



# Current Conditions Assessment Report

November 2016

***Appendix A*** of the  
*Little Bear Creek Basin Plan,  
A Final Watershed-Scale Stormwater Plan  
Prepared in Fulfillment of Special Condition  
S5.C.5.c.vi of the Phase I Municipal  
Stormwater Permit*

Prepared for:  
  
**Snohomish County**

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# **LITTLE BEAR CREEK BASIN PLANNING**

## **CURRENT CONDITIONS ASSESSMENT REPORT**

**Snohomish County**

November 2016

## CREDITS AND ACKNOWLEDGEMENTS

The Little Bear Creek Current Conditions Assessment was prepared by a team of Snohomish County and consultant staff.

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## EXECUTIVE SUMMARY

The Little Bear Creek system, in south Snohomish County (County), is an important resource for fish, recreation, and aesthetic enjoyment. Compared to other nearby Snohomish County watersheds undergoing urbanization, Little Bear Creek and its tributaries have enjoyed relatively good water quality and stream habitat conditions. However, land development over time has affected water quality and flow patterns in the watershed, and conditions may worsen with potential future development. Portions of the creek system are currently water quality impaired for bacteria, temperature, dissolved oxygen, mercury (Howell Creek tributary only), and bioassessment.

This Current Conditions Assessment report documents existing hydrologic, biologic, and water quality conditions within the Little Bear Creek study area, fulfilling requirement S5.C.5.c.iv(1) of the County's National Pollutant Discharge Elimination System (NPDES) Phase I Permit. Seventeen percent of the study area is within currently designated urban growth areas (UGAs).

Like other Puget Lowland streams, the geology of the Little Bear Creek basin strongly influences the hydrologic and geomorphic response of the channel and watershed. These are further affected by urban development, which began in earnest in the 1970s in the Little Bear Creek study area. Existing development is concentrated in UGAs: residential in the north end of the basin and primarily commercial in the southeast along the SR-9/SR-522 corridor. Development through the middle part of the basin is predominantly rural and low density residential. Several sections of largely intact forested buffer and wetlands have been preserved along Little Bear Creek and the Trout Creek and Cutthroat Creek tributaries.

There are more than 50 miles of mapped stream channels in the study area, with approximately 17.5 miles comprising mainstem Little Bear Creek and its major tributaries—Great Dane Creek, Cutthroat Creek, Trout Creek, and Rowlands Creek. Smaller streams and constructed drainage systems—predominantly ditch and culvert—convey stormwater runoff from the land surface to the main stream network. Stormwater treatment facilities provide varying levels of flow control and water quality treatment to runoff from the more developed areas, including residential subdivisions, commercial and industrial properties, and the road network. Three state highways cross the Little Bear Creek study area—SR9, SR-522, and SR-524 (Maltby Road).

Mean annual streamflow in Little Bear Creek increases from 4.0 cfs (1.1 cfs per square mile) in the northern third of the basin to approximately 20 cfs (1.5 cfs per square mile) near the county line. Relatively lower runoff in the upper basin is most likely associated with a regional groundwater divide (Golder, 2005) that diverts groundwater from a large portion of upper Little Bear, Trout, and Great Dane Creeks out of the basin to the Snohomish River. Much of the groundwater that remains within the Little Bear Creek system emerges into the stream network at springs that generally coincide with the transition along the streams from upland till geology to outwash ravines and valleys. Stream channels upstream of these areas can be ephemeral, drying out in the summer. Geomorphic observations suggest

that these transitional areas are prone to erosion and likely sensitive to changes in flows, which is consistent with conditions observed in urbanizing streams throughout the region (e.g. Booth, 1990).

State water quality standards, as given in Chapter 173-201A WAC, vary depending on the designated uses and criteria for a receiving water. Little Bear Creek has the following designated beneficial uses:

- Aquatic Life Uses: Core Summer Salmonid Habitat (in addition to spawning, rearing, and migration outside the summer season)
- Recreation Uses: Extraordinary Primary Contact
- Water Supply Uses: Domestic water, industrial water, agricultural water, and stock water
- Miscellaneous Uses: Wildlife habitat, harvesting, commerce/navigation, boating, and aesthetics

The Little Bear Creek basin planning study will target temperature, fecal coliform bacteria, dissolved copper, and dissolved zinc, per Section S5.C.5.c. of the Permit. Water quality monitoring data collected at multiple sites on Little Bear Creek indicate that standards have been exceeded for temperature and fecal coliform bacteria, but not for the dissolved metals. Portions of Little Bear Creek and its tributaries are included on the Washington State 2012 303(d) list of impaired water bodies for temperature, dissolved oxygen, and mercury (Howell Creek tributary only), as well as bioassessment.

In recent decades, a considerable body of research has shown that the overall quality of stream habitat to support fish and other aquatic species is well represented by the Benthic Index of Biotic Integrity (B-IBI), which is calculated from measurements of the species richness and abundance of benthic macroinvertebrates. In addition to meeting water quality standards, the Permit-required watershed planning also focuses on improving biotic integrity of streams, primarily as indicated by B-IBI. B-IBI has been investigated in Little Bear Creek since 1994, and data have been collected and evaluated at 30 different sites in the study area since 2002. Seven long-term monitoring sites have been investigated on a nearly annual basis, providing data to analyze temporal and spatial differences in B-IBI.

Overall, biological condition in Little Bear Creek (as characterized by B-IBI) has been generally fair to good, with no apparent temporal trend (since data have been collected). Inter-annual variability at a site can be substantial and tends to be more pronounced than spatial differences between sites. The long-term data show some suggestion of a spatial trend with the best conditions found in unincorporated Snohomish County. B-IBI scores on the major tributaries tend to be higher than on the Little Bear Creek mainstem.

Compared to other urban streams in the region, large portions of Little Bear Creek are in relatively good condition, but the stream has been affected by development, and many reaches do not meet current water quality standards. Reaches with intact riparian corridors that are farther removed from more intense development have generally better water quality and biological function (as indicated by B-IBI scores).

## TABLE OF CONTENTS

1	INTRODUCTION .....	1
1.1	Purpose.....	1
1.2	Basin Overview .....	1
1.3	Report Organization .....	2
2	BASIN CHARACTERIZATION .....	2
2.1	General Description.....	2
2.2	Soils and Geology.....	8
2.3	Land Use and Land Cover .....	14
2.4	Drainage Network.....	20
3	HYDROLOGIC/GEOMORPHIC CONDITIONS .....	32
3.1	Introduction.....	32
3.2	Precipitation .....	32
3.3	Streamflow .....	36
3.4	Wetlands.....	37
3.5	Groundwater .....	37
3.6	Geomorphology.....	39
3.7	Known Problems.....	59
4	WATER QUALITY CONDITIONS .....	62
4.1	Introduction.....	62
4.2	Water Quality Monitoring Data.....	63
4.3	Temperature.....	65
4.4	Metals and Hardness .....	68
4.5	Fecal Coliform Bacteria.....	72
4.6	Known Problems.....	74
5	BIOLOGIC CONDITIONS .....	77
5.1	Introduction.....	77
5.2	Aquatic Community .....	77
5.3	Habitat .....	86
5.4	Known Problems.....	91
6	REFERENCES .....	93

