low end of the natural frequency range (Murphy and Koski 1989).**

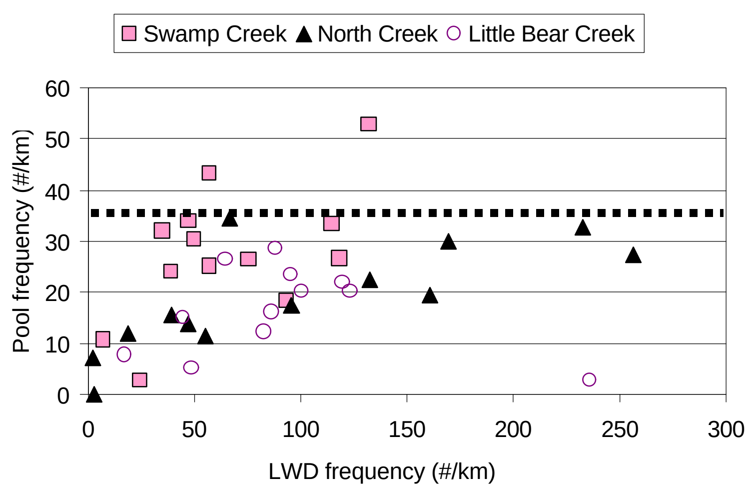


**Figure 24. Pool frequencies relationship to LWD frequencies. Pool frequencies were lowest where instream LWD frequencies were also low. Pool frequencies were mostly higher where LWD frequencies were high. $R^2$= 0.21, p < 0.01. Dashed line is the lowest frequency of pools that indicates properly functioning conditions (NOAA 1996).**

Only reaches above the city of Mill Creek in North Creek, scattered middle segments of Swamp Creek and a few segments in lower middle Little Bear Creek appear to have pool quantities approaching to natural conditions. Pool quantity (surface area fraction and frequency) was positively influenced by LWD (Figure 24) and the maintenance of a mature, forested riparian corridor with few breaks (Figure 25).

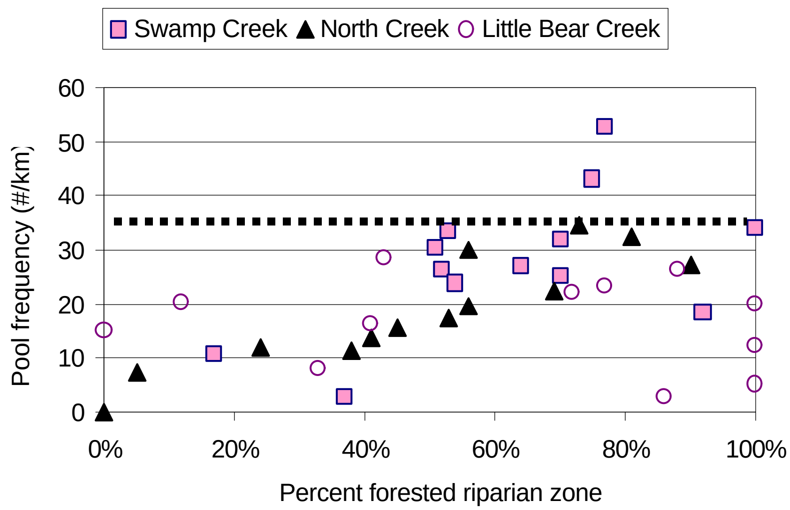


**Figure 25. The relationship between pool frequency and percentage of forested riparian zone. The relationship is relatively strong on Swamp and North Creeks ($R^2$=0.55, p <0.001; but less so on Little Bear Creek (all data: $R^2$=0.21, p< 0.01). Dashed line is the lowest frequency of pools that indicates properly functioning conditions (NOAA 1996).**

# Data Quality Assessment

Information collected from replicate reaches was used to assess data precision. Observer bias was found to occur in these assessments. This bias lead to a varying lack of precision for several assessment parameters. Parameters that required categorical estimation of conditions (e.g. streambank stability, shade, riparian vegetation) by field crews were often assigned different categories. This variation was especially high for riparian vegetation type, shading, and bank stability estimations. The opportunity for bias was likely increased for these parameters because a number of categories for classification were offered, but only one intensive field training session was held to train field crews to identify categories. These problems are consistent with those described by Platts et al. (1983).

Distribution of RQI scores relative to known habitat quality suggests that the index required too many qualitative judgements to assess riffle quality with accuracy. The embeddedness estimation portion of the RQI may require additional training, or needs to be replaced with a quantitative evaluation, which could then be incorporated into a description of riffle cover and proximity to pools and wetlands.

In-channel measurements were much more consistent among field crews. Number of recorded pools and riffles measured by the three field crews were the same in the replicate reach. Measurement of bankfull width, residual pool depth, pool quality index rating, riffle quality index rating, and number of LWD were similar. Emphasis is placed on these metrics in the HQI, which should provide the highest level of accuracy for the multi-metric index assessment.

The most consistent non-quantitative parameter was the narrative reach description. Although the data recorded had some discrepancies, the comments each crew recorded were remarkably similar for the replicate reach. It appears that more extensive training and a more quantitative protocol could greatly minimize observer bias in future assessments. Some methods used to decrease the variability between field technicians included providing training, reducing the number of people involved, and evaluating problems and making adjustments in the initial phase of the assessment. The data represented in this report do have an associated degree of error; however, measures were taken to minimize this error throughout the assessment.

# DISCUSSION

The cumulative impacts of land-use practices over the past century, including timber harvest, agriculture, and urbanization, have significantly modified the natural landscape characteristics of Puget Sound lowland watersheds, thereby altering many processes that maintain the natural structure and function of aquatic ecosystems. Due to increased population in our region, development has emerged as the most significant land-use in the lowland region today. The effects of watershed urbanization on aquatic resources are well documented (Leopold 1968, Hammer 1972, Hollis 1975, Klein 1979, Arnold et al. 1982, Booth 1991, May et al. 1997, May and Horner 2000) and include extensive changes in basin hydrologic regime, channel morphology, and physiochemical water quality. The cumulative effects of these alterations on natural ecosystem structure and function have produced an in-stream habitat that is considerably different from that in which salmonids and other aquatic biota have evolved. In addition, development pressure has negatively impacted riparian forests and wetlands, which are an integral component of PSL stream ecosystems (Richey 1982, Steward 1983, Scott et al. 1986, Booth 1990, Booth and Reinelt 1993, May et al. 1997, Horner and May 1999). Parameters measured in this study suggest that urbanization induced changes in hydrology, channel morphology, riparian integrity and instream habitat quality have occurred.

## Basin Landuse and Hydrology

One of the most influential factors affecting instream habitat is modification of the natural landscape. In the PSL, there has been a significant shift from undeveloped, coniferous-dominated forested watersheds to developed watersheds dominated by impervious surfaces (May and Horner 2000). Forest cover is significantly reduced from pre-settlement natural conditions in all three assessed watersheds. Swamp and North Creek watersheds had similar percentages and composition of forest cover–approximately 19 percent forested, with 3.4 to 5.6 percent of the watershed landuse classified as mixed forest. The less urbanized Little Bear Creek watershed had a higher percentage of forest cover and a higher percentage of that cover classified as mixed forest (32 percent and 13.4 percent, respectively, Appendix D). Road density has been highly correlated with the percentage of impervious surface in the Puget Sound Lowlands (May et al. 1997). Road density within the Swamp and North creek basins is quite high (Appendix D), which suggests land cover in these basins is increasingly impervious and hydrology will tend more toward surface-dominated runoff. The less developed Little Bear Creek basin has a lower basin road density (Appendix D).

A nearly continuous riparian corridor is important to stream ecosystem function (May et al. 1997, Naiman and Bilby 1998, Wenger 1999, Naiman et al. 2000). Road crossings, utility-line gaps, and other breaks in the riparian corridor fragment the stream-riparian ecosystem and allow direct access of surface runoff into the stream system (May et al. 1997). The frequency of road crossings found in these three streams is not as high as is found in other streams of similar urbanization levels (May et al. 1997). Although Little Bear Creek has much lower overall road density than Swamp and North creeks, the frequency of riparian corridor road crossings is similar to Swamp Creek, which may increase the affects of increased surface water runoff. However, several reaches in the three study streams were relatively intact with less than two breaks per kilometer of stream channel length. This is generally recognized as within the range of natural conditions for the PSL (May et al. 1997). Reduced fragmentation of the riparian corridor within these segments may decrease the potential of surface water runoff to the stream, reducing extent and volume of stormwater flow (May et al. 1997). Although long-term hydrologic (discharge) records for the three study streams are not available to conduct a trend analysis, changes detected in basin land cover and riparian zone integrity would tend to promote more rapid and higher volumes of surface runoff (Booth 1991). (Discharge records for the 1999 water year are located in Appendix H).

## Riparian Corridor

Riparian forest cover in the Swamp, North and Little Bear creek ecosystems is significantly diminished from pre-settlement conditions. The riparian vegetation has changed from the natural coniferous dominated forest cover to landscaped areas, herbaceous vegetation, shrubs, various invasive species, and only minimal natural riparian forest cover in most assessment segments (Appendix E). Those areas where riparian forest still occurs are typically dominated by small diameter deciduous species including red alder, willow and big-leaf maple. Current conditions in the riparian zones of the three assessed streams probably reflect a legacy of multiple logging cycles, and agricultural impacts, in addition to current development pressures. Tree removal in riparian areas reduces potential for LWD recruitment into streams. Lack of LWD is also directly correlated with instream habitat quality and diversity (Sedell et al. 1984, Andrus et al. 1988, Murphy and Koski 1989, Beechie and Sibley 1997).

## Stream Shade and Temperature

1999 temperature data from Swamp and Little Bear creeks indicate there were numerous occasions from June through August where temperatures exceeded the "properly functioning conditions temperature limit of $14^0$C (Appendix H). No reaches in any of the three streams were rated with the highest shade category (95-100%). Canopy cover data should reflect the capability of riparian vegetation for shading the stream and moderating stream temperatures. Canopy cover data from the three assessed streams generally correlated with riparian zone vegetation composition. In most segments where the riparian zone is greater than 70 percent forested, very few or no reaches were classified as having 0 percent shade. A stronger relationship between riparian cover composition and stream shading was expected, though each of these data sets was categorical and subject to the lack of precision associated with such data (Platts et al. 1983). Most of the riparian forests along these streams are simplified, even-aged stands of deciduous species which may, in mid-summer, result in more canopy gaps than are present in a multi-storied closed canopy, coniferous forest (Rot 1995).

## Channel Morphology

With increased surface water dominated hydrology, streamflow tends to increase for a given storm event, and the duration of high-flow events also increases (Booth 1991). The resultant higher peak flows and more frequent bankfull, channel-forming events increase streambank erosion, bedload transport, and streambed scour (Leopold 1968). Urbanizing streams tend to "over-widen" and incise as a result of more frequent bankfull flows (Dunne and Leopold 1978, Booth 1990). Evidence of this can be found in BFW: BFD ratios of Swamp Creek and some segments of North Creek in particular, where ratios are greater than 12 (Figure 5, Figure 11, Figure 17). BFW measurements of the three assessed streams plotted against sub-basin area with regional data complied by the University of Washington, Center for Urban Water Resources Management (Henshaw 1999), generally correspond with the regional data for urbanized streams (Figure 22). This confirms the conclusion that a modified hydrologic regime in these basins has negatively impacted stream channel morphology and has caused excessive streambank erosion and sediment deposition. The lack of LWD and poor riparian condition also contribute to poor streambank conditions in general.

The combination of atypically large sediment loads and stream channel enlargement has a profound impact on the longitudinal structure of urban streams. The sequence of pools and riffles that is characteristic of natural streams tends to be degraded into a uniform depth, glide-dominated channel as the gradient and dimensions of the stream adjust to accommodate more frequent, higher flows (Lisle and Hilton 1992). Elevated storm flow and resultant channel enlargement also have a significant impact on instream physical habitat conditions (Booth 1990, Booth 1991, May et al. 1997, May and Horner 2000). Washout of LWD is common, as is scouring and removal of salmonid spawning gravels. In addition, fine sediment from streambank erosion can be deposited on salmonid spawning areas and cause increased egg/ embryo mortality (Chapman 1988). In general, the combined impacts of modification of natural stream hydrology and channel morphology result in a loss of physical habitat quantity (both spawning and rearing) and degradation of instream habitat quality (May et al. 1997).

## Streambank Stability

Streambank stability ratings for the three study streams indicate streambank erosion due to frequent excessively high storm flow is common. All but a few assessment segments were dominated by eroding or armored streambanks (Figs. 6, 11, 18, Appendix K). Assessed segments of all three streams with high a percentage of forested riparian zone reaches often had more stable banks (e.g. Swamp Creek segment 11B, Little Bear Creek segments 11 and 13). Basin urbanization and loss of riparian vegetation are two of factors contributing to erosion and instability of streambanks (Booth 1991, Booth and Reinelt 1995, May et al. 1997). Besides vegetative cover, other stream corridor characteristics, such as soil-type and valley hillslope gradient, also contribute to the potential stability and current condition of the banks. Riparian vegetation stabilizes streambanks and minimizes streambank erosion, the roots of riparian vegetation and LWD provide the bulk of this function in the PNW (Bilby and Likens 1980).

## Large Woody Debris

Few segments in the three assessed streams had LWD frequencies above the *low end* of published ranges for natural conditions in the PNW (range: 150-670 pieces/ km, (Murphy and Koski 1989, Ralph et al. 1994, Beechie and Sibley 1997). In general, small non-urbanized, natural stream channels in the PNW tend to contain an abundance of LWD (Naiman and Bilby 1998). Only the upper segments of North Creek and uppermost segment of Little Bear Creek had LWD frequencies greater than 150 pieces/km. The importance of LWD and its functional role in streams in urbanizing watersheds of the PSL is very much the same as it is for streams draining natural forests in other PNW ecoregions. LWD performs critical functions in forested lowland streams, including flow energy dissipation, streambank protection, streambed stabilization, sediment storage, and providing instream cover and habitat diversity (Keller and Swanson 1979, Bilby 1984, Harmon et al. 1986, Bisson et al. 1987, Gregory et al. 1991). LWD in low-gradient pool-riffle or plane-bed streams found in this region has the greatest range of functional influences (Bilby and Ward 1989, 1991, Montgomery et al. 1995).

Natural frequencies and volumes of LWD were only found in assessed stream-segments that contained a wide, mature and coniferous dominated forest component within the riparian zone, which may function as a source of LWD and as a buffer to LWD removal by area residents. Numerous studies have found LWD recruitment potential depends heavily on riparian corridor quality and size (Murphy and Koski 1989, Van Sickle and Gregory 1990, Johnson and Ryba 1992, Fetherston et al. 1995, Rot et al. 2000). It is the general consensus of most scientists that nearly all LWD is derived from the riparian zone within one site potential tree height (SPTH) of the active (BFW) stream channel (FEMAT 1993). Having a fully forested riparian corridor did not, however, ensure natural levels of instream LWD (Figure 23). This emphasizes that numerous mechanisms of LWD loss are operating in an urbanized stream ecosystem, including washout due to high storm flows, and shows the importance of maintaining wide and continuous riparian buffers around sensitive ecosystems such as streams and wetlands.

Even more significant than the decreased LWD volume and frequency in urban streams was the lack of larger “key” pieces of LWD within these systems (Appendix I). Large pieces of LWD are particularly important for anchoring debris jams that can have significant effects on instream habitat (Maser et al. 1988), and pool size is also influenced by LWD size (Naiman and Bilby 1998). Riparian integrity, including riparian buffer width and the various aspects of riparian quality, such as stand-age and species composition, is especially influential on LWD size (May et al. 1997). LWD-influenced biological changes typically follow the physical changes (Harmon et al. 1986). The physically induced biological influences of LWD are substantial. Fish populations have been shown to decline rapidly following LWD removal (Bryant 1983, Hicks et al. 1991).

## Pool and Riffle habitats

The substantial reduction in quantity and quality of pool habitat in Swamp, North and Little Bear creeks is most likely due to cumulative effects of urbanization, which includes changes in the natural hydrologic regime and reduced LWD recruitment due to loss of riparian integrity. Stream segments with greater than 40 percent of their surface area as pool habitat were found only in reaches with relatively undisturbed (i.e. forested) riparian corridors (Figure 25). This seems to indicate that even where sub-watershed development is fairly high in these watersheds, salmonid habitat may still be maintained by preserving extensive riparian buffers. However, several stream segments with natural riparian conditions had less than optimum pool habitat– again demonstrating that instream habitat is a function of multiple external variables, in addition to riparian integrity. The linkage between riparian conditions and instream habitat hinges on many variables, an important one being LWD recruitment.

Pool frequency and depth has been shown to be directly proportional to LWD frequency. In addition, surface area, and cover-quality are also directly related to LWD quantity and quality (Andrus et al. 1988, Robison and Beschta 1990, Ralph et al. 1994). In general, the pervasive nature of urbanization has caused degradation of instream habitat, in general, and rearing habitat, in particular (Scott et al. 1986, Imhof et al. 1991, Lucchetti and Fuerstenberg 1993, May et al. 1997).