APPENDIX A Little Bear Creek GIS Data Inventory

APPENDIX B Streamwalk Data Summary Tables

APPENDIX C Habitat Survey Stream Metrics

## LIST OF TABLES

Table 1. Major Drainage Basins in the Little Bear Creek Watershed .....	4
Table 2. Soil Type Distribution .....	12
Table 3. Current Zoning in Little Bear Creek Study Area .....	15
Table 4. Modeling Land Use Distribution.....	16
Table 5. Existing Land Cover by Subbasin .....	18
Table 6. Stormwater Facility Types by Jurisdiction.....	22
Table 7. Summary of Stormwater Facilities in Study Area.....	25
Table 8. Distribution of Reviewed Stormwater Facilities by Type and Function .....	29
Table 9. Summary of Facility by Design Year and Facility Ownership.....	30
Table 10. Summary of Observed Maintenance Conditions .....	32
Table 11. Precipitation Stations Near Little Bear Creek.....	33
Table 12. Little Bear Creek Streamflow Gages.....	36
Table 13. Comparison of Selected Streamflow Statistics .....	36
Table 14. Little Bear Creek Drainage Investigation Summary .....	59
Table 15. Flooding Problems Identified in 2006 DNR Update .....	60
Table 16. Water Quality Standards for Permit-Mandated Constituents .....	63
Table 17. Ambient Water Quality Monitoring Locations.....	65
Table 18. Water Temperature Criteria Exceedances .....	66
Table 19. Hardness Ambient Monitoring Statistics .....	69
Table 20. Metals Standards Based on Observed Hardness .....	69
Table 21. Dissolved Metals Ambient Monitoring Statistics .....	70
Table 22. Total Recoverable Metals Ambient Data Statistics .....	71
Table 23. Fecal Coliform Bacteria Ambient Monitoring Statistics .....	73
Table 24. Comparison of Ambient Fecal Coliform Data to Standard.....	74
Table 25. Summary of Little Bear Creek Water Quality Criteria Exceedances .....	75
Table 26. Species Occurrence in Little Bear Creek.....	77
Table 27. Little Bear Creek B-IBI sampling sites and scores.....	79
Table 28. B-IBI Scores and Biological Condition Category for Long-Term Little Bear Creek Sites .....	81
Table 29. Variability of B-IBI scores by site and by year. ....	82
Table 30. Correlation coefficients among sites based on B-IBI score.....	82
Table 31. Functional Condition for Salmonid Habitat Indicators.....	87
Table 32. Stream Metric Site Contributing Characteristics.....	89
Table 33. Fine Sediment and Pebble Count Characteristics .....	90
Table 34. Physical Habitat Metrics.....	91



## LIST OF FIGURES

Figure 1. Little Bear Creek Study Area and Study Area Basin .....	3
Figure 2. Little Bear Creek Geology.....	10
Figure 3. NRCS Soil Survey Units .....	13
Figure 4. Existing Land Use (2013) for Hydrologic Modeling.....	17
Figure 5. Existing (2013) Land Cover in Little Bear Creek .....	19
Figure 6. Existing Stormwater Facilities .....	21
Figure 7. Hydrometric Monitoring Stations in Little Bear Creek Vicinity.....	34
Figure 8. Daily Precipitation Comparison of Little Bear Area Gages to Silver Lake .....	35
Figure 9. Cumulative Precipitation (2008-2015) for Little Bear Area Precipitation Gages.....	35
Figure 10. Wetland and Groundwater Features .....	38
Figure 11. Locations of the Little Bear Creek stream network surveyed following the streamwalk protocol.....	41
Figure 12. Photos illustrating the important role of plant roots in stabilizing the soil surface near channel-head locations. ....	43
Figure 13. Observations of channel presence/absence and logistic regression predicting probability of channel presence. ....	44
Figure 14. Stacked plots summarizing observed geomorphic conditions along Little Bear Creek. ....	46
Figure 15. Stacked plots summarizing observed geomorphic conditions along Trout Creek.....	47
Figure 16. Stacked plots summarizing observed geomorphic condition along Great Dane Creek.....	50
Figure 17. Stacked plots summarizing observed geomorphic condition along Cutthroat Creek. ....	52
Figure 18. Stacked plots summarizing observed geomorphic condition along Rowlands Creek. ....	53
Figure 19. Observed and inferred geomorphic process domains.....	58
Figure 20. Observed bank erosion and near-channel sediment sources.....	61
Figure 21. Water Quality Monitoring Stations.....	64
Figure 22. Summer 7DADMax Temperature, Monitoring Site LBLU .....	66
Figure 23. Summer 7DADMax Temperature, Monitoring Site DANE .....	67
Figure 24. Summer 7DADMax Temperature, Monitoring Site CUTT .....	67
Figure 25. Summer 7DADMax Temperature, Monitoring Site LBLD.....	67
Figure 26. Stream temperature by river mile for mainstem and tributary locations.....	68
Figure 27. Dissolved Copper and Dissolved Zinc.....	70
Figure 28. Total Recoverable Copper, Ambient Monitoring Sites .....	71
Figure 29. Total Recoverable Zinc, Ambient Monitoring Sites .....	72
Figure 30. Fecal Coliform Bacteria, Ambient Monitoring Sites.....	73
Figure 31. Potential Bacteria Sources .....	76
Figure 32. Little Bear Creek B-IBI sampling sites.....	80
Figure 33. Average B-IBI score by year for all sites.....	83
Figure 34. Year-to-year sum of B-IBI point change for seven sites.....	84
Figure 35. Time series of site B-IBI scores.....	85
Figure 36. Longitudinal plot of all B-IBI scores (2002-2014) by river mile.....	86

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# 1 INTRODUCTION

## 1.1 Purpose

The Little Bear Creek system, in south Snohomish County (County), is an important resource for fish, recreation, and aesthetic enjoyment. Compared to other nearby Snohomish County watersheds undergoing urbanization, Little Bear has enjoyed relatively good water quality and stream habitat conditions. However, land development over time has affected water quality and flow patterns in the watershed, and conditions may worsen with potential future development. Portions of the creek system are currently water quality impaired for bacteria, temperature, dissolved oxygen, and mercury (Howell Creek tributary only).

The Washington Department of Ecology (DOE) approved the County's selection of a subset of Little Bear Creek to meet the watershed planning requirement under Special Condition S5.C.5.c of the County's National Pollutant Discharge Elimination System (NPDES) Phase I Permit (Permit). The project site and study area for the S5.C.5.c planning effort is the portion of Little Bear Creek in unincorporated Snohomish County. The objective of the watershed planning requirement is to:

*Identify a stormwater management strategy or strategies that would result in hydrologic and water quality conditions that fully support "existing uses," and "designated uses," as those terms are defined in WAC 173-201A-020, throughout the stream system. (NPDES Phase I permit, Section S5.C.5.c.)*

This Current Conditions Assessment report documents existing hydrologic, biologic, and water quality conditions, fulfilling Permit requirement S5.C.5.c.iv(1). This report is based on existing available data at the onset of the watershed planning project, supplemented by new data developed through the project to fill identified needs and data gaps.

## 1.2 Basin Overview

Little Bear Creek drains more than 15 square miles in southern Snohomish County and northern King County and is one of four major tributaries to the Sammamish River. The Little Bear Creek Basin Plan, which will be the object of this study, applies only to the upper 90 percent (about 8,550 acres or 13.4 square miles) of the basin within unincorporated Snohomish County, also termed "Little Bear Creek study area" or "study area" in this report. The study area is located east of Bothell and Mill Creek and north of Woodinville. The "study area basin" for the Little Bear Creek Basin Plan includes all of the basin area within Snohomish County and additional areas tributary to Little Bear Creek at the county line in the City of Woodinville located within King County (about 156 acres) and the in City of Bothell located within Snohomish County (about 2.4 acres). Nearly seventeen percent of the study area (2.2 square miles) lies within currently designated urban growth areas (UGAs). Including the tributary areas within King County, about 18 percent of the study area basin (2.4 square miles) is within UGAs.

As indicated by the 2012 303(d) list approved by EPA on July 22, 2016, Little Bear Creek is listed for temperature, dissolved oxygen, mercury (Howell Creek tributary only), and bioassessment (through application of narrative criteria). It is also covered under a TMDL (total maximum daily load, or water quality clean-up plan) for bacteria (measured by fecal coliform). The Little Bear Creek system supports anadromous runs of Chinook, sockeye, kokanee, and coho salmon, coastal cutthroat trout (Kerwin, 2001), and several resident fish species.

Unless otherwise noted, references to the Little Bear Creek study area in this report apply only to the study area within unincorporated Snohomish County. References to the Little Bear Creek study area basin apply to the Little Bear Creek study area as described and to those areas tributary to Little Bear Creek at the county line, as noted above. The term “basin” may be used interchangeably with “watershed,” in describing general physical conditions of the area drained by Little Bear Creek, or a subarea, such as in connection with geography, geology, etc.