In general, quantity of riffle (spawning) habitat was also below the optimum 40-50% level in all but a few assessed stream segments (Figure 7, Figure 13). Riffle *quality* was below optimum in all three streams (range 1.3-4.2, out of a possible 5), primarily due to levels of embeddedness greater than 20 percent. The lowest quality riffles were generally in the lower gradient “response” reaches of Swamp and North Creeks where water velocities decrease and suspended sediments are deposited.

A general shift in habitat dominance from “balanced” pool-riffle morphology to a glide-dominated habitat structure was detected from the assessment data. Glides are intermediate habitat units, which have some of the characteristics of both pools and riffles but provide little of the functional habitat capabilities of either. While relatively deep and slow during baseflow conditions like pools, glides provide little cover or flow refuge during peak-flow periods, thus provide generally poor rearing or refugia habitat. In addition, glides also provide generally poor spawning habitat due to their lack of hyporheic flow and susceptibility to streambed “armoring” (May et al. 1997). All but a few segments in the three streams had greater than 25 percent glide area. The reason this shift to glide habitat may be due to the lack of a significant quantity of pool forming LWD in the assessed streams. Montgomery and Buffington (1997) found that forced pool-riffle reach morphology changes to glide dominated plane-bed morphology with the loss of instream LWD (Montgomery et al. 1999).

## Invasive Species

The number and quantity of invasive species found in the riparian corridors of Swamp, North, and Little Bear Creeks are significant, especially along more disturbed lower segments (Appendix F). In general, fragmentation and encroachment of the riparian corridor provides pathways for invasive and exotic species, especially plants. Himalayan blackberry (*Rubus discolor*) and reed canary grass (*Phalaris arundinacae)* are the most common invasive species along these streams, and dominate much of the riparian corridor of Swamp and North Creeks. Evergreen (*Rubus laciniatus*) blackberry, Japanese knotweed (*Polygonum cuspidatum*), and climbing nightshade (*Solanum dulcamara*) are generally present throughout each stream corridor, often most abundant in the lower reaches of the stream. Morning glory (*Convolvulus arvensis*), yellow flag iris (*Iris pseudacorus*), purple loosestrife

(*Lythrum salicaria*), and spirea (*Spirea douglasii*) are also present in less disturbed riparian locations along these streams. While many of these invasive plants may provide some beneficial functions to the stream ecosystem (shade, detritus, bank stabilization, etc.), they are not a source of LWD to the stream and also prevent native riparian species from becoming established.

## Habitat Quality Index

The habitat quality index is intended to be a simplified descriptor of habitat quality for a stream segment, mainly for comparison purposes during a stream assessment process. This index uses the major components of high quality instream habitat to define the "optimum" condition. Only elements that were directly a part of instream habitat quality, were included; LWD was included, however, riparian vegetation was not. In addition, wetlands were not included in the index, because wetland extent was not quantified and wetland quality was not assessed. The HQI evaluation of habitat quality may be useful for identifying areas for further investigation and examination. Habitat quality ratings may suggest actions to consider for future planning, or restoration projects. Segments rated "low" or "medium" may benefit from restoration activities. Segments rated "high" quality habitat by the HQI may be good candidates for acquisition or additional protection. ***Because many aspects of good quality stream ecosystems have not been included in this index, and the provisional and preliminary stage of the index development, this HQI should not be used as the sole source of habitat quality information for decision making***.

As expected, the majority of the HQI ratings appear to reflect the land use of adjacent, local areas. For example, Segment 3 in lower Swamp Creek was the only segment in the lower reaches rated "medium-high" and was mostly within Wallace Park, a natural conservation area. In addition, the only three segments (all on North Creek) rated "high quality" each had 50-80% of the riparian corridor categorized as forested with a coniferous component. On the other hand, Little Bear Creek had a relatively extensive forested riparian zone, as well as fewer channelized, simplified reaches, which suggested habitat quality would be high. However, generally low pool or riffle frequencies, and low LWD quantities and quality resulted in low overall HQI ratings of Little Bear Creek segments. Interestingly, riffle quantities were rarely low, and a number of segments scored high on the riffle quality metric. The continued presence of headwater wetlands in the Little Bear Creek watershed probably buffer the hydrology, preventing erosion and deposition of fines in spawning gravels and consequently resulting in higher RQI scores. This suggests that "local" conditions such as riparian integrity probably have as much influence on instream conditions as watershed scale land use.

Wetland contributions to overall habitat quality were not directly incorporated into the HQI, although the ecological functions of streams and wetlands are closely linked. Natural floodplains and riparian wetlands are critical components of a properly functioning aquatic ecosystem (Naiman and Bilby, 1998). Riparian wetlands serve many important ecological functions in the lowland stream ecosystem including stormwater storage, sediment filtering, and NPS pollutant uptake (Reinelt and Horner 1995). Stream basins with higher levels of urbanization generally have few riparian or headwater wetlands, and those that do exist are generally of low quality. The rural and low-density suburban streams such as Little Bear Creeks have a large fraction of their riparian and headwater wetlands still intact. In the medium-density suburban category, Swamp and North creeks still retain a good portion of their riparian wetlands although their headwater wetlands are significantly degraded. The evaluation of the stream segments only indirectly captures a number of the roles that wetlands play in creating good quality habitat, as previously discussed. The hydrologic buffering that wetlands provide to stream channels will be reflected in the higher quality pools and riffles, and greater frequency of LWD. Protection and enhancement of wetland areas associated with PSL streams should be a high priority.

# CONCLUSIONS

Processes occurring within the stream, in the surrounding riparian zone, and within the watershed all contribute to the creation and maintenance of instream habitat structure. These processes must be examined in order to evaluate factors, which contribute to degraded habitat quality. The data from the habitat assessments described in this document indicate many segments of Swamp, North and Little Bear Creeks lack the complex habitat structure that is important for sustaining a long-term, diverse salmonid population. Inadequate pool and riffle habitat—too few and poor quality—in all three streams is likely a result of the cumulative effects of the interruption of numerous natural processes such as large woody debris recruitment, and basin-wide hydrologic buffering processes that interact to create these habitats. Restoration and conservation planning efforts need to assess, and take into account the processes that create instream habitat structure.

Results of this study and others in the PSL region demonstrate that retention of a wide, nearly continuous riparian buffer in native vegetation has greater and more flexible potential than other options to uphold biological integrity when development increases. In newly developing areas riparian zones can be isolated from development, along with their associated streams. In developed landscapes riparian zones are often more lightly developed than upland areas, and could more easily be purchased and placed into protective status. Riparian retention fits nicely with other objectives, like flood protection and provision of wildlife corridors and open space. Instream habitat would benefit most from the securing and protecting of existing high quality riparian buffers, enhancing or restoring degraded, but undeveloped areas, and protecting developed riparian zones and upgrading the integrity of the buffer with planting natives (especially conifers) and removing invasive plants.

General forest retention throughout watersheds has also shown to offer important potential mitigation benefits (Horner and May 1999). It should be a high priority, especially for managing growth of undeveloped and lightly developed watersheds, in connection with impervious surface limitation and riparian protection efforts. Most likely, the potential benefits shown for riparian and forest retention could be compounded by pursuing both in concert.

The foundation of any effective environmental management effort, such as this discussion implies, must be goals developed with firm knowledge of what the ecosystem is capable of under varying circumstances, and what it needs to flourish at certain levels. Goals should be stated in concrete and measurable terms. Management actions must be prescribed with reference to individual ecosystem conditions. This study should provide a solid baseline for future management decisions regarding these three study streams.

Methods used for assessing stream health are continually refined as new information about parameters as indicators of habitat quality, accuracy and precision of methods, and resource management needs becomes available. As a result of the data analysis from these assessments, the following changes to the assessment methods are under consideration:

- The RQI was difficult to apply in a manner that was consistent between field technicians. One of the important pieces of information that is incorporated into the RQI scoring, is embeddedness. In the future direct measurement of spawning gravel composition using standard methods should be used.
- Since altered hydrology is one of the effects of urbanization on stream ecosystems, and examination of spawning gravel scour would help determine the extent of harm done to salmonid redds.

- In addition, it was difficult to draw definitive conclusions from the categorical data, i.e. streambank stability, riparian cover, and shade, because these data were imprecise as indicated by the replicate reach analysis. Additional staff training would reduce this imprecision and improve the quality of these data.
- Further testing and refinement of the HQI is also recommended to improve this assessment tool.

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# REFERENCES


Andrus, C. W., B. A. Long, and H. A. Froehlich. 1988. Woody debris and its contribution to pool formation in a coastal stream 50 years after logging. Canadian Journal of Fisheries and Aquatic Sciences **45**:2080-2089.

Arnold, C. L., P. J. Boison, and P. C. Patton. 1982. Sawmill Brook: an example of rapid geomorphic change related to urbanization. Jounal of Geology **90**:155-166.

Barbour, M. T., J. Gerritsen, B. D. Snyder, and J. B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish. EPA 841-B-99-002, U.S. Environmental Protection Agency, Office of Water, Washington, D.C.

Beechie, T. J., and T. H. Sibley. 1997. Relationships between Channel Characteristics, Woody Debries, and Fish Habitat in Northwestern Washington Streams. Transactions of the American Fisheries Society **126**:217-229.

Bilby, R. E., and G. E. Likens. 1980. Importance of organic debris dams in the structure and function of stream ecosystems. Ecology **61**:1107-1113.

Bilby, R. E. 1984. Removal of woody debris may affect stream channel stability. Journal of Forestry **82**:609-613.

Bilby, R. E., and J. W. Ward. 1989. Changes in characteristics and function of woody debris with increasing size of streams in Western Washington. Transactions of the American Fisheries Society **118**:368-378.

Bilby, R. E., and J. W. Ward. 1991. Characteristics and function of large woody debris in streams draining old-growth, clear-cut, and second-growth forests in SW Washington. Canadian Journal of Fisheries and Aquatic Sciences **48**:2499-2508.

Bisson, P. A., R. E. Bilby, M. D. Bryant, C. A. Dolloff, G. B. Grette, R. A. House, M. L. Murphy, K. V. Koski, and J. R. Sedell. 1987. Large woody debris in forested streams in the Pacific Northwest: past, present, and future. *in* E. O. a. T. W. C. Salo, Eds, editor. Streamside Management: Forestry and Fisheries Interactions. UW Forestry Publication No. 59, Seattle, WA.

Bisson, P. A., T. P. Quinn, G. H. Reeves, and S. V. Gregory. 1992. Best management practices, cumulative effects, and long-term trends in fish abundance in Pacific Northwest river systems. *in* R. J. Naiman, editor. Watershed Management: Balancing Sustainability and Environmental Change. Springer-Verlag, New York.

Bjorn, T. C., and D. W. Reiser. 1991. Habitat requirements of salmonids in streams. Pages 18-138 *in* W. R. Meehan, editor. American Fisheries Society Special Publication. American Fisheries Society, Bethesda, MD.

Booth, D. B. 1990. Stream channel incision following drainage-basin urbanization. Water Resources Bulletin **26**:407-417.

Booth, D. B. 1991. Urbanization and the natural drainage system-- impacts, solutions and prognosis. The Northwest Environmental Journal **7**:93-118.

Booth, D. B., and L. E. Reinelt. 1993. Consequences of urbanization on aquatic systems- measured effects, degradation thresholds, and corrective strategies. *in* Watershed '93 Conference, Seattle, WA.

Booth, D. B., and L. E. Reinelt. 1994. Consequences of Urbanization on Aquatic Systems - Measured Effects, Degradation Thresholds, and Corrective Strategies. King County Department of Natural Resources, Water and Land Resources Division, Seattle, WA.

Bryant, M. D. 1983. The role and management of woody debris in west coast salmonid nursery streams. North American Journal of Fisheries Management **3**:322-330.

Chapman, D. W. 1988. Critical review of variables used to define effects of fines in redds of large salmonids. Transactions of the American Fisheries Society **117**:1-21.

Crisp, D. T., and P. A. Carling. 1989. Observations on siting, dimensions, and structure of salmonid redds. Journal of Fish Biology **34**:119-134.

Dunne, T., and L. B. Leopold. 1978. Water in Environmental Planning.

Entranco. 1994. Bear, Evans, Cottage Lake, and Mackey Creeks: Habitat Problems, Prioritization, and Solutions Development - Technical Memorandum. Entranco, King County Water and Land Resources Division, John F. Orsborn, Caldwell & Associates, Lee & Associates, Seattle, WA.

Fetherston, K. L., R. J. Naiman, and R. E. Bilby. 1995. Large woody debris, physical process, and riparian forest development in montane river networks of the Pacific Northwest. Geomorphology **13**:133-144.

Giger, R. D. 1973. Streamflow requirements of salmonids. Job Final Report AFS-62-1, Oregon Wildlife Commission, Portland.

Gregory, S. V., F. J. Swanson, W. A. McKee, and K. W. Cummins. 1991. An ecosystem perspective of riparian zones: focus on links between land and water. BioScience **41**:540-551.

Groot, C., and L. Margolis, editors. 1991. Pacific Salmon Life Histories. UBC Press, Vancouver.

Hammer, T. R. 1972. Stream channel enlargement due to urbanization. Water Resources Research **8**:1530-1540.

Harmon, M. E., J. F. Franklin, P. Sollins, S. V. Gregory, J. D. Lattin, N. H. Anderson, S. P. Cline, N. G. Aumen, J. R. Sedell, G. W. Lienkaemper, K. Cromack, and K. W. Cummins. 1986. Ecology of coarse woody debris in temperate ecosystems. Advanced Ecological Research **15**:133-302.

Hartman, G. F., and T. G. Brown. 1987. Use of small, temporary, floodplain tributaries by juvenile salmonids in a west coast rainforest drainage basin, Carnation Creek, British Columbia. Canadian Journal of Fisheries and Aquatic Sciences **44**:262-270.

Henshaw, P. 1999. Restabilization of stream channels in urban watersheds. Masters of Science. University of Washington, Seattle.

Hicks, B. J., J. D. Hall, P. A. Bisson, and J. R. Sedell. 1991. Responses of salmonids to habitat changes. *in* W. R. Meehan, Ed., editor. Influences of Forest and Rangeland Management on Salmonid Fishes and their Habitats. American Fisheries Society.

Hollis, G. E. 1975. The effect of urbanization on floods of different recurrence interval. Water Resources Research **66**:84-88.

Horner, R., and C. M. May. 1999. Regional Study Supports Natural land cover Protection as the Leading Best Management Practice for Maintaining Stream Ecological Integrity. *in* Comprehensive Stormwater and Aquatic Ecosystem Conference, Auckland, NZ.

Imhof, J., R. J. Pland, F. M. Johnson, and L. C. Halyk. 1991. Watershed Urbanization and managing stream habitat for fish. *in* 56th North American Wildlife and Natural Resources Conference, Jackson, WY.

Johnson, A. W., and D. M. Ryba. 1992. A Literature Review of Recommended Buffer Widths to Maintain Various Functions of Stream Riparian Areas. Special Report King County Surface Water Management Division (SWM), Seattle.

Karr, J. R., and E. W. Chu. 1999. Restoring Life in Running Waters: Better Biological Monitoring. Island Press, Washington D.C.

Keller, E. A., and F. J. Swanson. 1979. Effects of large organic material on channel form and fluvial processes. Earth Surface Processes **4**:361-380.

Klein, R. D. 1979. Urbanization and stream quality impairment. Water Resources Bulletin **15**:948-963.

Kondolf, G. M., and M. G. Wolman. 1993. The sizes of salmonid spawning gravel. Water Resources Research **29**:2275-2285.

Konopacky, R. C. 1984. Sedimentation and productivity in a salmonid stream. Doctoral dissertation. University of Idaho, Moscow.

Leopold, L. B. 1968. The Hydrologic Effects of Urban Land Use: Hydrology for Urban Land Planning-- A Guidebook of the Hydrologic Effects of Urban Land Use. USGS Circular No. 554, USGS.

Lisle, T. E., and S. Hilton. 1992. The volume of fine sediment in pools: an index of sediment supply in gravel-bed streams. Water Research Bulletin **28**:371-383.

Lucchetti, G., and R. Fuerstenberg. 1993. Relative fish use in urban and non-urban streams. *in* Conference on Wild Salmon, Vancouver, BC.

Maser, C., R. F. Tarrant, J. M. Trappe, and J. F. Franklin. 1988. From the Forest to the Sea: A Story of Fallen Trees. PNW-GTR-229, USDA Forest Service.

Mattila, J. 1999. Field Notes. King County staff.

Mavros, B., S. Foley, K. Burton, and K. Walter. 2000. 1999 Chinook Spawner Survey Data Technical Report for the Lake Washington Watershed. King County Department of Natural Resources, Washington Department of Fish and Wildlife, Seattle Public Utilities, and Muckleshoot Indian Tribal Fisheries Department, Seattle, WA.