### **1.3 Report Organization**

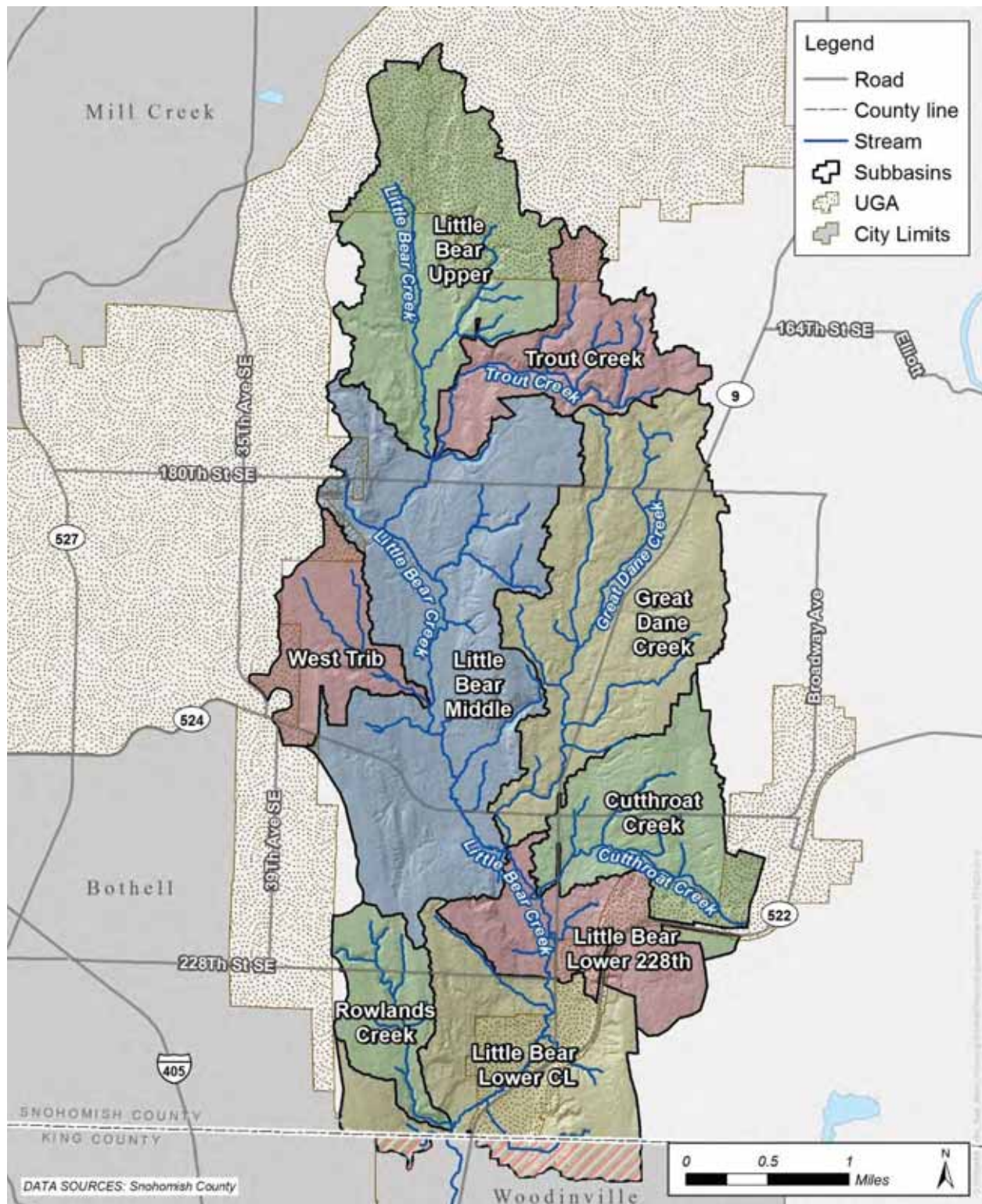
Chapter 2 of this report provides a description of the basin setting and characteristics related to stormwater and stream conditions. The next three chapters focus on assessment of current conditions in the Little Bear study area basin related to the three areas called out in the Permit: Hydrologic and Geomorphic Conditions (Chapter 3), Water Quality Conditions (Chapter 4), and Biologic Conditions (Chapter 5, which includes aquatic community and habitat).

The data presented and discussed in this report are factual data that existed at the start of the Little Bear Creek Basin Planning project, or that was collected for the project, for the purposes of characterizing current watershed conditions. Additional data collected, generated, and developed by the project for modeling existing, forested, and future water quality and biologic conditions in Little Bear Creek will be presented in a separate modeling report or reports.

## **2 BASIN CHARACTERIZATION**

### **2.1 General Description**

The Little Bear Creek system to the Snohomish-King County line (Figure 1) drains 13.6 square miles (8,710 acres) of mixed rural, residential, and commercial land use. There are over 50 miles of mapped stream channels in the study area, with approximately 17.5 miles comprising mainstem Little Bear Creek and its major tributaries—Great Dane Creek, Cutthroat Creek, Trout Creek, and Rowlands Creek. Most of the major streams traverse rural or lightly developed residential areas. Long stretches of the mainstem of Little Bear Creek between 156<sup>th</sup> Street SE and Great Dane Creek are characterized by wetland areas influenced by beaver activity. Downstream of the Brightwater Wastewater Treatment Plant (Brightwater) and 228<sup>th</sup> Street SE, the character of the stream corridor changes. The lower 1.5 miles of Little Bear Creek in Snohomish County parallel SR-9 and SR-522 in a predominantly commercial/industrial area.



**Figure 1. Little Bear Creek Study Area and Study Area Basin. Diagonal hatched areas within city limits are included in study area basin but not study area.**



### 2.1.1 Major Subbasins/Drainage Systems

From its headwaters near 156<sup>th</sup> Street SE, the mainstem of Little Bear Creek flows predominantly north to south to the King County line at 244<sup>th</sup> Street SE. Five major (named) tributaries contribute to Little Bear Creek, adding drainage area from east and west of the Little Bear Creek valley. From upstream to downstream, those are Trout Creek (left bank [east]) tributary at river mile [RM] 7.9), West Trib (right bank tributary at RM 5.8), Great Dane Creek (left bank tributary at RM 4.5), Cutthroat Creek (left bank tributary at RM 4), and Rowlands Creek (right bank tributary just upstream of the County Line at approximately RM 2). Drainage areas for these tributaries, as well as major segments of the Little Bear mainstem, are summarized in Table 1, and brief descriptions of each area follow.

**Table 1. Major Drainage Basins in the Little Bear Creek Watershed**

Drainage Basin	Area (acres)
Little Bear Upper (Upstream of Trout Cr)	1,275
Trout Creek	608
West Trib	432
Little Bear Middle (Trout Cr to Great Dane Cr)	2,087
Great Dane Creek	1,481
Cutthroat Creek	755
Little Bear Lower 228th (Great Dane Cr to 228 <sup>th</sup> St)	586
Little Bear Lower CL (228 <sup>th</sup> St to County Line)	1,111
Rowlands Creek	374

#### Little Bear Upper

The northern headwaters of Little Bear Creek lie within the Southwest County UGA and are dominated by the Silver Firs and Snohomish Cascade subdivisions. Stormwater from these developments goes through a series of pollution control and detention facilities constructed prior to current Ecology standards based on the 2012 *Storm Water Management Manual for Western Washington* (SWMMWW). Little Bear Creek emerges from a series of linked wetponds (possibly former wetlands prior to development) north of 156<sup>th</sup> Street SE. The creek then flows south through a relatively undisturbed wetland area to its confluence with Trout Creek.

#### Trout Creek

Trout Creek joins Little Bear Creek from the east upstream of 180<sup>th</sup> Street SE. Its watershed is dominated by low-density residential development with minimal formal stormwater treatment, though forested buffers have been preserved along most of the upland stream network upstream of West Interurban Boulevard.