May, C. W. 1996. Assessment of cumulative effects of urbanization on small streams in the Puget Sound Lowland Ecoregion: Implications for salmonid resource management. Ph.D. Dissertation. University of Washington, Seattle, WA.

May, C. W., E.B. Welch, R.R. Horner, J.R. Karr and B.W. Mar. 1997. Quality Indices for Urbanization Effects in Puget Sound Lowland Streams. Final Report for Washington Department of Ecology. Water Resources Series, Technical Report No. 154, University of Washington, Department of Civil Engineering, Environmental Engineering and Science, Seattle, Washington.

May, C. W., and R. R. Horner. 2000. The Cumulative Impacts of Urbanization on Stream-Riparian Ecosystems in the Puget Sound Lowlands. *in* AWRA Riparian Ecology and Management Conference, Portland OR.

McCain, M. E., D. D. Fuller, L. M. Decker, and K. C. Overton. 1990. Stream habitat classification and inventory procedures for northern California. Tech. Bull. FHR Currents No. 1 USFS R-5 Anadromous Fish Habitat Relationships, U.S. Department of Agriculture, Forest Service, Pacific Southwest Region, San Francisco.

McNeil, W. J. 1966. Effect of the spawning bed environment on reproduction of pink and chum salmon. Fisheries Bulletin **65**.

Meehan, W. R., editor. 1991. Influences of Forest and Rangeland Management on Salmonid Fishes and their Habitats. American Fisheries Society, Bethesda, MD.

Montgomery, D. R., E. M. Beamer, G. R. Pess, and T. P. Quinn. 1999. Channel type and salmonid spawning distribution and abundance. Canadian Journal of Fisheries and Aquatic Sciences **56**:377-387.

Montgomery, D. R., and J. M. Buffington. 1997. Channel-reach morphology in mountain drainage basinss. Geological Society of America Bulletin **109**:596-611.

Montgomery, D. R., J. M. Buffington, R. D. Smith, K. M. Schmidt, and G. Pess. 1995. Pool spacing in forest channels. Water Resources Research **31**:1097-1105.

Morley, S. A. 2000. Effects of urbanization on the biological integrity of Puget sound lowland streams: Restoration with a biological focus. Master of Science. University of Washington, Seattle.

Murphy, M. L., and K. V. Koski. 1989. Input and depletion of woody debris in Alaska streams and implications for streamside management. North American Journal Fisheries Management **9**:427-436.

Myers, J. M., R. G. Kope, G. J. Bryant, D. Teel, L. J. Lierheimer, T. C. Wainwright, W. S. Grant, F. W. Waknitz, K. Neely, S. T. Lindley, and R. S. Waples. 1998. Status Review of Chinook Salmon from Washington, Idaho, Oregon, and California. NOAA Technical Memorandum NMFS-NWFSC-35, U.S. National Marine Fisheries Service, Seattle, WA.

Naiman, R. J., and R. E. Bilby, editors. 1998. River Ecology and Management: Lessons from the Pacific Coastal Ecoregion. Springer Publishing, NY.

Naiman, R. J., R. E. Bilby, and P. A. Bisson. 2000. Riparian Ecology and Management in the Pacific Coastal Rain Forest. BioScience **50**:996-1011.

Nawa, R. K., C. A. Frissell, and W. J. Liss. 1990. Life History and Persistence of Anadromous Salmonid Stocks in Relation to Stream Habitats and Watershed Classification. Oregon Department of Fish and Wildlife and Oregon State University.

Nehlsen, W., J. Williams, and J. Lichatowich. 1991. Pacific salmon at the crossroads: Stocks at risk from California, Oregon, Idaho, and Washington. Fisheries **16**:4-21.

Nickelson, T. E., J. D. Rodgers, S. L. Johnson, and M. L. Solazzi. 1992. Seasonal changes in habitat use by juvenile Coho salmon in Oregon coastal streams. Canadian Journal of Fisheries and Aquatic Sciences:783-789.

NOAA. 1996. Coastal Salmon Conservation:  Working Guidance for Comprehensive Salmon Restoration Initiatives on the Pacific Coast. National Marine Fisheries Service.

NRC. 1996. Upstream: Salmon and Society in the Pacific Northwest. National Academy Press.

Ostergaard, E. 1998. 1996 Salmon Spawning Surveys in the Lake Washington Watershed. King County Water and Land Resources Division, Seattle, WA.

Overton, K. C., S. P. Wollrab, B. C. Roberts, and M. A. Radko. 1997. R1/R4 (Northern/ Intermountain Regions) Fish and Fish Habitat Standard Inventory Procedures Handbook. INT-GTR-346, USDA Forest Service, Ogden.

Peterson, N. P., A. Hendry, and T. P. Quinn. 1992. Assessment of Cumulative Effects on Salmonid Habitat: Some Suggested Parameters and Target Conditions. TFW-F3-92-001, WA Timber, Fish and Wildlife.

Platts, W. S., W. F. Megahan, and G. W. Minshall. 1983. Methods for evaluating Stream, Riparian and Biotic Conditions. General Technical Report INT-138, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Pleus, A. E., D. Schuett-Hames, and L. Bullchild. 1999. TFW Monitoring Program method manual for the habitat unit survey. TFW-AM9-99-003. DNR #105, Washington State Dept. of Natural Resources under the Timber, Fish, and Wildlife Agreement.

Ralph, S. C., G. C. Poole, L. L. Conquest, and R. J. Naiman. 1994. Stream channel morphology and woody debris in logged and unlogged basins of Western Washington. Canadian Journal of Fisheries and Aquatic Sciences **51**:37-51.

Reinelt, L. E., and R. Horner. 1995. Pollutant removal from stormwater runoff by palustrine wetlands based n comprehensive budgets. Ecological Engineering **4**:77-97.

Richey, J. S. 1982. Effects of Urbanization on a Lowland Stream in Western Washington. Dissertation. University of Washington, Seattle.

Robison, E. G., and R. L. Beschta. 1990. Characteristics of coarse woody debris for several coastal streams of southeast Alaska, USA. Canadian Journal of Fisheries and Aquatic Sciences **47**:1684-1693.

Rosgen, D. 1996. Applied River Morphology. Wildland Hydrology, Pagosa Springs.

Rot, B. W. 1995. The Interaction of Valley Constraint, Riparian Landform, and Riparian Plant Community Size and Age upon Channel Configuration of Small Streams of the Western Cascade Mountains, Washington. University of Washington, Seattle.

Rot, B. W., R. J. Naiman, and R. E. Bilby. 2000. Stream channel configuration, landform, and riparian forest structure in the Cascade Mountains, Washington. Canadian Journal of Fisheries and Aquatic Sciences **57**:699-707.

Salo, E. O., and T. W. Cundy, editors. 1987. Streamside Management: Forestry and Fisheries Interactions. UW Forestry Publication No. 59, Seattle.

Schuett-Hames, D., A. E. Pleus, J. Ward, M. Fox, and J. Light. 1999a. TFW Monitoring Program method manual for the large woody debris survey. Prepared for the Washington State Dept. of Natural Resources under the Timber, Fish, and Wildlife Agreement. **TFW-AM9-99-004**.

Schuett-Hames, D., R. , C. Pleus, A., and M. McHenry. 1999b. TFW Monitoring Program method manual for the salmonid spawning grave composition survey. TFW-AM9-99-006, DNR #108, Washington State Dept. of Natural Resources under the Timber, Fish, and Wildlife Agreement.

Schultz, L. P., and Students. 1935. The breeding activities of the little redfish, a landlocked form of the sockeye salmon, Oncorhyncus nerka. Mid-Pacific Magazine.

Scott, J. B., C. R. Steward, and Q. J. Stober. 1986. Effects of urban development on fish population dynamics in Kelsey Creek, Washington. Transactions of the American Fisheries Society **115**:555-567.

Sedell, J. R., F. J. Swanson, and S. V. Gregory. 1984. Evaluating fish response to woody debris. Pages 222-245 *in* Pacific Northwest Stream Habitat Management Workshop. American Fisheries Society, Western Division, Humboldt State University, Arcata, California.

Steward, C. R. 1983. Salmonid Populations in an Urban Stream Environment. Masters. University of Washington, Seattle.

Van Sickle, J. V., and S. W. Gregory. 1990. Modeling inputs of large woody debris to streams from falling trees. Canadian Journal of Fisheries and Aquatic Sciences **20**:1593-1601.

Vanderhoof, J., E. Ostergaard, and D. M. Gleisner. 2000. 1997 Volunteer Salmon Watcher Program in the Lake Washington Watershed. King County Department of Natural Resources, Seattle.

Washington Department of Fish and Wildlife and Western Washington Treaty Tribes. 1997. Wild Salmonid Policy.

Washington Forest Practices Board. 1997. Watershed Analysis Manual v4.0.

Wenger, S. 1999. A Review of the Scientific Literature on Riparian Buffer Width, Extent, and Vegetation. Office of Public Service and Outreach, Institute of Ecology, University of Georgia.

Williams, R. W., R. M. Laramie, J. J. Ames, and F. Biologists. 1975. A catalog of Washington Streams and salmon utilization. Washington Department of Fisheries.

# APPENDICES

## 1999 Habitat Inventory and Assessments of Three Tributaries to the Sammamish River:

## North, Swamp, and Little Bear Creeks

# Appendix A. Segment Descriptions

## Swamp Creek

| Seg. # | Name | Description | Length (km) | Percent assessed | SSHIAP Gradient/ Confinement Category* |
|---|---|---|---|---|---|
| 1 | Lower | Mouth to 73rd Ave NE | 2.41 | 35.5% | 0-1 %, U |
| 2 | Kenmore | 73rd Ave NE to Wallace Park | 0.63 | 70.9 | 1-2 %, U |
| 3 | Wallace | Wallace Park to Carter Rd | 1.08 | 33.1 | 1-2 %, U |
| 4 | Forsgren | Carter Rd to Locust Way | 1.97 | 50.9 | 1-2 %, C |
| 5 | Locust | Locust Way to Scriber Creek confluence | 1.26 | 100 | 1-2 %, M |
| 6 | Scriber | Lower Scriber Creek Tributary | 5.27 | 6.5 | 1-2 %, C |
| 7 | Cypress | Scriber Crk to Larch Way | 1.26 | 33.6 | 1-2 %, C |
| 8 | Larch | Larch Way to Filbert Rd | 2.26 | 61.1 | 0-1 %, C |
| 9 | Filbert | Filbert Rd to I-405 culvert | 0.15 | 100 | 2-4 %, C |
| 10 | Butternut | I-405 to I-5 | 1.21 | 49.4 | 0-1 %, C |
| 11 | Upper | Above Maple Rd to Lake Stickney | 5.5 | 14.9 | 0-1 %, U |

*Segment breaks coincide with SSHIAP breaks.

## North Creek

| Seg. # | Name | Description | Length (km) | Percent assessed | SSHIAP Gradient/ Confinement Category* |
|---|---|---|---|---|---|
| 1 | Lower | Mouth to UW-Bothell campus | 0.8 | 100% | 0-1 %, M |
| 2 | UW | UW-Bothell Campus to I-405 | 0.65 | 100 | 0-1 %, M |
| 3 | Bothell | I-405 to County Line/244th | 2.42 | 55.5 | 0-1 %, M |
| 4 | Fitzgerald | 244th (gage) to 228th | 2.06 | 70.7 | 0-1 %, M/U |
| 5 | Canyon Park | 228th to 208th | 3.61 | 42.6 | 0-1 %, U |
| 6 | Thrashers | 228th (Maltby Rd) to 196th St SE | 1.75 | 100 | 0-1 %, U; **1-2 %, M** |
| 7 | Silver/Tambark Tributaries* | | 5.08 | | |
| 8 | Middle | 196th to 183rd | 2.48 | 41.4 | 1-2 %, M |
| 9 | Nickel | 183rd to Penny Crk confluence | 1.21 | 33.1 | 0-1 %, U |
| 10 | Penny Creek Tributary | Confluence to golf course | 10.75 | **A:** 77.3<br>**B:** 57.5 | **A:** 2-4 %, M,C<br>**B:** 0-1 % C |
| 11 | Mill Creek | Penny Crk confluence to WDFW Office | 1.07 | 70.2 | 1-2 %, U |
| 12 | Wetland | WDFW to McCollum Park | 0.99 | 28.0 | 1-2 %, **0-1%,** U |
| 13 | McCollum | McCollum Park to 128th St SE | 1.14 | 44.5 | 1-2 %, U |
| 14 | Silver | 128th to I-5 culvert | 1 | | 1-2 %, M |
| 15 | Upper | Above I-5 (minimal habitat) | 3.83 | | 1-2 %, M |

*The segment breaks usually coincided with the SSHIAP segment breaks, where two SSHIAP segment types occur on one assessment segment the dominant type is in **bold type.**

# Little Bear Creek

| Seg. # | Name | Description | Length (km) | Percent assessed | SSHIAP Gradient/ Confine. Category* |
|---|---|---|---|---|---|
| 1 | Lower | Mouth to Hwy 202 | 0.51 | 100% | 0-1 %, U |
| 2 | Woodinville | Hwy 202 to Hwy 522/195th St SE | 1.67 | 59 | 0-1 %, C; U |
| 3 | High School | 195th to 205th | 0.96 | 100 | 0-1 %, U |
| 4 | Rowlands | 205th to 58th Ave SE | 0.32 | 100 | 0-1 %, U |
| 5 | Wellington | 58th Ave SE to 233rd Pl SE | 1.32 | 72 | 0-1 %, U |
| 6 | Lower Hwy 9 | 233rd Pl SE to 228th St SE | 0.64 | 100 | 0-1 %, U |
| 7 | Upper Hwy 9 | 228th St SE to 216th St SE | 1.39 | 99 | 0-1 %, U |
| 8 | Trout Stream Creek Tributary | | 21.58 | | 0-1 %, U |
| 9 | Maltby | 216th St SE to Little Bear Creek Rd | 1.51 | 78 | 0-1 %, U |
| 10 | Great Dane Creek Tributary | | 4.76 | 8 | 2-4 %, M |
| 11 | Middle | Along Little Bear Creek Rd neighborhood | 0.58 | 83 | 0-1 %, C; 1-2 % U |
| 12 | Jewell | From end of Little Bear Creek Rd to 196th St SE (Jewell Rd extension) | 0.5 | 0[†] | 1-2 %, U |
| 13 | Horse Farms | 196th to 51st Ave SE | 1.09 | 28 | 1-2 %, U |
| 14 | Beaver | 51st to 180th St SE | 0.75 | 49 | 0-1 %, U |
| 15 | Upper | Above 180th St SE | 3.19 | 0 | 0-1 %, U |

*The segment breaks usually coincided with the SSHIAP segment breaks, where two SSHIAP **segment types occur on one assessment segment the dominant type is in** bold type.

[†]A visual assessment of the Jewell segment indicated that the lower half was similar to segment 11 and the upper half was similar in structure to segment 13.

**North Trib. to the Sammamish River Habitat Assessment**

**Segment assessment start and end points**

**Swamp Creek**

| Segment | Date | Start point | End point | Meters surveyed |
|---|---|---|---|---|
| 1A | 8/26/99 | Swamp Creek Park, 170m d.s. NE 175th St. | Road crossing: NE 175th | 170 |
| 1B | 8/26/99 | Behind Bingo hall, approx 200m u.s. Bothell Way | At big wetland 75m u.s. | 75.8 |
| 2 | 8/26/99 | 73rd Ave NE crossing | Just below Wallace Park | 276.5 |
| 3 | 8/27/99 | Wallace Park, just u.s. R/D pond | 475 m upstream (did not reach NE 204th) | 475 |
| 3 | 8/30/99 | NE 204th | Carter Rd | 314 |
| 4 | 8/30/99 | Carter Rd | 650m u.s. | 650m |
| 4 | 8/31/99 | Bridge on Locust Way | 352m u.s. near bridge at Locust Way and 228th St SW | 352 |
| 5 | 8/31/99 | Locust Way and 228th Bridge | 615m u.s. | 615 |
| 5 | 9/1/99 | Continue from above survey | Locust Way crossing (Swamp Bridge 502) | 420 |
| 6 | 9/1/99` | u.s. of Cypress Way crossing | 344 meters u.s. | 334 |
| 7 | 9/8/99 | Confluence of Swamp Creek and Scriber Creek | In power line 310 meters u.s. | 310 |
| 7 | 9/9/99 | Below powerlines and south of Larch Rd. This is continuous with the previous survey. | 110 meters u.s. | 110 |
| 7 | 9/13/99 | 55? Meters d.s. upstream powerlines. (370 m d.s. road crossing) | Larch Road crossing. Swamp Creek Bridge 459 | 370 |
| 8 | 9/15/99 | Bridge on Larch Way | 797 m u.s. of bridge | 797 |
| 8 | 9/16/99 | 797 m u.s. of bridge (behind 20320 Locust Way) (continue from previous reach) | 375 m u.s. at 20218 Locust Way | 375 |
| 8 | 9/28/99 | Continue from previous (written down: 20320, is it 20218 Locust Way?) | 378 m u.s. | 378 |
| 9 | 9/29/99 | Filbert and Magnolia Bridge | u.s. of I-405 (279 m u.s. of start) | 279 |
| 10 | 9/29/99 | u.s. of 405 culvert | u.s. 598m | 598 |
| 11A | 9/30/99 | 139m ds. Ash Way Br. | 50m u.s. of Ash Way Br. | 189m |
| 11A | 9/30/99 | 162 m d.s. of 164th St. Bridge | 164th St Br. | 162 |
| 11B | 10/20/99 | 164th St. Bridge | 382m u.s. | 382 |

**North Trib. to the Sammamish River Habitat Assessment**
**Segment assessment start and end points**

**North Creek**

| Segment | Date | Start point | End point | Meters surveyed |
|---|---|---|---|---|
| 1 | 8/30/99 | Trail bridge ds I-405 | 360.4m u.s | 360.4 |
| 2 | 9/1/99 | Continuing above | I-405 south bound | 817.6 |
| 3 | 9/8/99 | u.s. side of I-405 bridge | Ds North Creek pkwy bridge | 400.6 |
| 3 | 9/9/99 | u.s. North Creek pkwy bridge | Bridge at 240th st. SE | 677 |
| 4 | 9/10/99 | 240th St SE bridge | 904 meters u.s. | 904 |
| 4 | 9/13/99 | "nick pt" in channel approx. 269m d.s. from 228th St SE bridge | 228th St SE bridge | 256 |
| 5 | 9/15/99 | Bridge at 228th St SE | 912 meters u.s. | 912 |
| 5 | 9/17/99 | u.s. side of 527 bridge | Confluence of trib on RB (u.s. of 214th SE | 318 |
| 6 | 9/20/99 | 20m u.s. of 208th St. SE bridge | North Creek Estates, 20326 Bothell-Everett Hwy | 585 |
| 6 | 9/21/99 | (Continue) North Creek Estates, 20326 Bothell-Everett Hwy | 701m u.s. | 701 |
| 6 | 9/22/99 | 300 m below 196 St. SE | 196th St. SE | 300 |
| 8 | 9/22/99 | 196th St SE | 246m u.s. | 246 |
| 8 | 10/4/99 | Residence at end of Waxon Rd. | 533m u.s. | 533 |
| 9 | 10/4/99 | End of John Bailey Rd. | 308 m u.s. | 308 |
| 9 | 10/6/99 | Chainlink fence 201m d.s of Penny Creek confluence | 201 m u.s. | 201 |
| 10A | 10/18/99 | Penny Creek: confluence with North Creek | 88m u.s. at 9th Ave. SE | 88 |
| 10A | 10/13/99 | u.s. 9th St. Bridge | d.s. S.R. 527 (this reach is longer than 271, impenetrable brush forced surveyor out of the stream in a number of spots) The 271 meters was a representative sample. | 271 |
| 10A | 10/13/99 | u.s. S.R. 527. | 55 m (this reach below Mill Creek Rd.) | 55 |
| 10A | 10/13/99 | u.s. Mill Creek Rd. | End at fish ladder | 50m |
| 10B | 10/13/99 | u.s. of Mill Creek duck pond above fish ladder—where channel begins. | 305 u.s. (at gauge at footbridge) | 305 |
| 10B | 10/18/99 | Even with R&D pond RR. Approx. 200m u.s. of prev. end | 500 m u.s. below golf course. | 500 |
| 11 | 10/6/99 | Confluence with Penny Creek | 30 m u.s. of 164 St SE | 330 |
| 11 | 10/6/99 | d.s. end of WDFW property at LB culvert | u.s. end of industrial park property | 407 |
| 12 | 10/11/99 | u.s edge of industrial park (start of forest LB) | 310 m u.s. | 310 |
| 12 | 10/13/99 | End of driveway 146th St. SE | 304m u.s. | 304 |
| 13 | 10/15/99 | South end of County Park | Approx. 75m d.s. of pedestrian foot bridge. | 325 |
| 13 | 10/15/99 | Near picnic shelter on RL above footbridge | At confluence with Trib (approx. 120m d.s. of 128th St. SE | 80 |

**North Trib. to the Sammamish River Habitat Assessment**
**Segment assessment start and end points**

**Little Bear Creek**

| Segment | Date | Start point | End point | Meters surveyed |
|---|---|---|---|---|
| 1 | 9/20/99 | Mouth of Little Bear Creek | 202 Bridge | 425 |
| 2 | 9/20/99 | U.s 202 Bridge | Near 134th bridge (still d.s.) | 280 |
| 2 | 9/22/99 | 134th Av NE bridge | 228 m u.s. (prop. Owner—13632 NE 177th Pl denied access) | 228 |
| 2 | 9/22/99 | u.s. SR 522 bridge | 195 St. NE bridge | 289 |
| 3 | 9/23/99 | u.s. 195th St. NE bridge | 333 m u.s. Just north of site where stream and hwy are adjacent | 333 |
| 3 | 9/27/99 | Continue from previous day | 205 St NE bridge (county line) 656m u.s. | 656 |
| 4 | 10/20/99 | 244th St. SE | 58th Av SE (u.s end of bridge—end of pool) | 340 |
| 5 | 10/20/99 | 58th Av. SE | 300 m u.s. (stopped where channel too deep to proceed) | 300 |
| 5 | 10/21/99 | 6200 238th St SE | 510 m u.s. | 510 |
| 5 | 10/25/99 | Continued from previous survey | d.s. 233rd bridge | 172 |
| 6 | 10/22/99 | 233rd St. SE | 228th St. SE | 667 |
| 7 | 10/25/99 | 228th St SE | 408 m u.s. at residential bridge | 408 |
| 7 | 10/26/99 | Continue from prev. | 220288 SR 9 residential bridge (next u.s LB prop. Owner denies entry) | 579 |
| 7 | 11/1/99 | 500 m d.s. of 216 St. SE | 216th SE | 500 |
| 9 | 10/27/99 | 216th St. SE | 296 m u.s. | 296 |
| 9 | 10/28/99 | Hwy 524 | 406 m u.s. just downstream of powerline | 406 |
| 9 | 11/2/99 | Continuation of previous | 471 m u.s. @ Little Bear Creek Rd. bridge | 471 |
| 10 | 10/27/99 | (Great Dane Trib) @ Maltby Rd | 394 u.s. just above bridge. At Bear Creek Raceway, or starrrley Stump? Ranch | 394 |
| 11 | 11/2/99 | Bridge at Little Bear Creek rd. | 484 m u.s. at residential bridge | 484 |
| 13 | 11/2/99 | 196th St SE, bridge on private property | 300 m u.s. | 300 |
| 14 | 11/2/99 | 51st Ave SE | 161 m u.s. | 161 |
| 14 | 11/8/99 | 18232 51st Av SE, residential pedestrian bridge | 210 m u.s. at culvert on 51st Av SE | 210 |

**Appendix B.** Field assessment methods

## Habitat Inventory

Two persons, one with measurement and the other with note-taking tasks, conducted the assessments. Assessments were conducted in an upstream direction during low flow conditions from late August to early November. Hip chain string was tied to known reference points, and personnel recorded locations of instream habitat units. Habitat units were identified as pools, riffles or glides. Categories were kept simple to avoid compounding error due to observer differences. The length, maximum thalweg depth, bankfull width, depth, as well as the residual pool depth (deepest point of pool minus the depth at the hydraulic control) were measured. Pool Quality Index (PQI) (attached) was determined for each pool using a rating system adopted from Platts et al. (1983). Pools receive a higher rating if they are large in relation to the size of the channel and have cover for fish. Riffles were rated using a riffle quality index (RQI) developed by King County staff and Chris May (attached). Riffle quality is based on substrate composition, degree of embeddedness, and proximity of pools or wetlands. In order to determine the relative flow level at the time of the assessment, flow velocity and discharge were measured at the beginning of each assessment day when equipment was available. Water quality parameters, including temperature, DO, and conductivity were also measured when equipment was available.

Habitat units are defined as:

**Pool**: Slow water, length and width at least 1/2 the bankfull channel width and 10 cm minimum residual pool depth. Subcategories define the general type of pool, and include: scour (lateral, channel, channel confluence, plunge), dam, and backwater as defined by Overton et al. (1997);
**Riffle**: Swiftly flowing, turbulent water; some partially exposed substrate; substrate cobble and/or boulder dominated;
**Glide**: Wide, uniform channel volume, low to moderate water velocity, little surface agitation. Anything not qualifying as pool, riffle, or other habitat type.

## Large Woody Debris (LWD)

LWD are defined as logs at least 2 meters (6 feet) long and at least 15 cm (6 inches) diameter (Peterson et al. 1992). Size of each piece of LWD was estimated and stream reach and the zone it occupied noted. Measurements included: diameter, length estimate to nearest 0.5 meter, and whether tree is alive, dead, or stump. Stumps were tallied if they were affecting the stream channel, regardless of size. Zones include:

**1**: in or touching the water
**2**: not in water, but protrudes below bankfull
**3**: spanning the channel, not protruding below bankfull

## Reach Characterization

While assessing, changes in land use, riparian condition, and stream character were noted as reach breaks. Riparian condition, land use, bank condition, bankfull width and depth were measured and noted in homogeneous reaches (approximately 10 and 300 meters long). Locations of fences and other property boundary markers were identified by hip chain and noted on data sheets. The following provides a brief description of the measurements that were conducted in each reach.

### Riparian Condition

Amount and type of riparian cover in terms of percent shading from the center of the channel was visually estimated for each channel reach. Land use type was described for each bank within the channel reach using the following categories: a) forest (greater than20 ft. in height) with coniferous, deciduous or mixed and an indication of maturity; b) shrubs and/or vines; c) tall herbaceous (e.g. unmowed field); d) short herbaceous (e.g., mowed grass, pasture, etc.), e) buildings, roads, asphalt, etc.; f) residential landscaped (mowed lawn with ornamental shrubs/trees). Presence of invasive plant species were noted (reed canary grass, blackberry, climbing nightshade, Japanese knotweed, etc.), as were the presence of snags or downed wood outside the channel.

**Bank Condition**

Percent channel-bank scour was estimated for each designated reach on each bank using the method described by Booth (1994). Categories are:

**Stable**: vegetated or low bars to level of low flow
**Low Scour**: steep, raw banks only below bankfull level
**Full Scour**: steep, raw banks above bankfull level
**Armored**: artificial bank protection of any kind

**Side Channels, Tributaries, Pipes and Wetlands**

Location and size of pipes, and inflow or uptake was noted. Tributaries and other side channels entering the stream were mapped and locations of on-channel and nearby wetlands were also indicated.

**Reach Description and Other Features**

Other channel features such as fences crossing the stream, possible barriers to fish passage, culverts, areas of erosion or large sediment deposition, dominant substrate size, hillside seeps or springs, undercut banks, overhanging vegetation, etc. were noted. For each reach of uniform condition (confinement, gradient, land use, etc.), the staff wrote a brief narrative (about three to four sentences, longer if necessary) describing the quality of habitat, species and life history stages observed, and relative abundance of fish and wildlife, and any obvious problems or concerns such as point of discharge or withdrawal, and opportunity and/or need for protection or a restoration project.

**Photographs**

Photographs depicting the general nature of each characterized reach were taken as the staff proceeded upstream. Roll numbers were indicated on the film canister, and roll number and photograph numbers were noted in field notes for later cross-reference.

**Pool Quality Index (PQI) for Puget Sound Lowland Streams (1st to 3rd Order)** Modified from [Platts et al., 1983]

| Step | Description | PQI |
|---|---|---|
| 1A | Maximum pool diameter is approximately = average wetted-width…go to step 2 | |
| 1B | Maximum pool diameter is > about one-half average wetted-width…go to step 3 | |
| 1C | Maximum pool diameter < about one-half average wetted-width…go to step 4 | |
| 2A | Maximum pool depth < 0.5 m…go to step 5 | |
| 2B | Maximum pool depth > 0.5 m…go to step 3 | |
| 3A | Maximum pool depth > 1 m, regardless of cover conditions, or maximum pool depth > 0.5 m <u>and</u> cover is abundant/excellent | **5** |
| 3B | Maximum pool depth < 0.5 m with, good to excellent cover, or is between 0.5 m & 1 m maximum depth, but has only fair or good cover | **4** |
| 3C | Maximum pool depth < 0.5 m, with only poor to fair cover | **3** |
| 4A | Maximum pool depth > 0.5 m, with good to excellent cover | **3** |
| 4B | Maximum pool depth < 0.5 m, but cover is good to excellent, <u>or</u> maximum pool depth > 0.5 m, but cover is only poor to fair | **2** |
| 4C | Maximum pool depth < 0.5 m, with only poor to fair cover | **1** |
| 5A | Pool cover is good to excellent | **3** |
| 5B | Pool cover is poor to fair | **2** |

**Riffle Quality Index (RQI) for Puget Sound Lowland Streams (1st to 3rd Order)**

| Step | Description | RQI |
|---|---|---|
| 1A | Riffle substrata is a mixture of cobble and gravel, with little sand or silt (low embeddedness) <u>and</u> streambed is relatively stable, with little evidence of scour or deposition (i.e. exposed bed or fresh gravel-bars)…go to step **2** | |
| 1B | Riffle substrata consists mostly of gravel, with some sand/silt (moderate embeddedness) <u>or</u> some evidence of moderate streambed instability (scour or deposition)…go to step **3** | |
| 1C | Riffle substrata consists mostly of sand and silt, with some gravel (high embeddedness), <u>or</u> some evidence of severe instability…go to step **4** | |
| 2A | Pool tail-out at head of riffle or riparian wetland within 10 m of riffle, <u>and</u> abundant/excellent-quality cover on riffle | **5** |
| 2B | Pool tail-out at head of riffle or riparian wetland within 10 m of riffle and poor to good-quality cover on riffle, <u>or</u> glide or run upstream of riffle, no wetland within 10 m upstream, <u>and</u> abundant/excellent-quality cover on riffle | **4** |
| 2C | Glide or run upstream of riffle, no wetland within 10 m upstream, <u>and</u> little or no cover on riffle | **2** |
| 3A | Pool tail-out at head of riffle, riparian wetland within 10 m of riffle, <u>or</u> pool just downstream of riffle <u>or</u> abundant/excellent-quality cover on riffle | **4** |
| 3B | Glide or run upstream of riffle, no wetland within 10 m upstream, <u>and</u> no pool downstream of riffle <u>and</u> moderate/good-quality cover on riffle | **3** |
| 3C | Glide or run upstream of riffle, no wetland within 10 m upstream, <u>and</u> no pool downstream of riffle <u>and</u> little or no cover on riffle | **2** |
| 4A | Pool tail-out at head of riffle, riparian wetland within 10 m of riffle, <u>or</u> pool just downstream of riffle <u>and</u> good-excellent cover on riffle | **2** |
| 4B | Glide or run upstream of riffle, no wetland within 10 m upstream, <u>and</u> no pool downstream of riffle <u>or</u> poor-fair cover on riffle | **1** |

**Stream Habitat Survey Data Sheet** **King County DNR, Water and Land Resources Division August 1999**

Stream______________________Segment_____________________Start Location______________________________End Location_________________

Date__________________ Flow________cfs Flow Method _______________Water Temp__________F C Air Temp________F C Time____________

Weather___________________________________Crew______________________________________________________________________________

| Dist | Thalweg | Habitat Unit | | | Pool | | | | | Riffle | LWD | | | | | | FW | Fish | Comment (trib, pipe, side channel, fence, etc) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (m) | Depth (m) | Type | Length | Wetted Width | Type | Max Depth | Tail Depth | RPD (max-tail) | PQI | RQI | Qty/ # | Type/ Sp. | Zone | Form Pool? Y/N | Length | Diam | Mussels Y/N, #'s | Y/N | |
| | | | | | | | | | | | | | | | | | | | |
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Stream______________________Segment______________Crew______________________________Date_________________Page ___ of ___

Reaches are defined as contiguous areas sampled within a stream segment.  Take reach measurements at least every 50 m, or where there are distinct breaks in land use / riparian condition / habitat quality.

| Reach Ref (Dist) | BFW (m) | BFD (m) | Riparian | | | Inva-sives | Bank Cond | | Roll/ Photo # | Notes/Description (Use back for narrative descriptions of reach) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | RB | LB | % Shade | | RB | LB | | |
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**General Instructions**: First page is for recording habitat unit and continuous measurements (i.e., LWD). Second page is for reach-level measurements - collect every 50 m or at each reach, whichever is shorter.