#### Little Bear Middle – Trout Creek to Great Dane Creek

Between Trout Creek and Great Dane Creek, the Little Bear Creek valley is an almost continuous forested wetland. Large undeveloped parcels remain in the local drainage area to this reach of the stream, primarily north of Maltby Road (SR-524). Development in this drainage basin is almost exclusively

residential—mainly at densities less than two units per acre—with very few formal stormwater treatment facilities. South of Maltby Road, development is somewhat denser.

### **West Trib**

The so-called West Trib joins Little Bear Creek from the northwest upstream of Little Bear Creek Road. The drainage area is still largely lower density residential with no stormwater treatment, but roughly a quarter of the West Trib basin lies within the Southwest County UGA, and adjacent areas in the North Creek basin to the west have been rapidly developing over the past several years.

### **Great Dane Creek**

With nearly 1,500 acres of drainage area, Great Dane Creek is the largest tributary to Little Bear Creek. Starting from the headwaters near Trout Creek, the upper two thirds of the Great Dane Creek basin drains to two roughly parallel main channels west of SR-9. These channels converge to a single channel near 196<sup>th</sup> Street SE and continue in a south-southwest direction to the Little Bear Confluence south of Maltby Road (SR-524). SR-9 bisects the basin, with clusters of commercial areas along the highway that are unique to the upper Little Bear basin. Unlike the steeper Trout Creek, forested buffers along the two main channels are largely absent and there are frequent road crossings in the upland part of the basin (north of 188<sup>th</sup> Street SE).

### **Cutthroat Creek**

Cutthroat Creek joins Little Bear Creek from the east approximately half a mile downstream of the Great Dane Creek confluence. The creek corridor itself is largely undisturbed with forest and wetland buffers, but the headwaters drain commercial and industrial areas in the SR-522 corridor (part of the Maltby UGA).

### **Little Bear Lower 228<sup>th</sup> – Great Dane Creek to 228<sup>th</sup> St SE**

This is a transitional reach of Lower Bear Creek. Upstream of Great Dane Creek, the valley is characterized by large undeveloped areas and extensive wetlands. As the creek approaches SR-9 in this reach, it turns south to parallel the highway, and the stream corridor becomes confined between the highway and adjacent land uses. Much of the local drainage area is similar to the upper basin, with lower density residential land use and some open space, but land use is much more intense where the creek enters the UGA along the SR-9 corridor, including part of the Brightwater Wastewater Treatment Plant facility.

### **Little Bear Lower County Line – 228<sup>th</sup> St SE to County Line**

From 228<sup>th</sup> Street SE to the Snohomish-King county line, Little Bear Creek parallels SR-9 then SR-522. For most of this reach, within the UGA, the creek is confined to a narrow (roughly 200-foot wide) corridor between the highways and adjacent commercial land uses. East of the UGA boundary, the Howell (aka Parsons) Creek and Vintage Creek tributaries drain a mixture of residential area and open space.

## Rowlands Creek

Rowlands Creek is the smallest major tributary to Little Bear Creek and flows in from the northwest just upstream of the county line. For most of its length, Rowlands Creek traverses residential upland areas. About 3,000 feet upstream of its mouth, Rowlands Creek drops into a steep-sided ravine that emerges into a forested area extending to the Little Creek Bear Creek confluence.

### 2.1.2 Climate

Climate in the Little Bear Creek basin is typical of the Puget Sound lowlands, with a maritime climate influenced by Puget Sound to the west and the Cascade Mountains to the east. The majority of precipitation occurs in the winter wet season, from approximately November through April. Summers are characteristically dry. Mean annual precipitation averages about 41 inches, ranging from 29 inches in a very dry year to more than 56 inches in a very wet year. Winter temperatures are moderate, and precipitation falls almost exclusively as rain. Lowland snow occurs occasionally, but significant accumulation is rare, and snow usually melts off within a day.

Precipitation in the basin is also affected by the Puget Sound Convergence Zone (PSCZ), an atmospheric phenomenon caused by upper level winds splitting around the Olympic Mountains and re-converging, typically, over southern Snohomish County. Convergence zones are characterized by convective activity, which can lead to locally more intense precipitation and stronger precipitation gradients during a storm. The location and intensity of the PSCZ varies, which can result in highly variable precipitation distributions from event to event. The convergence effect is also balanced by the Olympic rain shadow, which tends to reduce precipitation over the convergence zone in more widespread storms, resulting in annual precipitation that is consistent with adjacent areas outside the PSCZ.

### 2.1.3 Jurisdictions and Stormwater Programs

The Little Bear Creek study area basin includes the Little Bear Creek study area, in unincorporated Snohomish County, and small portions of the City of Bothell (2.3 acres) and the City of Woodinville (156 acres) that drain into the Little Bear Creek study area (see Figure 1).

Stormwater in Snohomish County is managed by Snohomish County Surface Water Management (SWM) within the Department of Public Works. Snohomish County is an NPDES Phase I permittee, and the County's municipal separate storm sewer system (MS4) is managed under the County stormwater management program.

The MS4s for areas within Woodinville and Bothell that drain to the Little Bear Creek study area are managed under the respective city stormwater management program. Both cities are NPDES Phase II permittees.

The state highway system within the study area basin (SR-522, SR-524, and SR-9) is under the jurisdiction of the Washington State Department of Transportation (WSDOT). WSDOT is an NPDES permittee as the



owner and operator of a transportation MS4. The state highway drainage system within the Little Bear Creek study area is managed by WSDOT's stormwater management program.

#### 2.1.4 Previous Studies

A number of previous studies have documented hydrologic, water quality, and/or biological conditions in Little Bear Creek. Several key studies that provided information included in this assessment are described briefly below. Relevant components of these studies are referenced herein, and the reader is referred to the original reports for further information.

*Habitat Inventory and Assessment of Three Sammamish River Tributaries: North, Swamp, and Little Bear Creeks* (King County, 2001a) – In 1999, King County performed a habitat assessment that included the Snohomish County reaches of Little Bear Creek. The study applied the Puget Lowland Stream assessment protocols of May (1997).

*Salmon and Steelhead Habitat Limiting Factors Report for the Cedar-Sammamish Basin (Water Resources Inventory Area 8)* (Kerwin, 2001) – This 2001 report by the Washington Conservation Commission documents salmonid species use and habitat conditions in streams and rivers throughout the Cedar-Sammamish Water Resources Inventory Area (WRIA) 8. For Little Bear Creek, the report describes known salmonid usage and identifies anthropogenically-influenced habitat factors affecting salmonid populations, including fish passage barriers, altered hydrology and sediment transport, loss of channel complexity, degraded riparian conditions, and water quality.

*Little Bear Creek Drainage Needs Report (DNR No. 9)* (Snohomish County, 2002; draft update 2006) – Snohomish County Surface Water Management completed a set of Drainage Needs Reports (DNRs) for 11 urbanized or urbanizing areas within the County in 2002. Little Bear Creek was designated as a Small Drainage Needs Report, and only areas of the basin within the UGA were included in the original study. Snohomish County staff subsequently updated and expanded the study to include the entire Little Bear Creek basin (available only in draft form). The DNR studies employed standardized hydrologic and hydraulic modeling protocols for the identification of drainage issues and potential capital improvement projects (CIPs). The protocols developed for the DNRs continue to be used by the County's Surface Water Management department for drainage planning and analysis.

*Green River Watershed Assessment and Sammamish-Washington, Analysis and Modeling Program (SWAMP) Watershed Modeling Calibration Report* (King County, 2003) – King County Department of Natural Resources and Parks completed a set of detailed hydrologic and water quality modeling studies that used HSPF (Hydrologic Simulation Program – FORTRAN, a continuous runoff model) to simulate pollutant loads to the Green River and Sammamish River. Little Bear Creek, as a tributary to the Sammamish River, was included in the study.