**Habitat Type**:
POOL - Slow water, length and width at least 1/2 the bankfull channel width.
RIF - Swiftly flowing, turbulent water; some partially exposed substrate; substrate cobble and/or boulder dominated;
GLD - Wide, uniform channel volume, low to moderate water velocity, little surface agitation. Anything not qualifying as pool, riffle, or other habitat type.
W - Riparian Wetland
RIRN - Low-gradient valley bottom stream with both shallow and somewhat deep water across a given cross-section, a thalweg meandering from one bank to another, and the presence of both fast and slow water. A series of shallow lateral pools on alternating sides of the channel connected by short riffle sections (often < one channel width).

**FW Mussels**: Freshwater mussels - are they present? Indicate relative abundance.
**Fish?**: Note whether salmonids (any age class) are seen in habitat unit.

**LWD**:
Measure all, minimum 2 m (6 ft) length & 15 cm (6 in) diam, no min for stumps.
Qty/#: If DJ, count number of LWD.
Type: L=Log, RW = Root-wad, DJ=Debris jam (count based on average diam & l
Species: C=Coniferous, D=Deciduous (combine w/ type, i.e., LC, RWD)
Form Pool? Has the log caused a pool to form? (yes or no)
Zone: 1 – within wetted channel
2 – not in wetted channel, but protrudes below bankfull;
3 – spanning or suspended over the channel, not within bankfull

**Pools**:
Type: SP-scour (lateral, channel, channel confluence, plunge), DP-dam, and BP backwater or side channel
Tail Depth: Water depth @ hydraulic control at d/s end of pool
RPD: Max pool depth minus tail depth

**Substrate** (sizes refer to intermediate diameter):
F - Fines <2 mm
G - Gravel 2- 64 mm
C - Cobble 64-256 mm
B - Boulder >256 mm

**Bank Condition**:
S Stable – vegetated or low bars to level of low flow
LS Low Scour – steep, raw banks only below bankfull level
FS Full Scour – steep, raw banks above bankfull level
A Armored – artificial bank protection of any kind

**Canopy Cover / Percent Shading**:
1 - 0-5%
2 - 6-25%
3 - 26-75%
4 - 76-95%
5 - 95-100%

**Riparian Type**:
FD, FC, FM = Forested deciduous, coniferous or mixed
SH = Shrubs or vines
HT = Herbaceous tall (unmowed/ungrazed)
HS = Herbaceous short (mowed/grazed)
IMP = impervious (roads, pavement, buildings)
LAND = Landscaped ( mowed lawn, ornamental shrubs/trees)

**Invasives**: Dominant (D) = >20% cover on bank over reach. Species: (first two letters of genus & species):
RUDI / RULA Himalayan blackberry (*Rubus discolor*) or Evergreen blackberry (*Rubus laciniatus*)
SODA climbing nightshade (*Solanum dulcamara*)
ILHE English ivy (*Ilex hedera*)
PHAR reed canary grass (*Phalaris arundinacea*)
SPDO spirea/hardhack (*Spirea douglasii*)
POCU Japanese knotweed (*Polygonum cuspidatum*)
IRPS yellow flag iris (*Iris pseudacorus*)
COAR bindweed (morning glory) (*Convolvulus arvensis*)
LYSA - purple loosestrife (*Lythrum salicaria*)

**Notes**: Describe quality of habitat, species, life history stages, relative abundance of fish and wildlife, and any obvious problems or concerns such as point of discharge or withdrawal, potential fish passage barrier, and opportunity and/or need for protection or a restoration project

# **Appendix C.** Matrix of Pathways and Indicators

| WRIA 8 Reconnaissance Assessment Workshop Matrix | | | | |
|---|---|---|---|---|
| Matrix developed using "Coastal Salmon Conservation: Working Guidance for Comprehensive Salmon Restoration Initiatives on the Pacific Coast, " NOAA, Sept. 15, 1996, Appendix II. For additional parameter definition, use Timber, Fish and Wildlife Monitori | | | | |
| **PATHWAY** | **INDICATORS** | **Properly functioning** | **At risk** | **Not properly functioning** |
| Water Quality: | Temperature | 50-57° F[1] | 57-60° (spawning)<br>57-64° (migration & Rearing)[2] | > 60° (spawning)<br>> 64° (migration & Rearing)[2] |
| | Sediment/Turbidity | < 12% fines (<0.85mm) in gravel[3], turbidity low | 12-17% (west-side)[3],<br>12-20% (east-side)[2],<br>turbidity moderate | 17% (west-side)[3],<br>20% (east-side)[2], fines at surface or depth in spawning habitat[2], turbidity high |
| | Chemical Contamination/ Nutrients | low levels of chemical contamination from agricultural, industrial, and other sources, no excess nutrients, no CWA 303d designated reaches[5] | moderate levels of chemical contamination from agricultural, industrial, and other sources, some excess nutrients, one CWA 303d designated reach[5] | high levels of chemical contamination from agricultural, industrial, and other sources, high levels of excess nutrients, more than one CWA 303d designated reach[5] |
| Habitat Access: | Physical Barriers | any man-made barriers present in watershed allow upstream and downstream fish passage at all flows | any man-made barriers present in watershed do not allow upstream and/or downstream fish passage at base/low flows | any man-made barriers present in watershed do not allow upstream and/or downstream fish passage at a range of flows |
| Habitat Elements:<br><br>**North Trib. Survey data:**<br>RQI | Substrate | dominant substrate is gravel or cobble (interstitial spaces clear), or embeddedness <20%[3] | gravel and cobble is subdominant, or if dominant, embeddedness 20-30%[3] | bedrock, sand, silt, or small gravel dominant, or if gravel and cobble dominant, embeddedness >30%[2] |

| PATHWAY | INDICATORS | Properly functioning | At risk | Not properly functioning |
|---|---|---|---|---|
| **North Trib. Survey data**, min. diameter used = 30", no minimum length. | Large Woody Debris | Coast: >80 pieces/mile >24" diameter >50 ft. length[4]; East-side: >20 pieces/mile >12"diameter >35 ft. length[2]; and adequate sources of woody debris recruitment in riparian areas | currently meets standards for properly functioning, but lacks potential sources from riparian areas of woody debris recruitment to maintain that standard | does not met standards for properly functioning and lacks potential large woody debris recruitment |
| **North Trib. Survey data:**<br>North and Little Bear Creeks average width = 20"<br>Swamp = 25" | Pool Frequency<br><br>channel width #pools/mile[6]<br>5 feet 184<br>10 " 96<br>15 " 70<br>20 " 56<br>25 " 47<br>50 " 26<br>75 " 23 | meets pool frequency standards (left) and large woody debris recruitment standards for properly functioning habitat (above) | meets pool frequency standards but large woody debris recruitment inadequate to maintain pools over time | does not meet pool frequency standards |
| **North Trib. Survey data:**<br>PQI | Pool Quality | pools >1 meter deep (holding pools) with good cover and cool water[3], minor reduction of pool volume by fine sediment | few deeper pools (>1 meter) present or inadequate cover/temperature[3], moderate reduction of pool volume by fine sediment | no deep pools (>1 meter) and inadequate cover/temperature[3], major reduction of pool volume by fine sediment |
| | Off-Channel Habitat | backwaters with cover, and low energy off-channel areas (ponds, oxbows, etc.)[3] | some backwaters and high energy side channels[3] | few or no backwaters, no off-channel ponds[3] |

| PATHWAY | INDICATORS | Properly functioning | At risk | Not properly functioning |
|---|---|---|---|---|
| | Refugia (important remnant habitat for sensitive aquatic species) | habitat refugia exist and are adequately buffered (e.g., by intact riparian reserves); existing refugia are sufficient in size, number, and connectivity to maintain viable populations or sub-populations[7] | habitat refugia exist but are not adequately buffered (e.g., by intact riparian reserves); existing refugia are insufficient in size, number, and connectivity to maintain viable populations or sub-populations[7] | adequate habitat refugia do not exist[7] |
| Channel Condition & Dynamics:<br><br>**North Trib. Survey data** | Width/Depth Ration | <10[2, 4] | 10-12 (we are unaware of any criteria to reference) | >12 (we are unaware of any criteria to reference) |
| **North Trib. Survey data** | Streambank Condition | >90 % stable; i.e., on average, less than 10% of banks are actively eroding[2] | 80-90% stable | <80% stable |
| | Floodplain Connectivity | off-channel areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession | reduced linkage of wetland, floodplains, and riparian areas to main channel; overbank flows are reduced relative to historic frequency, as evidenced by moderate degradation of wetland function, riparian vegetation/succession | severe reduction in hydrologic connectivity between off-channel, wetland, floodplain, and riparian areas; wetland extent drastically reduced and riparian vegetation/succession altered significantly |
| Flow-Hydrology: | Change in Peak/Base Flows | watershed hydrograph indicates peak flow, base flow, and flow timing characteristics comparable to an undisturbed watershed of similar size, geology, and geography | some evidence of altered peak flow, baseflow, and/or flow timing relative to an undisturbed watershed of similar size, geology, and geography | pronounced changes in peak flow, baseflow, and/or flow timing relative to an undisturbed watershed of similar size, geology and geography |

| PATHWAY | INDICATORS | Properly functioning | At risk | Not properly functioning |
|---|---|---|---|---|
| | Increase in Drainage Network | zero or minimum increases in drainage network density due to roads[8, 9] | moderate increases in drainage network density due to roads (e.g., = 5%)[8, 9] | significant increases in drainage network density due to roads (e.g., = 20-25%)[8, 9] |
| Watershed Conditions:<br><br>**North Trib. Survey data** | Road Density & Location | <2mi.mi$^{2}$[11], no valley bottom roads | 2-3- mi/mi$^{2}$, some valley bottom roads | >3 mi/mi$^{2}$, many valley bottom roads |
| | Disturbance History | <15% ECA (entire watershed) with no concentration of disturbance in unstable or potentially unstable areas, and/or refugia, and/or riparian area; and for NWFP area (except AMAs), ≥15% retention of LSOG in watershed[10] | <15% ECA (entire watershed) but disturbance concentrated in unstable or potentially unstable areas, and/or refugia, and/or riparian area; and for NWFP area (except AMAs), ≥ 15% retention of LSOG in watershed[10] | <15% ECA (entire watershed) but disturbance concentrated in unstable or potentially unstable areas, and/or refugia, and/or riparian area; does not meet NWFP standard for LSOG retention |
| | Riparian Reserves | the riparian reserve system provides adequate shade, large woody debris recruitment, and habitat protection and connectivity in all sub-watersheds, and buffers or includes known refugia for sensitive aquatic species (>80% intact), and/or for grazing impact | moderate loss of connectivity or function (shade, LWD recruitment, etc.) of riparian reserve system, or incomplete protection of habitats and refugia for sensitive aquatic species (=70-80% intact), and/or for grazing impacts: percent similarity of riparian | riparian reserve system is fragmented, poorly connected, or provides inadequate protection of habitats and refugia for sensitive aquatic species (<70% intact), and/or for grazing impacts: percent similarity of riparian vegetation to the potential natural |

# Appendix D. Basin Conditions

## Swamp Creek

| NUMBER | LOCATION | AREA (km^2) | Segment Length (km) | % MIXED FOREST | % CONIFER -EARLY | % CONIFER-MIDDLE | % CONIFER -LATE | % FOREST | All STREAMS (KM) | ROADS (km) | ROAD DENSITY (km/km^2) | ROAD X STREAM (#/ sub-basin) | Road X within Segment (ortho)* | Crossing frequency (#/km)* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S-1 | Lower | 63.44 | 2.41 | 3.4 | 0.1 | 0 | 0 | 18.9 | 40.34 | 482.61 | 7.61 | 141 | 3 | 1.2 |
| S-2 | Kenmore | 57.97 | 0.63 | 3.5 | 0.1 | 0 | 0 | 18.6 | 35.77 | 450.75 | 7.78 | 129 | 0 | 0 |
| S-3 | Wallace | 57.29 | 1.08 | 3.5 | 0.1 | 0 | 0 | 18.6 | 40.75 | 445.52 | 7.78 | 120 | 2 | 1.8 |
| S-4 | Forsgren | 54.07 | 1.97 | 3.2 | 0.1 | 0 | 0 | 18.3 | 30.82 | 421.82 | 7.8 | 103 | 2 | 1.0 |
| S-5 | Locust | 50.92 | 1.26 | 3.1 | 0.1 | 0 | 0 | 17.9 | 28.51 | 399.14 | 7.84 | 98 | 1 | 0.8 |
| S-6 | Scriber | 15.92 | 5.27 | 1 | 0 | 0 | 0 | 8.5 | 9.34 | 146.22 | 9.19 | 48 | 5 | 1.0 |
| S-7 | Cypress | 34.1 | 1.26 | 3.9 | 0.1 | 0 | 0 | 21.7 | 17.89 | 246.93 | 7.24 | 48 | 1 | 0.8 |
| S-8 | Larch | 32.78 | 2.26 | 3.9 | 0.1 | 0 | 0 | 22 | 16.63 | 235.34 | 7.18 | 48 | 1 | 0.4 |
| S-9 | Filbert | 30.99 | 0.28 | 3.4 | 0.1 | 0 | 0 | 21.7 | 14.37 | 220.8 | 7.13 | 44 | 2 | 7.1 |
| S-10 | Butternut | 25.87 | 1.21 | 3 | 0.1 | 0 | 0 | 22.7 | 13.14 | 208.5 | 8.06 | 34 | 2 | 1.6 |
| S-11 | Upper | 24.52 | 5.5 | 2.7 | 0.1 | 0 | 0 | 23.1 | 9.87 | 169.1 | 6.9 | 22 | 10 | 1.8 |

*These numbers should be considered a conservative estimate and only includes large roads visible on the King County NIES orthophotographs.

## Swamp Creek

| NUMBER | LOCATION | AREA (km^2) | Segment Length (km) | % MIXED FOREST | % CONIFER -EARLY | % CONIFE R- MIDDLE | % CONIFER -LATE | % FOREST | All STREAMS (KM) | ROADS (km) | ROAD DENSITY (km/km^2) | ROAD X STREAM (#/ sub-basin) | Road X within Segment (ortho)* | Crossing frequency (#/km)* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S-1 | Lower | 63.44 | 2.41 | 3.4 | 0.1 | 0 | 0 | 18.9 | 40.34 | 482.61 | 7.61 | 141 | 3 | 1.2 |
| S-2 | Kenmore | 57.97 | 0.63 | 3.5 | 0.1 | 0 | 0 | 18.6 | 35.77 | 450.75 | 7.78 | 129 | 0 | 0 |
| S-3 | Wallace | 57.29 | 1.08 | 3.5 | 0.1 | 0 | 0 | 18.6 | 40.75 | 445.52 | 7.78 | 120 | 2 | 1.8 |
| S-4 | Forsgren | 54.07 | 1.97 | 3.2 | 0.1 | 0 | 0 | 18.3 | 30.82 | 421.82 | 7.8 | 103 | 2 | 1.0 |
| S-5 | Locust | 50.92 | 1.26 | 3.1 | 0.1 | 0 | 0 | 17.9 | 28.51 | 399.14 | 7.84 | 98 | 1 | 0.8 |
| S-6 | Scriber | 15.92 | 5.27 | 1 | 0 | 0 | 0 | 8.5 | 9.34 | 146.22 | 9.19 | 48 | 5 | 1.0 |
| S-7 | Cypress | 34.1 | 1.26 | 3.9 | 0.1 | 0 | 0 | 21.7 | 17.89 | 246.93 | 7.24 | 48 | 1 | 0.8 |
| S-8 | Larch | 32.78 | 2.26 | 3.9 | 0.1 | 0 | 0 | 22 | 16.63 | 235.34 | 7.18 | 48 | 1 | 0.4 |
| S-9 | Filbert | 30.99 | 0.28 | 3.4 | 0.1 | 0 | 0 | 21.7 | 14.37 | 220.8 | 7.13 | 44 | 2 | 7.1 |
| S-10 | Butternut | 25.87 | 1.21 | 3 | 0.1 | 0 | 0 | 22.7 | 13.14 | 208.5 | 8.06 | 34 | 2 | 1.6 |
| S-11 | Upper | 24.52 | 5.5 | 2.7 | 0.1 | 0 | 0 | 23.1 | 9.87 | 169.1 | 6.9 | 22 | 10 | 1.8 |

*These numbers should be considered a conservative estimate and only includes large roads visible on the King County NIES orthophotographs.