*Little Bear Creek Hydrogeologic Overview* (Golder, 2005) – This report provides an overview of groundwater conditions in the Little Bear Creek basin. It was intended to briefly summarize existing

information, depict hydrogeologic conditions, and describe potential groundwater contamination pathways or issues specific to Little Bear Creek.

*Brightwater Treatment System Environmental Impact Statement* (King County, 2005) – King County Wastewater Treatment Division performed a comprehensive Environmental Impact Analysis for a regional wastewater treatment facility that serves portions of King and Snohomish County. The Brightwater facility, completed in 2012, is located in the southeastern portion of the Little Bear Creek study area. The EIS and accompanying appendices include background information about Little Bear Creek and the underlying hydrogeology (based on Golder, 2005).

*Little Bear Creek Fecal Coliform Bacteria Total Maximum Daily Load* (Ecology, 2005) – The Washington State Department of Ecology completed a fecal coliform TMDL for Little Bear Creek that includes a water cleanup plan. Key actions identified by the plan are to acquire and protect riparian areas; monitor water quality to identify bacteria sources such as septic systems and animal access to streams; promote agricultural Best Management Practices (BMPs); manage pet waste; promote infiltration; control litter; and expand pollution control identification activities.

*Brightwater Culverts Hydrologic and Hydraulic Modeling* (NHC, 2013a) – NHC updated and recalibrated the County’s Little Bear Creek HSPF model with current (through 2012) land use and flow monitoring data. The updated model was used to evaluate impacts of potential barrier culvert replacements at several sites on Little Bear, Great Dane, and Cutthroat creeks related to Brightwater mitigation activities.

*Runoff Model Selection and BMP Tool Recommendation* (NHC, 2013b) and *Monitoring Needs Assessment of Watershed-Scale Runoff Modeling* (NHC, 2013c) – In October 2013, prior to initiating the watershed planning project, Snohomish County conducted two assessments to determine what Section S5.C.5.c of the Permit would require. The first of these was a modeling needs assessment (NHC, 2013b) that identified which models would be suitable for use in this study. The second was a monitoring needs assessment (NHC, 2013c), which included a review of existing flow and water quality data and also identified the need to collect additional storm and baseflow water quality and flow data to support model calibration. This data collection effort was conducted as part of the Little Bear Creek Basin Planning project.

*2013 NPDES Phase I Final Stormwater Monitoring Reports* (Snohomish County, 2015a, 2015b, and 2015c) – Snohomish County performed an extensive monitoring effort to characterize stormwater runoff and stormwater BMP treatment performance as part of Sections S8.D and S8.F under the 2007-2013 NPDES Phase 1 Permit. Three reports from this effort summarize the results from the monitoring program.

## 2.2 Soils and Geology

### 2.2.1 Geologic Setting

The Little Bear Creek watershed is located in the Puget Lowlands, a region dominantly shaped by Pleistocene glaciations and paraglacial processes that occurred during—and immediately after—glacier

recession (Booth et al., 2003). Surface exposures of five separate geologic units have been mapped and described by Minard (1985) within the basin (Figure 2). The oldest unit is Fraser-age advance glacial outwash (Qva), which consists mostly of clean, well-stratified and over-consolidated sand with gravel and some cobbles. It was deposited as bar and channel deposits of meltwater streams flowing south from the advancing Puget Lobe of the Cordilleran Ice Sheet. The outwash forms a deposit up to 200 feet thick and is one of the most extensive aquifers in the region. As the ice flowed over the basin, it deposited a 10- to 60-foot thick mantle of glacial till (Qvt) over the advance outwash. The till consists of a consolidated unsorted mixture ranging in size from clay to boulders. The top three to six feet of this material is often loose and heavily weathered, providing good drainage, but below this, water ponds and moves laterally. Preliminary field observations suggest that the mapping of Minard (1985) overestimates the lateral extent of surficial coverage of till, and that many smaller tributary valleys to Little Bear Creek have incised through the till unit to expose advance outwash.

The dominant topographic feature in the basin is the Little Bear Creek valley. The valley slopes from north to the south, where it empties into the Sammamish River valley, and is incised up to 350 feet below surrounding uplands. The watershed boundary at the north end of the basin crosses several pronounced glacial outwash channels that were formed during the recession of the Cordilleran Ice Sheet. Flow through these channels followed low topography between drumlins and eroded the modern Little Bear Creek valley. In downstream portions of the valley, till and advance outwash eroded from near the basin divide were deposited, forming the recessional outwash unit (Qvr). This unit is typically around ten feet thick and is composed of loose, permeable, sand and gravel.

The youngest geologic unit in the basin is Holocene-age alluvium (Qa), which has been eroded from uplands in the basin and deposited by Little Bear Creek. This deposit consists of unconsolidated and stratified clay, silt, and fine sand overlying medium to coarse sand and gravel. Field observations and topography developed from LiDAR (laser-based remote sensing technology) elevations suggest that larger tributaries have deposited sediment at the edges of the Little Bear Creek Valley to form alluvial fans that were not mapped by Minard (1985).