**Basin Conditions (continued)**

# Little Bear Creek

| NUMBER | LOCATION | AREA (km^2) | Segment Length (km) | % MIXED FOREST | % CONIFER -EARLY | % CONIFER-MIDDLE | % CONIFER -LATE | % FOREST | All STREAMS (KM) | ROADS (km) | ROAD DENSITY (km/km^2) | ROAD X STREAM #/sub-basin | Road X within Segment (orthos)* | Crossing frequency (#/km)* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LB-1 | Lower | 39.1 | 0.51 | 13.4 | 0.1 | 0 | 0 | 31.7 | 38 | 223.76 | 5.72 | 119 | 3 | 5.9 |
| LB-2 | Woodinville | 38.92 | 1.67 | 13.4 | 0.1 | 0 | 0 | 31.8 | 37.49 | 220.89 | 5.68 | 114 | 1 | 0.6 |
| LB-3 | 'High School' | 35.76 | 0.96 | 14.1 | 0.2 | 0 | 0 | 33.2 | 32.14 | 193.39 | 5.41 | 95 | 1 | 1.0 |
| LB-4 | Rowlands | 34.13 | 0.32 | 14.5 | 0.2 | 0.1 | 0 | 33.8 | 30.64 | 181.88 | 5.33 | 93 | 1 | 3.1 |
| LB-5 | Wellington | 31.84 | 1.32 | 14.6 | 0.2 | 0.1 | 0 | 34.3 | 27.43 | 167.31 | 5.26 | 84 | 1 | 0.8 |
| LB-6 | 'Lower Hwy 9' | 30.09 | 0.64 | 15.3 | 0.2 | 0.1 | 0 | 35.5 | 26.11 | 156.24 | 5.19 | 83 | 1 | 1.6 |
| LB-7 | 'Upper Hwy 9' | 27.94 | 1.39 | 15 | 0.2 | 0.1 | 0 | 36.1 | 25.07 | 145.06 | 5.19 | 74 | 2 | 1.4 |
| LB-8 | 'Trout Stream Cr Tributary | 2.76 | 21.58 | 16.3 | 0.1 | 0 | 0 | 37.7 | 23.67 | 11.3 | 4.09 | 5 | 1 | 0 |
| LB-9 | Maltby | 23.6 | 1.51 | 15 | 0.2 | 0.1 | 0 | 36 | 21.51 | 125.49 | 5.32 | 58 | 2 | 1.3 |
| LB-10 | 'Gr. Dane Creek Tributary' | 5.96 | 4.76 | 16 | 0.1 | 0.1 | 0 | 35 | 6.53 | 30.85 | 5.17 | 23 | 3 | 0.5 |
| LB-11 | Middle | 14.51 | 0.58 | 15.3 | 0.2 | 0.1 | 0 | 36.7 | 12.34 | 74.42 | 5.13 | 30 | 0 | 0 |
| LB-12 | Jewell | 13.68 | 0.5 | 14.8 | 0.2 | 0.1 | 0 | 36.6 | 10.19 | 69.68 | 5.1 | 23 | 1 | 2 |
| LB-13 | Horse Farms | 11.43 | 1.09 | 14.6 | 0.2 | 0.1 | 0 | 37.1 | 12.05 | 60.62 | 5.31 | 19 | 2 | 1.8 |
| LB-14 | Beaver | 9.21 | 0.75 | 14.4 | 0.2 | 0.1 | 0 | 36.3 | 9.09 | 52.13 | 5.66 | 17 | 2 | 2.4 |
| LB-15 | Upper | 8.19 | 3.19 | 12.4 | 0.2 | 0.1 | 0 | 34.3 | 7.49 | 48.36 | 5.9 | 12 | 6 | 1.9 |

*These numbers should be considered a conservative estimate and only includes large roads visible on the King County NIES orthophotographs

# **Appendix E.** Riparian Vegetation

***Swamp Creek***

| Segment | Land. | Herb. short | Herb. tall | Shrub | Decid. forest | Conif. forest | Mixed forest | Imperv. |
|---|---|---|---|---|---|---|---|---|
| **Lower 1A** | --- | --- | --- | 63% | 37% | --- | --- | --- |
| **Lower 1B** | --- | --- | --- | 23% | 77% | --- | --- | --- |
| **Kenmore 2** | --- | 68% | --- | --- | 17% | --- | --- | 15% |
| **Wallace 3** | 3% | 21% | 12% | 10% | 52% | --- | --- | 2% |
| **Forsgren 4** | 8% | --- | --- | 38% | 60% | --- | 12% | --- |
| **Locust 5** | 37% | --- | --- | 3% | 51% | --- | --- | --- |
| **Scriber 6** | --- | 5% | --- | 19% | 45% | --- | 25% | 6% |
| **Cypress 7** | 12% | --- | 5% | 41% | 28% | 7% | 13% | --- |
| **Larch 8** | 10% | --- | --- | 26% | 52% | --- | 12% | --- |
| **Filbert 9** | --- | --- | --- | 100% | --- | --- | --- | --- |
| **Butternut 10** | --- | --- | --- | 8% | 16% | 46% | 30% | --- |
| **Upper 11 A** | 14% | --- | --- | 11% | 75% | --- | --- | --- |
| **Upper 11 B** | --- | --- | --- | --- | 100% | --- | --- | --- |

***North Creek***

| Segment | Land. | Herb. short | Herb. tall | Shrub | Decid. forest | Conif. forest | Mixed forest | Imperv. |
|---|---|---|---|---|---|---|---|---|
| **Lower 1** | --- | --- | 7% | 93% | --- | --- | --- | --- |
| **UW 2** | --- | --- | 28% | 67% | 5% | --- | --- | --- |
| **Bothell 3** | --- | --- | 48% | 28% | 14% | --- | 10% | --- |
| **Fitzgerald 4** | 26% | --- | --- | 22% | 38% | 2% | 5% | 5% |
| **Canyon Park 5** | --- | 37% | --- | 25% | 18% | --- | 20% | --- |
| **Thrashers 6** | 12% | --- | --- | 44% | 29% | --- | 15% | --- |
| **Middle 8** | 9% | --- | 9% | 26% | 46% | --- | 10% | --- |
| **Nickel 9** | 9% | 18% | 30% | 2% | 41% | --- | --- | --- |
| **Penny Ck.10A** | 19% | --- | --- | 8% | 73% | --- | --- | --- |
| **Penny Ck.10B** | --- | --- | --- | 31% | 48% | --- | 21% | --- |
| **Mill Ck. 11** | --- | 27% | --- | 17% | 56% | --- | --- | --- |
| **Wetland 12** | 10% | --- | --- | 9% | 50% | --- | 31% | --- |
| **McCollum 13** | 10% | --- | --- | --- | 33% | 57% | --- | --- |

**Riparian Vegetation (continued)**

## Little Bear Creek

| Segment | Land. | Herb. short | Herb. tall | Shrub | Decid. forest | Conif. forest | Mixed forest | Imperv. |
|---|---|---|---|---|---|---|---|---|
| **Mouth 1** | --- | --- | --- | 67% | --- | --- | 33% | --- |
| **Woodinville 2** | --- | --- | --- | 10% | 55% | --- | 22% | 13% |
| **High School 3** | --- | --- | --- | 28% | 57% | --- | 15% | --- |
| **Rowlands 4** | 12% | --- | --- | --- | 48% | 12% | 28% | --- |
| **Wellington 5** | --- | --- | 34% | 23% | 43% | --- | --- | --- |
| **Lower Highway 6** | 2% | 35% | 21% | 42% | --- | --- | --- | --- |
| **Upper Highway 7** | 40% | 6% | 0% | 42% | 12% | --- | --- | --- |
| **Maltby 9** | 13% | --- | 4% | 42% | 32% | --- | 9% | --- |
| **Great Dane 10** | --- | --- | --- | --- | 19% | --- | 81% | --- |
| **Middle 11** | --- | --- | --- | --- | --- | --- | 100% | --- |
| **Jewell 12*** | --- | --- | --- | --- | --- | --- | 100% | --- |
| **Horse Farms 13** | --- | --- | --- | --- | --- | --- | 100% | --- |
| **Beaver14** | --- | --- | --- | 14% | 86% | --- | --- | --- |

*these data are based on visual assessment of the segment indicating that the riparian vegetation of segment 12 is the same as segments 11 and 13.

# **Appendix F.** Invasives

## Swamp Creek

| Segment description | Blackberry* | Reed canary grass | Japanese knotweed | Climbing nightshade | Morning glory | English ivy | Yellow Flag Iris | Purple Loosestrife | Spirea |
|---|---|---|---|---|---|---|---|---|---|
| Lower 1A | $D^A$ | $D^A$ | P | P | | | | P | |
| Lower 1B | | | P | P | P | | | P | |
| Kenmore 2 | P | P | P | | | | | P | |
| Wallace 3 | $D^A$ | P | P | | | | | | |
| Forsgren 4 | $D^A$ | P | P | | | | | | |
| Locust 5 | $D^A$ | P | P | P | | | | | |
| Scriber 6 | $D^A$ | | | | | | P | | |
| Cypress 7 | $D^A$ | P | | | | P | | | |
| Larch 8 | $D^A$ | P | P | P | P | P | P | | |
| Filbert 9 | $D^A$ | | P | P | | | | | |
| Butternut 10 | P | | | P | | | | | |
| Upper 11 A | | P | | P | | | | | |
| Upper 11 B | P | P | | | | P | | | |

## North Creek

| Segment description | Blackberry* | Reed canary grass | Japanese knotweed | Climbing nightshade | Morning glory | English ivy | Yellow Flag Iris | Purple Loosestrife |
|---|---|---|---|---|---|---|---|---|
| Lower 1 | D | D | | | | | | |
| UW 2 | D | D | P | | | | | |
| Bothell 3 | D | D | | | | | | |
| Fitzgerald 4 | P | P | | P | P | P | | |
| Canyon Park 5 | P | $D^A$ | | | | P | | |
| Thrashers 6 | $D^A$ | P | P | | | | | |
| Silver/Tam. Trib. 7 | $D^A$ | P | P | P | | | | |
| Middle 8 | $D^A$ | P | P | P | | | | |
| Nickel 9 | D | D | P | P | | | | |
| Penny Ck. 10A | $D^A$ | D | | | | P | | |
| Penny Ck. 10B | D | D | | | | | | |
| Mill Ck. 11 | D | D | | | | P | | |
| Wetland 12 | D | | | | | P | | |
| McCollum 13 | P | | | | | | | |

P Present within the reach
D Dominant in the reach
* Himalayan or Evergreen species
$D^A$ Dominant in some reaches

## Little Bear Creek

| Segment description | Blackberry* | Reed canary grass | Japanese knotweed | Climbing nightshade | Morning glory | English ivy | Yellow Flag Iris | Spirea |
|---|---|---|---|---|---|---|---|---|
| Mouth 1 | D | P | P | | | P | | |
| Woodinville 2 | P | P | P | P | | | | |
| High School 3 | P | P | P | P | | | | |
| Rowlands 4 | P | P | P | P | | | | |
| Wellington 5 | D[A] | P | P | P | | | P | |
| Lower Hwy 6 | D | P | P | P | | P | P | |
| Upper Hwy 7 | D | P | P | P | | | | |
| Maltby 9 | P | P | | P | | | | |
| Great Dane 10 | P | | P | | | | | P |
| Middle 11 | P | | | | | | P | P |
| Jewell 12** | | | | | | | | |
| Horse Farms 13 | | | | P | | | | |
| Beaver 14 | P | P | | | | | | P |

P Present within the reach
D Dominant in the reach
* Himalayan or Evergreen
[A] Dominant in some reaches
**No data

Blackberry is Himalayan blackberry (*Rubus discolor*) or Evergreen blackberry (*Rubus laciniatus*)
Climbing nightshade (*Solanum dulcamara*)
English ivy (*Ilex hedera*)
Reed canary grass (*Phalaris arundinacea*)
Spirea/hardhack (*Spirea douglasii*)
Japanese knotweed (*Polygonum cuspidatum*)
Yellow flag iris (*Iris pseudacorus*)
Bindweed (morning glory) (*Convolvulus arvensis*)
Purple loosestrife (*Lythrum salicaria*)

**Appendix G.** Percent Shade

| ***Swamp Creek*** | Percent shade categories | | | | |
|---|---|---|---|---|---|
| **Segment** | **0-5%** | **6-25%** | **26-75%** | **76-95%** | **96-100%** |
| **1A Lower** | 26% | 0% | 74% | 0% | 0% |
| **1B Lower** | 0% | 0% | 45% | 55% | 0% |
| **2 Kenmore** | 16% | 84% | 0% | 0% | 0% |
| **3 Wallace** | 10% | 50% | 40% | 0% | 0% |
| **4 Forsgren** | 12% | 55% | 33% | 0% | 0% |
| **5 Locust** | 0% | 67% | 33% | 0% | 0% |
| **6 Scriber** | 11% | 11% | 78% | 0% | 0% |
| **7 Cypress** | 10% | 39% | 43% | 8% | 0% |
| **8 Larch** | 0% | 38% | 62% | 0% | 0% |
| **9 Filbert** | 0% | 0% | 100% | 0% | 0% |
| **10 Butternut** | 0% | 0% | 41% | 59% | 0% |
| **11A Upper** | 0% | 11% | 77% | 12% | 0% |
| **11B Upper** | 0% | 0% | 31% | 69% | 0% |

| ***North Creek*** | Percent shade categories | | | | |
|---|---|---|---|---|---|
| **Segment** | **0-5%** | **6-25%** | **26-75%** | **76-95%** | **96-100%** |
| **1 Lower** | 0% | 51% | 49% | 0% | 0% |
| **2 UW** | 57% | 43% | 0% | 0% | 0% |
| **3 Bothell** | 23% | 44% | 6% | 28% | 0% |
| **4 Fitzgerald** | 20% | 48% | 32% | 0% | 0% |
| **5 Canyon Park** | 28% | 40% | 32% | 0% | 0% |
| **6 Thrashers** | 11% | 23% | 66% | 0% | 0% |
| **7 Silver/ Tambark Tribs*** | 0% | 62% | 26% | 12% | 0% |
| **8 Middle** | 19% | 33% | 48% | 0% | 0% |
| **9 Nickel** | 17% | 25% | 58% | 0% | 0% |
| **10A Penny Creek Tribs** | 18% | 16% | 66% | 0% | 0% |
| **10B Penny Creek Tribs** | 0% | 25% | 34% | 41% | 0% |
| **11 Mill Creek** | 0% | 24% | 76% | 0% | 0% |
| **12 Wetland** | 0% | 0% | 100% | 0% | 0% |
| **13 McCollum** | 0% | 0% | 100% | 0% | 0% |

* Data from May et al. 1997

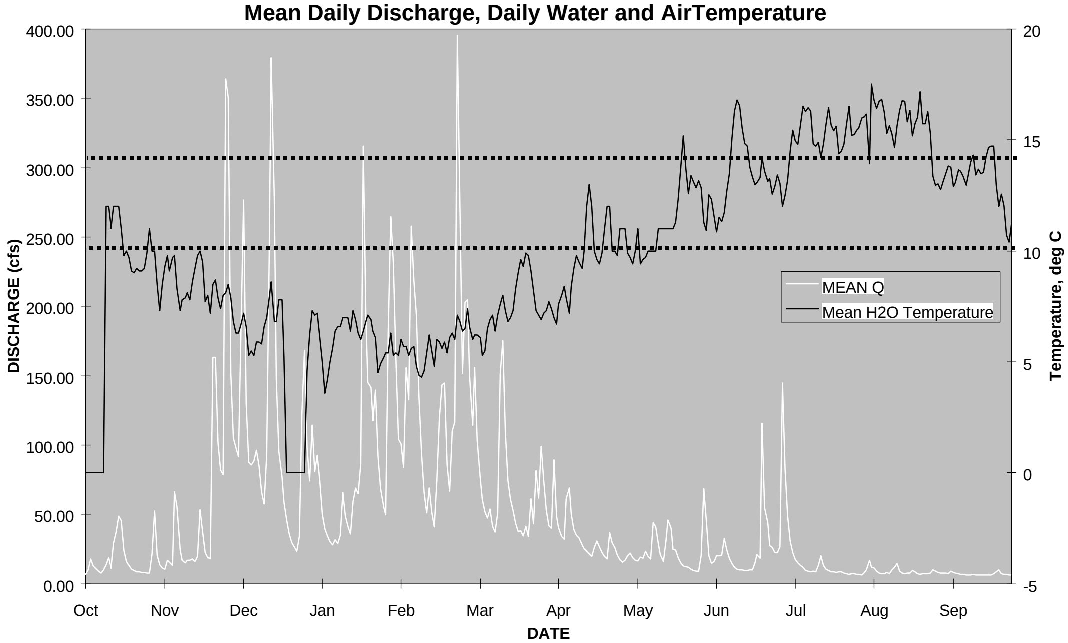
**Canopy Cover (Continued)**

| *Little Bear Creek* | Percent shade categories | | | | |
|---|---|---|---|---|---|
| **Segment** | **0-5%** | **6-25%** | **26-75%** | **76-95%** | **96-100%** |
| **1 Mouth** | 32% | 34% | 33% | 0% | 0% |
| **2 Woodinville** | 0% | 10% | 54% | 36% | 0% |
| **3 High School** | 0% | 0% | 100% | 0% | 0% |
| **4 Rowlands** | 28% | 0% | 72% | 0% | 0% |
| **5 Wellington** | 40% | 25% | 36% | 0% | 0% |
| **6 Lower Hwy 9** | 0% | 62% | 26% | 12% | 0% |
| **7 Upper Hwy 9** | 0% | 64% | 36% | 0% | 0% |
| **9 Maltby** | 17% | 49% | 34% | 0% | 0% |
| **10 Great Dane** | 0% | 38% | 0% | 62% | 0% |
| **11 Middle** | 0% | 0% | 100% | 0% | 0% |
| **12 Jewell*** | 0% | 0% | 100% | 0% | 0% |
| **13 Horse Farms** | 0% | 0% | 100% | 0% | 0% |
| **14 Beaver** | 0% | 19% | 38% | 43% | 0% |