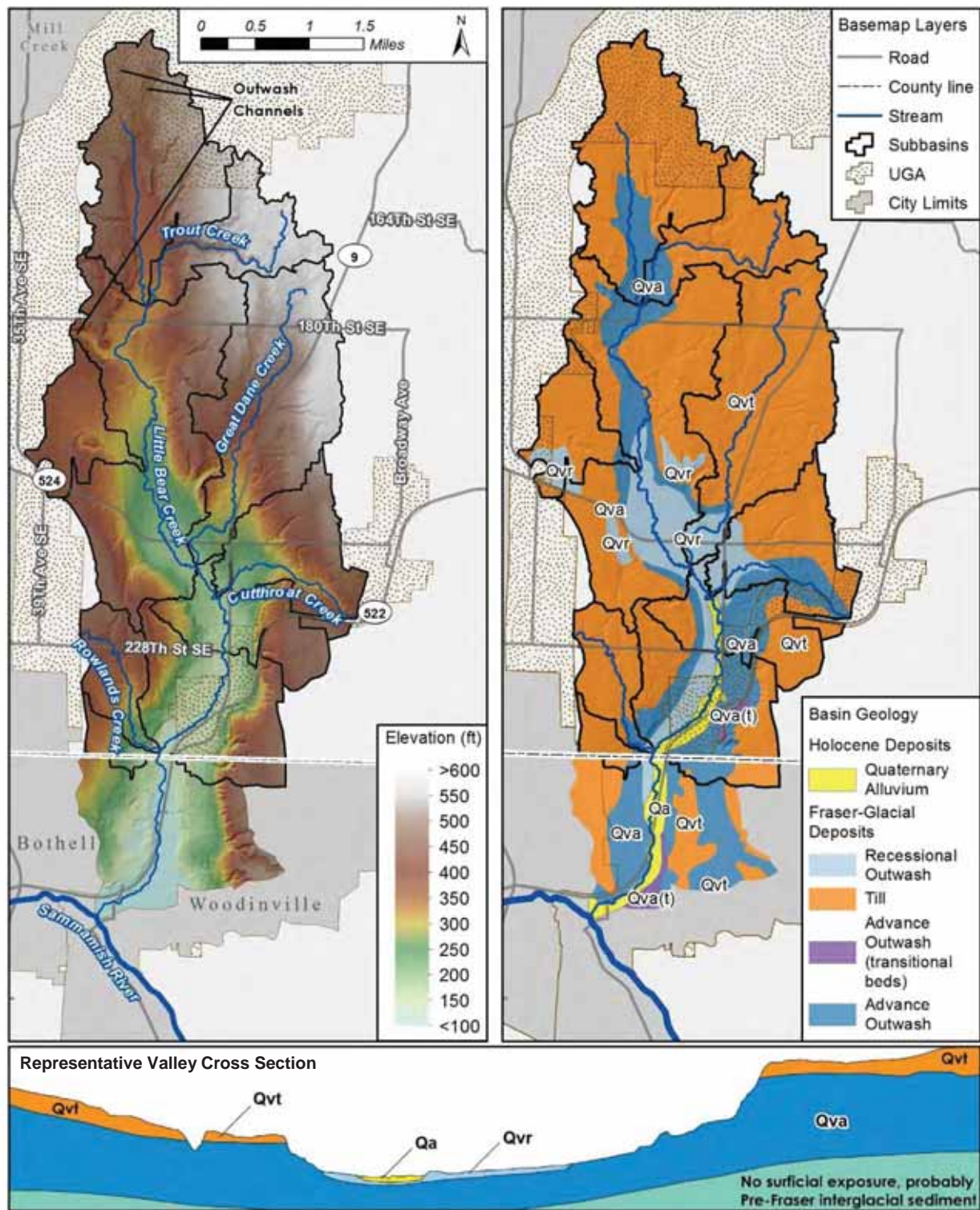


Figure 2. Little Bear Creek Geology

### 2.2.2 Soil Characteristics and Distribution

The NRCS (formerly SCS) Soil Survey for Snohomish County (NRCS, 1983) shows that the Little Bear Creek watershed is dominated by Alderwood gravelly sandy loam, a glacial till-derived soil prevalent in upland areas of the Puget Sound lowlands. As shown in Figure 3, other soil types in the basin occur exclusively in stream valleys and corridors. Table 2 lists the types and general distribution of soils in the Little Bear Creek watershed; slope categories distinguished in the soil survey and associated geospatial data (SSURGO, Soil Survey Geographic Database, NRCS, 2015) have been combined to simplify the map and table.

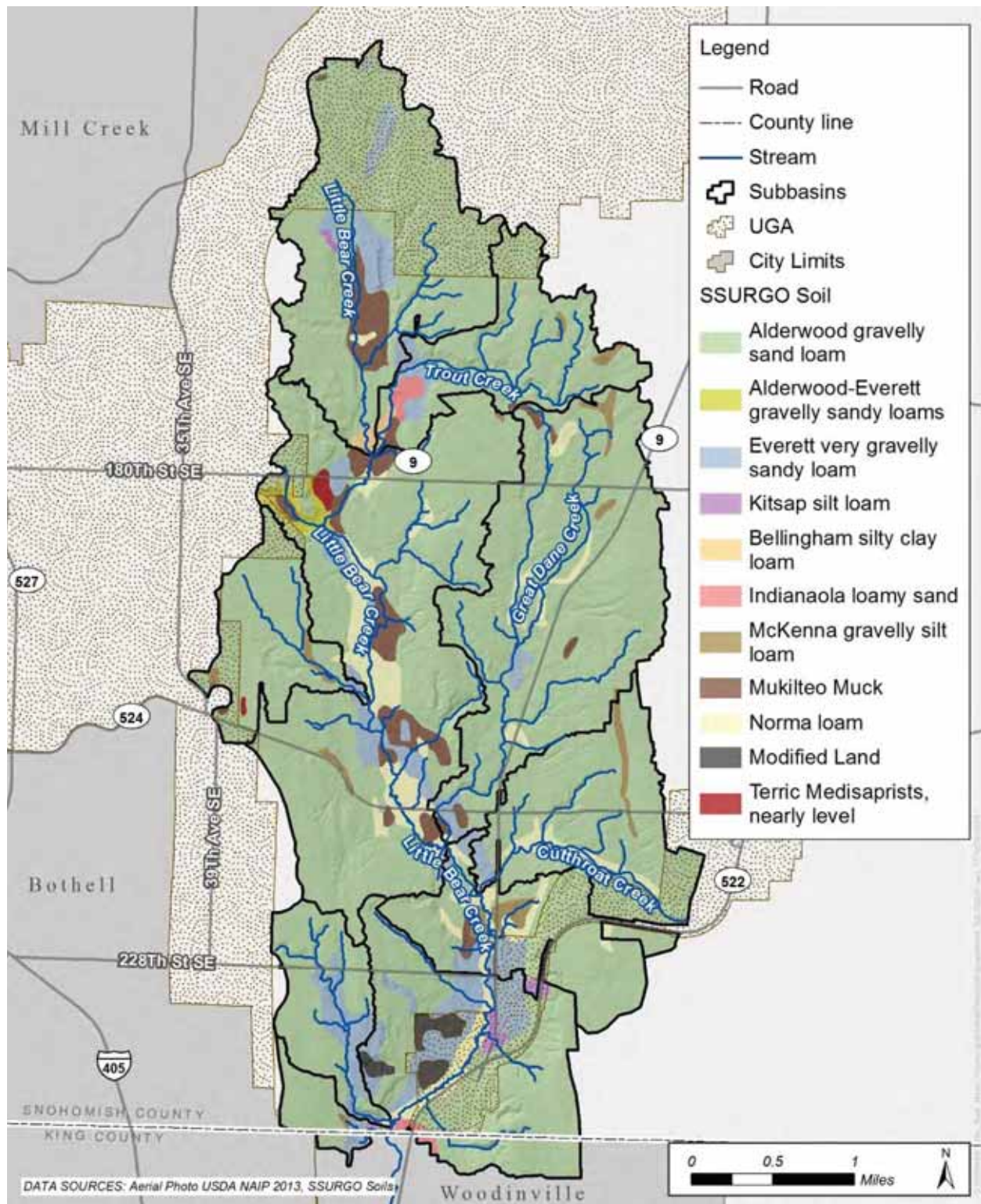
Snohomish County soils can be divided into six general categories, five of which are present in the Little Bear basin: well-drained soils formed in glacial till; well-drained soils formed in glacial lake sediments; well-drained soils formed in glacial outwash; poorly drained soils formed in alluvium; and organic soils.

The first two categories, which include Alderwood, McKenna, and Kitsap soils, exhibit similar drainage behavior. Surface drainage through the top layer is generally good, but the compacted glacial till (often referred to as hardpan) or fine-grained lacustrine deposits below restrict vertical drainage through the soil. In contrast, soils underlain by outwash (including Everett and Indianola) drain easily through the soil profile. Aquifers are often present where these outwash soils occur on top of relatively impermeable soil layers. The poorly drained alluvial and organic soils (including Norma, Bellingham, and Mukilteo) commonly occur in areas with poorly established drainage, such as wetlands and glacial lake depressions, and exhibit saturated conditions through most or all of the year. Norma soils are actually quite permeable but occur in areas with seasonally high water tables; so dry season drainage is rapid, but soils are effectively saturated during the wet season.



### Table 2. Soil Type Distribution

Soil Type	Little Bear Upper	Trout Cr	West Trib	Little Bear Middle	Great Dane Cr	Cutthroat Cr	Little Bear Lower 228th	Little Bear Lower CL	Rowlands Cr	Whole Basin
Alderwood Gravelly Sandy Loam	84%	86%	93%	75%	91%	89%	70%	68%	75%	80%
Kitsap Silt Loam	0%	0%	0%	0%	0%	0%	1%	3%	0%	0.5%
McKenna Gravelly Silt Loam	0%	2%	4%	0%	1%	3%	6%	0%	0%	1.3%
Alderwood-Everett Grav Sandy Loam	0%	0%	0%	2%	0%	0%	0%	0%	0%	0.5%
Everett Gravelly Sandy Loam	1%	2%	0%	0%	0%	0%	0%	0%	0%	0.3%
Indianola Loamy Sand	0%	3%	0%	0%	0%	0%	0%	3%	0%	0.6%
Norma Loam	0%	0%	1%	10%	4%	7%	12%	6%	1%	5.2%
Bellingham Silty Clay Loam	8%	5%	1%	5%	2%	2%	9%	16%	25%	7.0%
Mukilteo Muck	7%	2%	1%	7%	1%	0%	2%	0%	0%	3.2%
Terric Medisaprists	0%	0%	1%	1%	0%	0%	0%	0%	0%	0.2%
Modified Land	0%	0%	0%	0%	0%	0%	0%	6%	0%	0.7%
Modified land includes soil survey areas designated as pits and urban land.										