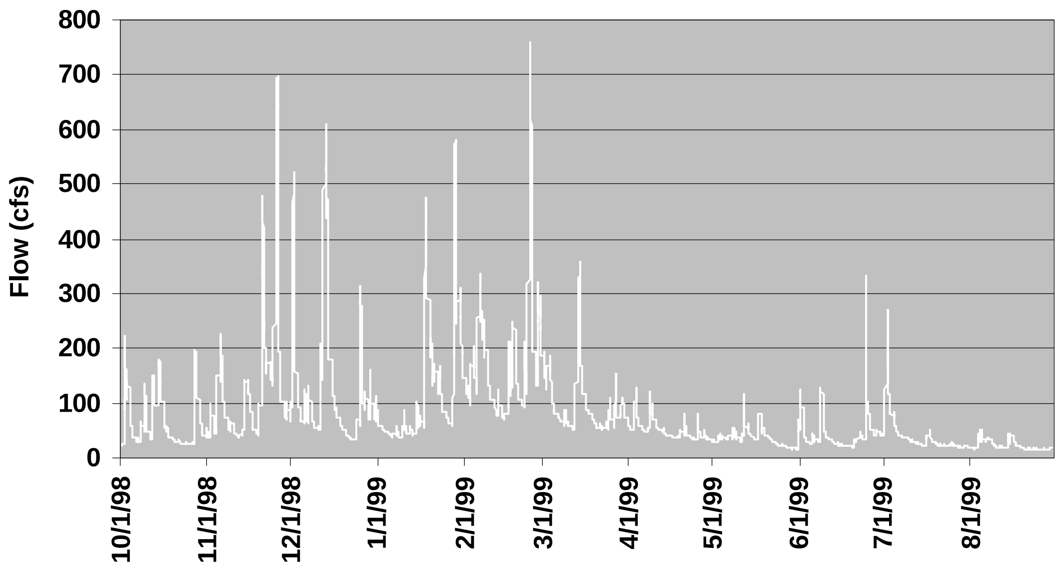
*Data estimated from comparative visual assessment of segments 11-13

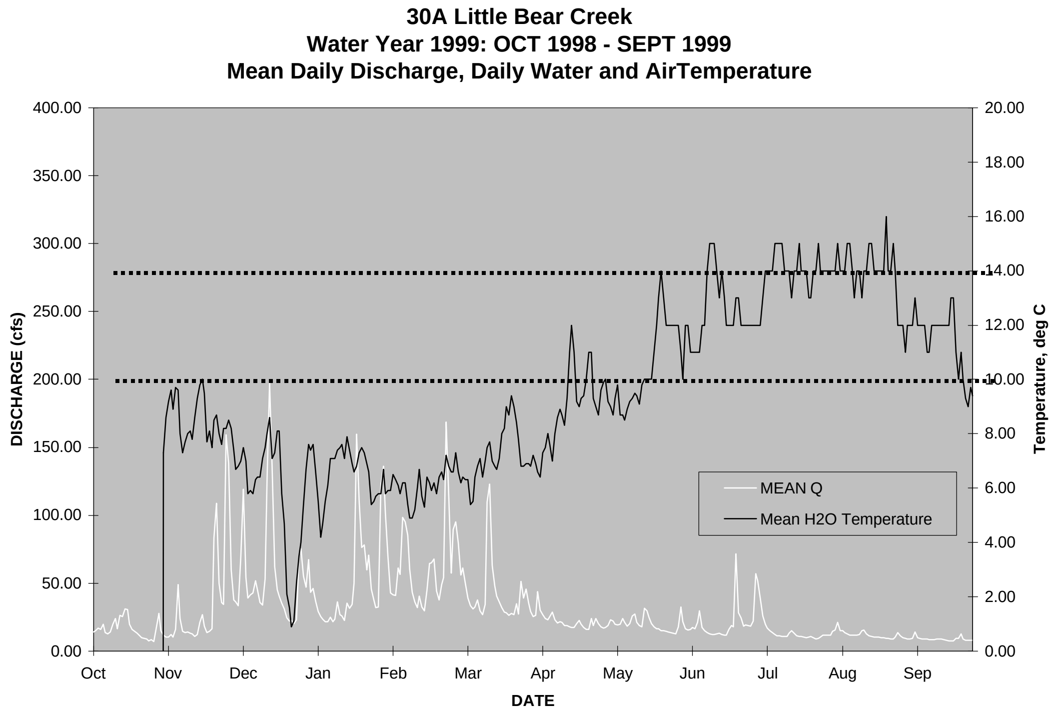
**Appendix H.** Steam Temperature and Hydrology Data
1999 Water Year.

## 56B Swamp Creek at 73rd AV NE
## Water Year 1999: OCT 1998 - SEPT 1999
## Mean Daily Discharge, Daily Water and AirTemperature




## NC10 North Creek
## Water Year 1999: OCT 1998-SEPT 1999
## Daily Discharge






Data for Swamp and Little Bear Creeks are from King County hydrologic monitoring sites. Data for North Creek is from Snohomish County.

**Appendix I.** LWD: Large Piece Frequencies

LWD Large frequencies in Swamp, North and Little Bear Creeks, using size and frequency standards estabished by Timber, Fish and Wildlife (1999), WDFW and Western Washington Treaty Tribes (1997) and NMFS (1996).

| **Swamp Creek** Stream segment | **Diam.** 0.5m (#/km) | **TFW*** (volume def.) #/km | **TFW*** (volume def.) #/BFW | **NMFS** (0.6 X 15m) #/ km | **WSP/WSA**** #/BFW |
|---|---|---|---|---|---|
| 1A | 0.00 | 0 | 0.00 | 0 | 0.00 |
| 1B | 0.00 | 0 | 0.00 | 0 | 0.00 |
| 2 | 0.00 | 0 | 0.00 | 0 | 0.00 |
| 3 | 28.3 | 0 | 0.00 | 0 | 0.00 |
| 4 | 28.2 | 2.00 | 0.02 | 0 | 0.01 |
| 5 | 22.5 | 0.71 | 0.01 | 0 | 0.00 |
| 6 | 33.3 | 5.81 | 0.04 | 0 | 0.04 |
| 7 | 22.4 | 2.38 | 0.01 | 0 | 0.01 |
| 8 | 36.2 | 2.90 | 0.02 | 0.72 | 0.01 |
| 9 | 12.5 | 3.58 | 0.02 | 0 | 0.00 |
| 10 | 32.1 | 10.03 | 0.09 | 3.34 | 0.03 |
| 11A | 20.0 | 0 | 0.00 | 0 | 0.00 |
| 11B | 0 | 0 | 0.00 | 0 | 0.00 |
| **'properly functioning conditions' standard:** | | | | **50/ km** | **0.3** |

| **North Creek** Stream segment | **Diam.** 0.5m (#/km) | **TFW*** (variable) #/km | **TFW*** (variable) #/BFW | **NMFS** (0.6 X 15m) #/km | **WSP/WSA**** (.55 X 10m) #/BFW |
|---|---|---|---|---|---|
| 1 | 0 | 0.00 | 0.00 | 0 | 0.00 |
| 2 | 0 | 0.00 | 0.00 | 0 | 0.00 |
| 3 | 7.4 | 0.93 | 0.01 | 0 | 0.00 |
| 4 | 5.2 | 1.72 | 0.02 | 0 | 0.01 |
| 5 | 32.5 | 5.69 | 0.04 | 0 | 0.03 |
| 6 | 18.2 | 3.82 | 0.03 | 0.55 | 0.01 |
| 8 | 46.3 | 4.88 | 0.04 | 1.22 | 0.03 |
| 9 | 5.9 | 0.00 | 0.00 | 0 | 0.00 |
| 10A | 15.1 | 4.31 | 0.02 | 0 | 0.01 |
| 10B | 23.6 | 2.48 | 0.01 | 0 | 0.00 |
| 11 | 76.0 | 4.07 | 0.03 | 1.36 | 0.01 |
| 12 | 40.7 | 3.26 | 0.02 | 0 | 0.00 |
| 13 | 64.2 | 14.81 | 0.12 | 4.94 | 0.06 |

**LWD, Large Piece frequencies, continued.**

| **Little Bear Creek** Stream segment | **Diam.** 0.5m (#/km) | **TFW*** (variable) #/km | **TFW*** (variable) #/BFW | **NMFS** (0.6 X 15m) #/km | **WSP/WSA**** (.55 X 10m) #/BFW |
|---|---|---|---|---|---|
| 1 | 14.2 | 0.00 | 0.00 | 0 | 0.00 |
| 2 | 12.7 | 0.88 | 0.00 | 0 | 0.00 |
| 3 | 12.8 | 3.29 | 0.02 | 0 | 0.02 |
| 4 | 8.4 | 0.00 | 0.00 | 0 | 0.00 |
| 5 | 6.3 | 0.00 | 0.00 | 0 | 0.00 |
| 6 | 6.0 | 0.00 | 0.00 | 0 | 0.00 |
| 7 | 13.2 | 1.34 | 0.01 | 0 | 0.01 |
| 9 | 20.5 | 2.56 | 0.01 | 0 | 0.01 |
| 10 | 17.8 | 0.00 | 0.00 | 0 | 0.00 |
| 11 | 22.7 | 6.20 | 0.04 | 0 | 0.00 |
| 12*** | 0.0 | | | | |
| 13 | 0.0 | 0.00 | 0.00 | 0 | 0.00 |
| 14 | 25.6 | 2.70 | 0.01 | 0 | 0.00 |

No reaches meet properly functioning conditions as defined by NMFS, or WSP/WSA.

# Appendix J. Instream Habitat Data

## Swamp Creek

| Segment description | Segment surveyed (%) | Mean BFW (m) | Mean BFD (m) | BFW/BFD Ratio | Total Pools | Pool Freq (km) | Pool Spacing (#/BFW) | Pool Area (m^2/km ) | Mean Residual Pool Depth (m) | % Pool Habitat | mean PQI | % Riffle Habitat | Mean RQI | % Glide Habitat | LWD Freq (#/km) | LWD Freq (#/BFW) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lower 1A | 40.0% | 9.77 | 0.64 | 15 | 1 | 2.77 | 36.89 | 1011 | 0.95 | 27% | 5.00 | 0% | NA | 73% | 24.97 | 0.24 |
| Lower 1B | 18.1% | 9.70 | 0.45 | 22 | 4 | 52.77 | 1.95 | 5545 | 0.72 | 69% | 4.00 | 9% | 2.00 | 22% | 131.93 | 1.28 |
| Kenmore 2 | 70.9% | 5.39 | 0.384 | 14 | 3 | 10.85 | 17.10 | 734 | 0.91 | 17% | 3.33 | 36% | 2.43 | 47% | 7.23 | 0.04 |
| Wallace 3 | 33.1% | 8.68 | 0.67 | 13 | 21 | 26.35 | 4.37 | 1976 | 0.63 | 55% | 3.95 | 33% | 3.47 | 12% | 75.28 | 0.65 |
| Forsgren 4 | 50.9% | 9.64 | 0.70 | 14 | 24 | 23.95 | 4.33 | 2184 | 0.64 | 40% | 3.63 | 38% | 2.33 | 22% | 38.92 | 0.38 |
| Locust 5 | 78.0% | 7.01 | 0.60 | 12 | 22 | 22.56 | 6.32 | 1975 | 0.59 | 31% | 3.64 | 48% | 2.86 | 21% | 41.02 | 0.29 |
| Scriber 6 | 6.5% | 6.98 | 0.45 | 16 | 11 | 31.98 | 4.48 | 986 | 0.43 | 28% | 3.00 | 46% | 2.58 | 26% | 34.88 | 0.24 |
| Cypress 7 | 63.2% | 8.00 | 0.70 | 11 | 35 | 44.30 | 2.82 | 1807 | 0.50 | 31% | 3.71 | 38% | 3.86 | 32% | 122.78 | 0.98 |
| Larch 8 | 61.1% | 7.46 | 0.82 | 9 | 37 | 26.79 | 5.00 | 1163 | 0.47 | 29% | 3.50 | 17% | 3.48 | 54% | 118.02 | 0.88 |
| Filbert 9 | 100.0% | 6.32 | 0.51 | 12 | 7 | 25.09 | 6.31 | 1120 | 0.50 | 30% | 3.57 | 6% | 5.00 | 64% | 57.35 | 0.36 |
| Butternut 10 | 49.4% | 9.42 | 0.53 | 18 | 11 | 18.39 | 5.77 | 1007 | 0.55 | 30% | 3.91 | 7% | 4.17 | 63% | 93.65 | 0.88 |
| Upper 11 A | 14.9% | 12.90 | 1.57 | 8 | 15 | 43.10 | 1.80 | 2431 | 0.43 | 54% | 3.13 | 0% | NA | 46% | 57.47 | 0.74 |
| Upper 11 B | | 12.37 | 0.74 | 17 | 16 | 34.04 | 2.38 | 1272 | 0.45 | 34% | 3.69 | 18% | 4.19 | 48% | 46.81 | 0.58 |

## North Creek

| Segment description | Segment assessed (%) | Mean BFW (m) | Mean BFD (m) | BFW/BFD Ratio | Pool Freq (km) | Pool Spacing (#BFW) | Mean Residual Pool Depth (m) | % Pool Habitat | mean PQI | % Riffle Habitat | RQI | % Glide Habitat | LWD Freq (#/km) | LWD Freq (#/BFW) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lower 1 | 100.0% | 6.8 | 0.84 | 8.1 | 0.00 | 0.0 | = | 0% | | 19% | 2.5 | 81% | 2.8 | 0.02 |
| UW 2 | 100.0% | 6.8 | 0.81 | 8.5 | 7.33 | 20.0 | 0.68 | 15% | 3.8 | 18% | 1.3 | 67% | 2.4 | 0.02 |
| Bothell 3 | 55.5% | 7.9 | 0.86 | 9.2 | 12.06 | 10.5 | 0.78 | 30% | 4.5 | 29% | 2.7 | 42% | 18.6 | 0.15 |
| Fitzgerald 4 | 70.7% | 9.7 | 0.61 | 15.9 | 15.52 | 6.7 | 0.82 | 41% | 4.4 | 27% | 2.5 | 32% | 38.8 | 0.37 |
| Canyon Park 5 | 42.6% | 7.1 | 0.82 | 8.7 | 11.38 | 12.4 | 0.86 | 23% | 4.5 | 12% | 2.7 | 64% | 55.3 | 0.39 |
| Thrashers 6 | 100.0% | 8.1 | 0.63 | 12.8 | 17.47 | 7.1 | 0.55 | 25% | 3.8 | 36% | 3.6 | 39% | 95.5 | 0.77 |
| Middle 8 | 41.4% | 7.3 | 0.73 | 10.1 | 19.51 | 7.0 | 0.70 | 27% | 3.7 | 23% | 3.7 | 50% | 161.0 | 1.18 |
| Nickel 9 | 33.1% | 7.3 | 0.83 | 8.8 | 13.75 | 9.9 | 0.69 | 28% | 3.7 | 11% | 3.0 | 61% | 47.2 | 0.35 |
| Penny Ck.10A | 77.3% | 4.0 | 0.58 | 6.9 | 34.48 | 7.2 | 0.57 | 27% | 3.8 | 44% | 3.4 | 29% | 66.8 | 0.27 |
| Penny Ck.10B | 57.5% | 4.8 | 0.37 | 12.9 | 22.36 | 9.4 | 0.51 | 24% | 3.6 | 15% | 3.4 | 62% | 132.9 | 0.63 |
| Mill Crk 11 | 70.2% | 7.0 | 0.64 | 11.0 | 29.85 | 4.8 | 0.60 | 45% | 4.0 | 28% | 3.9 | 27% | 169.6 | 1.19 |
| Wetland 12 | 28.0% | 6.3 | 0.38 | 16.8 | 32.57 | 4.9 | 0.65 | 46% | 4.0 | 16% | 4.0 | 38% | 232.9 | 1.47 |
| McCollum 13 | 44.5% | 7.8 | 0.95 | 8.2 | 27.16 | 4.7 | 0.44 | 46% | 3.7 | 17% | 2.9 | 37% | 256.8 | 2.00 |

## Little Bear Creek

| Segment description | Segment assessed (%) | Mean BFW (m) | Mean BFD (m) | BFW/BFD Ratio | Pool Freq (km) | Pool Spacing (#BFW) | Mean Residual Pool Depth (m) | % Pool Habitat | mean PQI | % Riffle Habitat | RQI | % Glide Habitat | LWD Freq (#/km) | LWD Freq (#/BFW) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mouth 1 | 100% | 5.5 | 0.95 | 5.8 | 9.43 | 19.2 | 0.60 | 14% | 3.8 | 43% | 3 | 43% | 21.2 | 0.12 |
| Woodinville 2 | 59% | 5.2 | 0.98 | 5.3 | 17.51 | 11.1 | 0.63 | 25% | 3.9 | 37% | 3.2 | 39% | 71.8 | 0.37 |
| High School 3 | 100% | 7.2 | 0.90 | 8.0 | 21.91 | 6.4 | 0.79 | 50% | 4.6 | 20% | 3.6 | 30% | 119 | 0.86 |
| Rowlands 4 | 100% | 5.9 | 0.80 | 7.4 | 26.47 | 6.4 | 0.56 | 49% | 3.7 | 10% | 2.5 | 42% | 64.7 | 0.38 |
| Wellington 5 | 72% | 7.1 | 0.84 | 8.5 | 28.45 | 5.0 | 0.67 | 47% | 4.3 | 4% | 3.8 | 49% | 88.5 | 0.63 |
| Lower Hwy 6 | 100% | 4.9 | 0.61 | 8.0 | 14.99 | 13.7 | 0.80 | 26% | 4.4 | 18% | 2.3 | 56% | 45 | 0.22 |
| Upper Hwy 7 | 99% | 6.6 | 0.56 | 11.9 | 20.17 | 7.5 | 0.65 | 27% | 4.3 | 25% | 3.9 | 48% | 101 | 0.67 |
| Maltby 9 | 78% | 5.6 | 0.67 | 8.3 | 16.20 | 11.0 | 0.67 | 30% | 4.2 | 18% | 2.6 | 52% | 86.1 | 0.48 |
| Great Dane 10 | 8% | 3.3 | 0.50 | 6.7 | 5.08 | 58.9 | 0.34 | 2% | 3.0 | 9% | 4.0 | 89% | 48.2 | 0.16 |
| Middle 11 | 83% | 6.6 | 0.68 | 9.7 | 12.40 | 12.2 | 0.58 | 10% | 3.8 | 39% | 3.3 | 51% | 82.6 | 0.55 |
| Jewell 12* | 0% | | | | | | | | | | | | | |
| Horse Farms 13 | 28% | 6.0 | 0.64 | 9.5 | 20.00 | 8.3 | 0.47 | 19% | 4.0 | 7% | 2.0 | 73% | 123 | 0.74 |
| Beaver14 | 49% | 3.7 | 0.56 | 6.7 | 2.70 | 100.0 | 0.42 | 2% | 3.0 | 1% | 3.5 | 97% | 236 | 0.88 |

*A visual assessment of the Jewell segment indicated that the lower half was similar to segment 11 and the upper half was similar to segment 13.

# **Appendix K**. Streambank Stability Ratings

**Swamp Creek**

| Segment | Armored | Full Scour | Low Scour | Stable |
|---|---|---|---|---|
| 1A Lower | 0% | 26% | 74% | 0% |
| 1B Lower | 27% | 0% | 73% | 0% |
| 2 Kenmore | 88% | 0% | 12% | 0% |
| 3 Wallace | 5% | 11% | 10% | 74% |
| 4 Forsgren | 5% | 27% | 59% | 9% |
| 5 Locust | 4% | 24% | 72% | 0% |
| 6 Scriber | 6% | 39% | 36% | 19% |
| 7 Cypress | 0% | 4% | 14% | 82% |
| 8 Larch | 19% | 0% | 22% | 59% |
| 9 Filbert | 0% | 0% | 60% | 40% |
| 10 Butternut | 4% | 0% | 79% | 17% |
| 11A Upper | 0% | 6% | 20% | 74% |
| 11B Upper | 0% | 0% | 0% | 100% |

**North Creek**

| Segment | Armored | Full Scour | Low Scour | Stable |
|---|---|---|---|---|
| 1 Lower | 0% | 0% | 0% | 100% |
| 2 UW | 2% | 0% | 0% | 98% |
| 3 Bothell | 0% | 0% | 0% | 100% |
| 4 Fitzgerald | 32% | 5% | 33% | 30% |
| 5 Canyon Park | 15% | 0% | 22% | 63% |
| 6 Thrashers | 9% | 0% | 57% | 34% |
| 7 Silver/ Tambark Tribs* | 33% | 29% | 27% | 11% |
| 8 Middle | 8% | 0% | 65% | 27% |
| 9 Nickel | 0% | 28% | 38% | 34% |
| 10A Penny Creek Tribs | 0% | 3% | 77% | 20% |
| 10B Penny Creek Tribs | 18% | 16% | 66% | 0% |
| 11 Mill Creek | 3% | 20% | 77% | 0% |
| 12 Wetland | 15% | 0% | 43% | 42% |
| 13 McCollum | 0% | 0% | 50% | 50% |

* Data from Chris May 1998

## Streambank Stability Ratings (continued)

***Little Bear Creek***

| Segment | Armored | Full Scour | Low Scour | Stable |
|---|---|---|---|---|
| **1 Lower** | 32% | 32% | 33% | 0% |
| **2 Woodinville** | 9% | 18% | 46% | 27% |
| **3 High School** | 6% | 16% | 26% | 52% |
| **4 Rowlands** | 0% | 25% | 75% | 0% |
| **5 Wellington** | 0% | 15% | 23% | 62% |
| **6 Lower Hwy 9** | 0% | 58% | 23% | 42% |
| **7 Upper Hwy 9** | 48% | 0% | 21% | 31% |
| **9 Maltby** | 7% | 0% | 33% | 60% |
| **10 Great Dane** | 0% | 0% | 0% | 100% |
| **11 Middle** | 0% | 0% | 0% | 100% |
| **12 Jewell*** | 0% | 0% | 0% | 100% |
| **13 Horse Farms** | 0% | 0% | 0% | 100% |
| **14 Beaver** | 0% | 0% | 0% | 100% |

*Data from Chris May 1998

## **Appendix L.** PQI and RQI Scores

## Swamp Creek

| Segment description | Number of Pools | Percent ≥ 1.0 meter depth | Mean PQI | Number of Riffles | Mean RQI |
|---|---|---|---|---|---|
| Lower 1A | 1 | 100 | 5.0 | 0 | NA |
| Lower 1B | 4 | 25 | 4.0 | 1 | 2.0 |
| Kenmore 2 | 3 | 67 | 3.3 | 7 | 2.4 |
| Wallace 3 | 21 | 24 | 4.0 | 17 | 3.5 |
| Forsgren 4 | 24 | 17 | 3.6 | 24 | 2.3 |
| Locust 5 | 22 | 18 | 3.6 | 28 | 2.9 |
| Scriber 6 | 11 | 0 | 3.0 | 12 | 2.6 |
| Cypress 7 | 35 | 6 | 3.7 | 35 | 3.9 |
| Larch 8 | 37 | 0 | 3.5 | 31 | 3.5 |
| Filbert 9 | 7 | 0 | 3.6 | 1 | 5.0 |
| Butternut 10 | 11 | 9 | 3.9 | 6 | 4.2 |
| Upper 11 A | 6 | 7 | 3.5 | 0 | NA |
| Upper 11 B | 25 | 0 | 3.4 | 14 | 4.2 |

## North Creek

| Segment description | Number of Pools | Percent ≥ 1.0 meter depth | Mean PQI | Number of Riffles | Mean RQI |
|---|---|---|---|---|---|
| Lower 1 | 0 | 0% | NA | 2 | 2.5 |
| UW 2 | 6 | 33% | 3.8 | 8 | 1.3 |
| Bothell 3 | 13 | 54% | 4.5 | 16 | 2.7 |
| Fitzgerald 4 | 18 | 50% | 4.4 | 19 | 2.5 |
| Canyon Park 5 | 14 | 64% | 4.5 | 14 | 2.7 |
| Thrashers 6 | 28 | 3% | 3.8 | 29 | 3.6 |
| Silver/Tambark Tribs. 7 | No Data | = | 3.0 | No Data | 3.5 |
| Middle 8 | 16 | 19% | 3.7 | 17 | 3.7 |
| Nickel 9 | 7 | 29% | 3.7 | 5 | 3.0 |
| Penny Ck. 10A | 16 | 6% | 3.8 | 16 | 3.4 |
| Penny Ck. 10B | 18 | 11% | 3.6 | 14 | 3.4 |
| Mill Ck 11 | 22 | 9% | 4.0 | 18 | 3.9 |
| Wetland 12 | 20 | 10% | 4.0 | 10 | 4.0 |
| McCollum 13 | 11 | 18% | 3.7 | 8 | 2.9 |

**PQI and RQI Scores (continued)**

## Little Bear Creek

| Segment description | Number of Pools | Percent ≥ 1.0 meter depth | Mean PQI | Number of Riffles | Mean RQI |
|---|---|---|---|---|---|
| Mouth 1 | 4 | 25% | 3.8 | 8 | 3.0 |
| Woodinville 2 | 20 | 10% | 3.9 | 17 | 3.2 |
| High School 3 | 20 | 35% | 4.6 | 16 | 3.6 |
| Rowlands 4 | 9 | 0% | 3.7 | 5 | 2.5 |
| Wellington 5 | 27 | 11% | 4.3 | 4 | 3.8 |
| Lower Hwy 6 | 10 | 40% | 4.4 | 5 | 2.3 |
| Upper Hwy 7 | 30 | 10% | 4.3 | 27 | 3.9 |
| Maltby 9 | 19 | 21% | 4.2 | 16 | 2.6 |
| Great Dane 10 | 2 | 0% | 3.0 | 3 | 4.0 |
| Middle 11 | 6 | 0% | 3.8 | 11 | 3.3 |
| Jewell 12 | No Data | | No Data | No Data | No Data |
| Horse Farms 13 | 6 | 17% | 4.0 | 2 | 2.0 |
| Beaver 14 | 1 | 0% | 3.0 | 2 | 3.5 |

**Appendix M.** HQI Scores

## Swamp Creek

| Segment description | Pool Frequency | % Pool Area | Weighted PQI | % Riffle Area | Weighted RQI | LWD Frequency | LWD Vol/km | Weighted WQI | Total HQI Score | Habitat Quality Rating |
|---|---|---|---|---|---|---|---|---|---|---|
| Lower 1A | 1 | 4 | 1 | 1 | 1 | 1 | 1 | 1 | ***11*** | Low |
| Lower 1B | 7 | 7 | 5 | 1 | 3 | 4 | 1 | 1 | ***29*** | Med. Low |
| Kenmore 2 | 1 | 4 | 3 | 4 | 5 | 1 | 1 | 1 | ***20*** | Low |
| Wallace 3 | 4 | 7 | 3 | 4 | 5 | 4 | 4 | 3 | ***34*** | Med. High |
| Forsgren 4 | 4 | 7 | 3 | 4 | 5 | 1 | 1 | 1 | ***26*** | Med. Low |
| Locust 5 | 4 | 4 | 3 | 7 | 5 | 1 | 1 | 1 | ***26*** | Med. Low |
| Scriber 6 | 4 | 4 | 3 | 7 | 5 | 1 | 4 | 1 | ***29*** | Med. Low |
| Cypress 7 | 7 | 4 | 5 | 4 | 5 | 4 | 4 | 3 | ***36*** | Med. High |
| Larch 8 | 4 | 4 | 3 | 4 | 5 | 4 | 4 | 5 | ***33*** | Med. High |
| Filbert 9 | 4 | 4 | 3 | 1 | 3 | 4 | 1 | 1 | ***21*** | Low |
| Butternut 10 | 1 | 4 | 3 | 1 | 3 | 4 | 4 | 3 | ***23*** | Low |
| Upper 11 A | 7 | 7 | 3 | 1 | 1 | 4 | 1 | 1 | ***25*** | Med. Low |
| Upper 11 B | 7 | 4 | 3 | 4 | 5 | 1 | 1 | 1 | ***23*** | Low |
| **Metric Values** | ***1-4-7*** | ***1-4-7*** | ***1-3-5*** | ***1-4-7*** | ***1-3-5*** | ***1-4-7*** | ***1-4-7*** | ***1-3-5*** | ***9-50*** | |

**HQI Scores (Continued)**

## North Creek

| Segment description | Pool Frequency | % Pool Area | Weighted PQI | % Riffle Area | Weighted RQI | LWD Frequency | LWD Vol/km | Weighted WQI | Total HQI Score | Habitat Quality Rating |
|---|---|---|---|---|---|---|---|---|---|---|
| **Lower 1** | 1 | 1 | 1 | 4 | 5 | 1 | 1 | 1 | ***15*** | Low |
| **UW 2** | 1 | 4 | 1 | 4 | 3 | 1 | 1 | 1 | ***16*** | Low |
| **Bothell 3** | 1 | 4 | 3 | 4 | 5 | 1 | 1 | 1 | ***20*** | Low |
| **Fitzgerald 4** | 1 | 7 | 3 | 4 | 5 | 1 | 1 | 1 | ***23*** | Low |
| **Canyon Park 5** | 1 | 4 | 3 | 1 | 5 | 4 | 4 | 3 | ***25*** | Med. Low |
| **Thrashers 6** | 1 | 4 | 3 | 4 | 5 | 4 | 4 | 3 | ***28*** | Med. Low |
| **Silv/Tam. Tribs. 7*** | 7 | 4 | 3 | 4 | 1 | 1 | 4 | 1 | ***25*** | Med. Low |
| **Middle 8** | 1 | 4 | 3 | 4 | 5 | 4 | 4 | 5 | ***30*** | Med. Low |
| **Nickel 9** | 1 | 4 | 3 | 1 | 3 | 1 | 1 | 1 | ***15*** | Low |
| **Penny Ck. 10A** | 7 | 4 | 3 | 4 | 5 | 4 | 4 | 3 | ***34*** | Med. High |
| **Penny Ck. 10B** | 4 | 4 | 3 | 4 | 3 | 4 | 4 | 3 | ***29*** | Med. Low |
| **Mill Ck 11** | 4 | 7 | 3 | 4 | 5 | 7 | 7 | 5 | ***42*** | High |
| **Wetland 12** | 4 | 7 | 3 | 4 | 5 | 7 | 4 | 5 | ***39*** | High |
| **McCollum 13** | 4 | 7 | 3 | 4 | 3 | 7 | 4 | 5 | ***37*** | High |
| **Metric Values** | ***1-4-7*** | ***1-4-7*** | ***1-3-5*** | ***1-4-7*** | ***1-3-5*** | ***1-4-7*** | ***1-4-7*** | ***1-3-5*** | ***9-50*** | |

*Data from Chris May 1998

HQI Scores (Continued)

## Little Bear Creek

| Segment description | Pool Frequency | % Pool Area | Weighted PQI | % Riffle Area | Weighted RQI | LWD Frequency | LWD Vol./km | Weighted WQI | Total HQI Score | Habitat Quality Rating |
|---|---|---|---|---|---|---|---|---|---|---|
| **Mouth 1** | 1 | 4 | 1 | 4 | 5 | 1 | 1 | 1 | ***18*** | Low |
| **Woodinville 2** | 4 | 4 | 3 | 4 | 5 | 4 | 4 | 3 | ***31*** | Med. Low |
| **High School 3** | 4 | 7 | 3 | 4 | 5 | 4 | 4 | 3 | ***34*** | Med. High |
| **Rowlands 4** | 4 | 7 | 3 | 1 | 3 | 4 | 4 | 1 | ***27*** | Med. Low |
| **Wellington 5** | 4 | 7 | 3 | 1 | 3 | 4 | 1 | 3 | ***26*** | Med. Low |
| **Lower Highway 6** | 1 | 4 | 3 | 4 | 3 | 1 | 1 | 1 | ***18*** | Low |
| **Upper highway 7** | 4 | 4 | 3 | 4 | 5 | 4 | 4 | 3 | ***31*** | Med. Low |
| **Maltby 9** | 1 | 4 | 3 | 4 | 5 | 4 | 4 | 3 | ***28*** | Med. Low |
| **Great Dane 10** | 1 | 1 | 1 | 1 | 3 | 1 | 1 | 3 | ***10*** | Low* |
| **Middle 11** | 1 | 1 | 3 | 4 | 5 | 4 | 4 | 3 | ***25*** | Med. Low |
| **Jewell 12** | | | | | | | | | ***22*** | Low** |
| **Horse Farms 13** | 1 | 4 | 3 | 1 | 3 | 4 | 1 | 3 | ***18*** | Low |
| **Beaver 14** | 1 | 1 | 1 | 1 | 1 | 7 | 4 | 3 | ***19*** | Low |
| **Metric Values** | ***1-4-7*** | ***1-4-7*** | ***1-3-5*** | ***1-4-7*** | ***1-3-5*** | ***1-4-7*** | ***1-4-7*** | ***1-3-5*** | ***9-50*** | |

*Tributary

**Representative Reach

# Appendix N. Photographs