**Figure 3. NRCS Soil Survey Units**

## **2.3 Land Use and Land Cover**

### **2.3.1 Development History**

Prior to the 1970s, development in the Little Bear Creek study area basin was sparse and generally limited to rural homes and hobby farms. Commercial and industrial development in the SR-522 corridor and expanded residential development, mainly at the south end of the study area basin, began in the 1970s. The Snohomish Cascade and Silver Firs subdivisions in the Little Bear Creek headwaters were constructed in the 1980s and 1990s, respectively, and remain two of the larger areas of residential development in the study area basin. A downzone of portions of the Little Bear Creek study area in Snohomish County in 1996 reduced residential density from one or two and a half acres per dwelling unit to five acres per dwelling unit. Since 2000, the watershed has experienced gradual infill with clustered residential development, though large areas of the basin remain lightly developed and have retained significant forest cover.

In 2005, the UGA in the study area expanded slightly, coupled with requirements for low impact development (LID) stormwater practices for non-single family development in the UGA expansion areas. (This special LID provision for Little Bear, which was voluntary for other locations, was repealed in 2016 when LID requirements became standardized throughout the County through Ordinance 15-102, which implemented the new stormwater requirements of the County's current NPDES Phase I permit.)

### **2.3.2 Land Use/Land Cover Distribution**

The Little Bear Creek study area basin is zoned for a variety of land uses, ranging from rural residential (R-5) to a variety of commercial and industrial categories. Table 3 summarizes the zoning designations within each jurisdiction and the amount of area within each designation. Nearly 80 percent of the study area basin is zoned as Rural-5 Acre. Commercial and industrial zoning covers just over seven percent of the study area.

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**Table 3. Current Zoning in Little Bear Creek Study Area**

<b>Jurisdiction</b>	<b>Short Code</b>	<b>Long Code</b>	<b>Acres</b>
<b>Snohomish County</b>	CRC	Clearview Rural Commercial	69
	HI	Heavy Industrial	69
	LDMR	Low Density Multiple Residential	7
	LI	Light Industrial	470
	NB	Neighborhood Business	10
	PRD SA-1	Suburban Agriculture-1 Acre	108
	PRD-20,000	Residential 20,000 sq. ft.	16
	PRD-9,600	Residential 9,600 sq. ft.	528
	R-5	Rural-5 Acre	6,926
	R-7,200	Residential 7,200 sq. ft.	123
	R-7,200(PRD)	Residential 7,200 sq. ft.	6
	R-9,600	Residential 9,600 sq. ft.	154
	RB	Rural Business	24
	SA-1	Suburban Agriculture-1 Acre	41
<b>Bothell</b>	R 5,400d	Residential 5,400 sq. ft. minimum lot size (only detached units permitted)	0
	R 9,600	Residential 9,600 sq. ft. minimum lot size	2
<b>Woodinville</b>	I	I - Industrial	30
	R-1	R-1 - Residential - 1 Unit Per Acre	91
	R-6	R-6 - Residential - 6 Units Per Acre	19
	ROW	Right of Way	15
<b>Total</b>			<b>8,708</b>

For the purposes of this study, an interpretation of existing land use was derived for hydrologic modeling based on County Assessor parcel codes and visual confirmation against 2013 aerial photos. This interpretation is distinct from County land use planning designations and zoning, and is needed to better characterize current land cover, as it affects hydrologic response and pollutant loadings, in contrast to allowed use and development densities as represented by zoning. For this purpose, land use was classified under broader “modeling land use” categories as shown in Table 4 and Figure 4. Single-family residential areas are further broken out by density: Rural is less than 0.2 dwelling units (DU) per acre (ac), Low is from 0.2 to 2 DU/ac, Medium is from 2 to 6 DU/ac, and High is greater than 6 DU/ac. The Parks category includes parks, playfields, and other grassy areas. Forest and pasture areas are defined for purposes of the table and figure as Undeveloped.

Consistent with the zoning distribution, existing modeling land use in the study area basin is predominantly single family residential, the great majority at densities of less than two units per acre. With the exception of commercial and industrial land uses, which are concentrated at the downstream end of the study area basin in the vicinity of the Maltby UGA, land use patterns and distribution are fairly consistent across the individual drainage basins. Approximately 20 percent of the watershed remains undeveloped (forest or pasture land use).

#### Table 4. Modeling Land Use Distribution

Drainage Basin	Area (ac)	Roads	Commercial/ Industrial	Single Family Residential by Density				Parks	Undeveloped
				High	Medium	Low	Rural		
Little Bear Upper	1,275	11%	2%	10%	11%	31%	5%	0%	25%
Trout Cr	608	10%	0%	0%	5%	65%	1%	4%	17%
West Trib	432	6%	3%	0%	5%	57%	9%	4%	19%
Little Bear Middle	2,087	5%	0%	0%	6%	57%	6%	2%	24%
Great Dane Cr	1,481	9%	6%	0%	5%	65%	1%	4%	14%
Cutthroat Cr	755	8%	13%	0%	16%	27%	7%	0%	26%
Little Bear Lower 228th	586	10%	15%	0%	1%	48%	3%	3%	15%
Little Bear Lower CL	1,111	5%	9%	0%	10%	18%	5%	0%	18%
Rowlands Cr	374	7%	5%	0%	9%	68%	4%	2%	7%
Total	8,709	9%	7%	2%	7%	50%	4%	2%	19%
1. SFR Density Categories: Rural < 0.2 DU/ac, Low 0.2-2 DU/ac, Medium 2-6 DU/ac, High > 6 DU/acre 2. Parks includes parks, playfields, and other grassy areas. Undeveloped includes forest and pasture areas.									

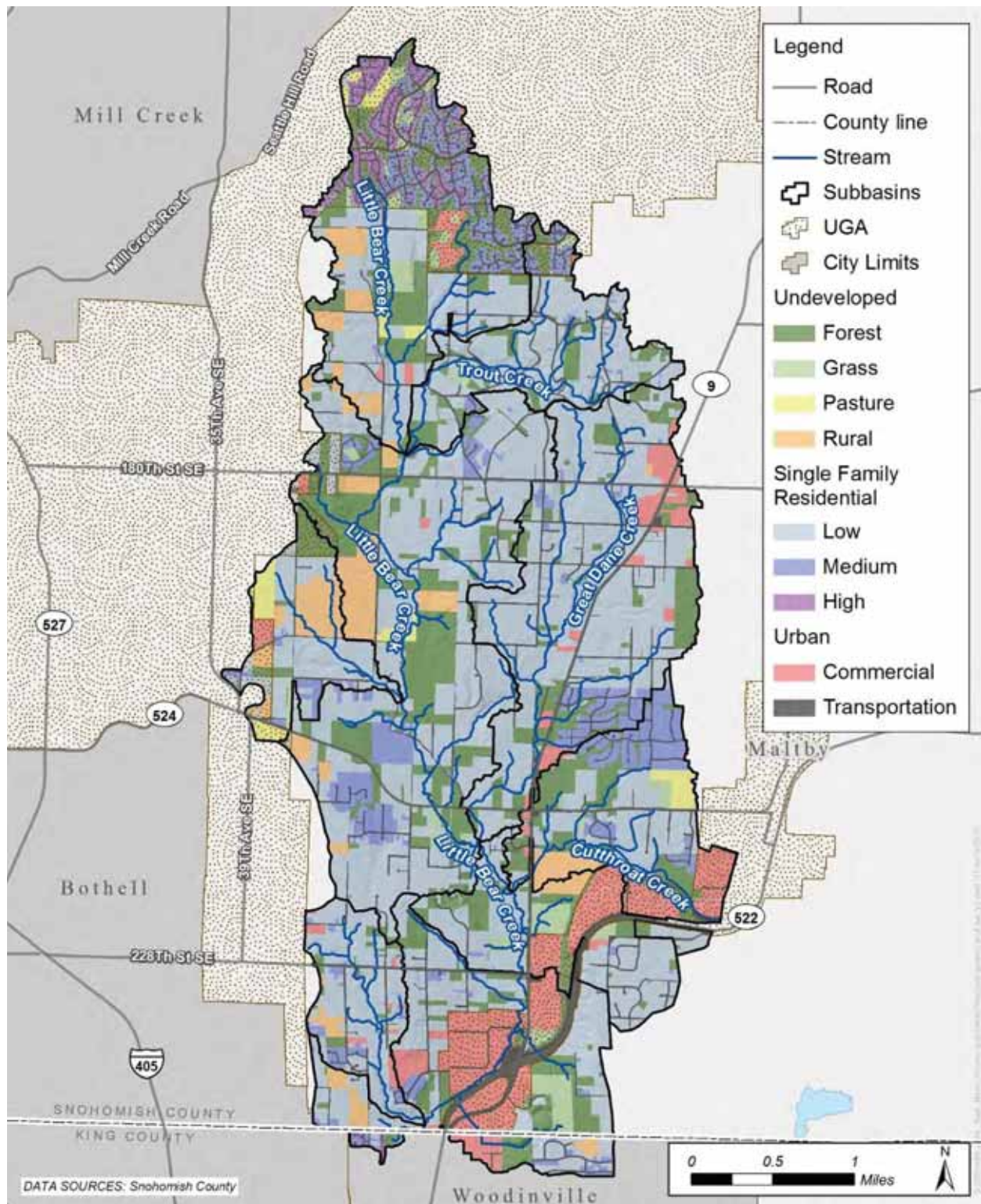


Figure 4. Existing Land Use (2013) for Hydrologic Modeling

High-resolution land cover mapping for the watershed was not available at the outset of this project. Estimates of forested land cover in earlier reports (e.g. Kerwin, 2001) may have been based on low-resolution remotely-sensed data (e.g. National Land Cover Dataset) or visual assessment of aerial photos. Previous land cover estimates for purposes of hydrologic modeling used representative land cover percentages based on land use (Snohomish County, 2002; NHC, 2013a).

As part of this project, Snohomish County developed high-resolution land cover data using image analysis techniques to evaluate remotely-sensed data and current (2013) orthoimagery. The analysis classified land cover into six categories: forest, scrub/shrub vegetation, pasture, grass, impervious, and water. The distribution is shown in Figure 5 and summarized by subbasin in Table 5. Water surface area makes up a negligible fraction of the study area basin and is not included in Table 5. The land cover analysis found that over 50 percent of the Little Bear Creek study area basin has forested land cover, with the highest percentages in the lightly developed Little Bear Middle subbasin and the Trout Creek and Rowlands Creek tributaries. Impervious surfaces cover 18 percent of the study area basin. Impervious area is highest in the subbasins with the most area included in UGAs (up to 25 percent in Little Bear Upper and 31 percent in Little Bear Lower CL).

**Table 5. Existing Land Cover by Subbasin**

Drainage Basin	Area (ac)	Forest	Scrub/Shrub	Pasture	Grass	Impervious
Little Bear Upper	1,275	41%	4%	18%	14%	23%
Trout Cr	608	59%	1%	15%	11%	13%
West Trib	432	50%	1%	21%	14%	14%
Little Bear Middle	2,087	60%	1%	15%	13%	11%
Great Dane Cr	1,481	58%	2%	14%	10%	17%
Cutthroat Cr	755	52%	4%	15%	8%	22%
Little Bear Lower 228th	586	48%	4%	15%	12%	20%
Little Bear Lower CL	1,111	36%	2%	13%	18%	31%
Rowlands Cr	374	41%	1%	16%	26%	16%
<b>Total</b>	<b>8,709</b>	<b>51%</b>	<b>2%</b>	<b>15%</b>	<b>13%</b>	<b>18%</b>



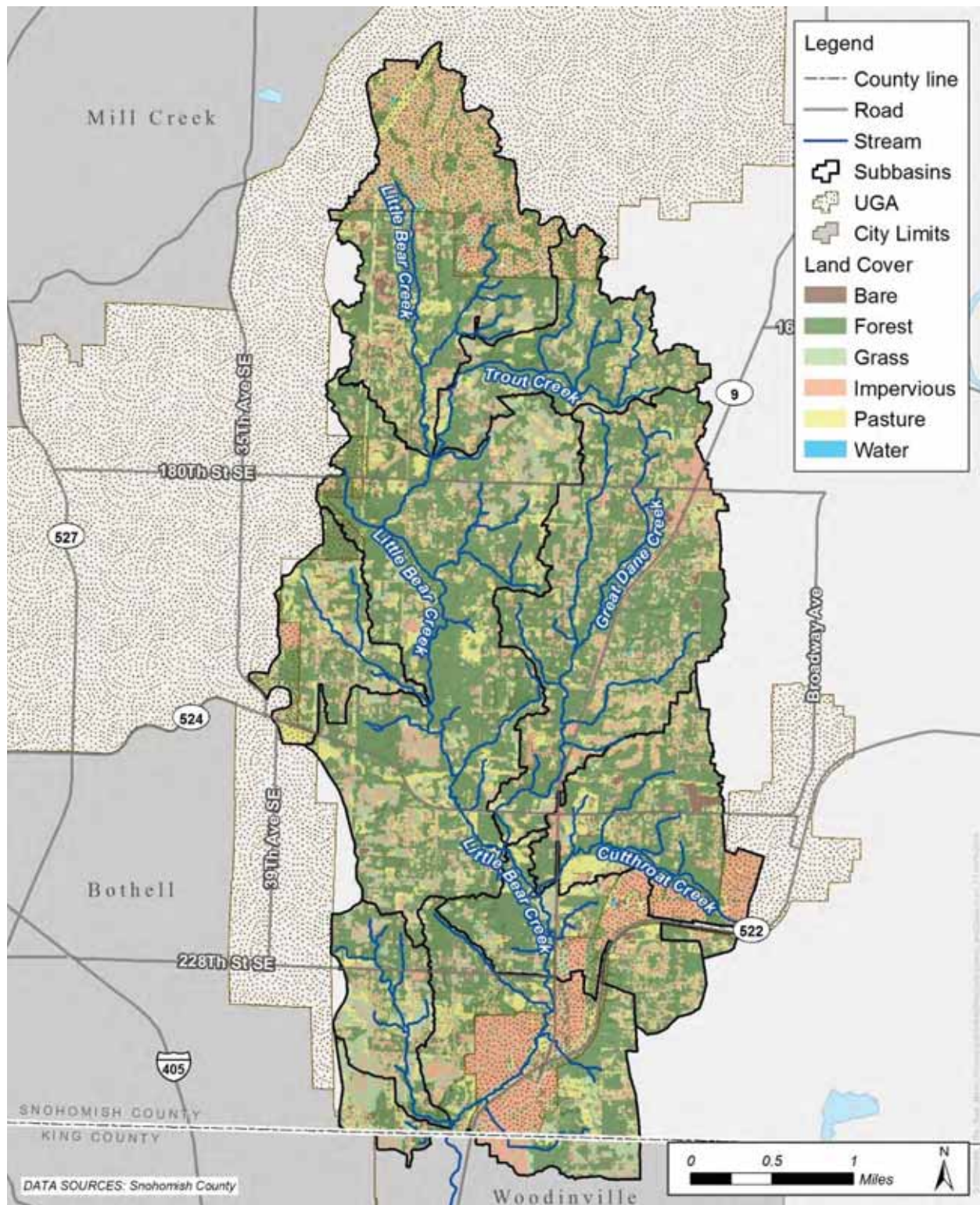


Figure 5. Existing (2013) Land Cover in Little Bear Creek

## 2.4 Drainage Network

### 2.4.1 Streams

Little Bear Creek and its tributaries are the primary drainage pathways in the study area basin. There are more than 50 miles of mapped stream channels in the study area basin, with approximately 17.5 miles comprising mainstem Little Bear Creek and its major tributaries—Great Dane Creek, Cutthroat Creek, Trout Creek, and Rowlands Creek. Mapping of the stream network is subject to interpretation using available data and field observation, as topographic flow pathways in parts of the study area basin (especially headwater areas) do not necessarily support perennial stream channels, and drainage pathways, particularly in some of the wetland complexes in the Little Bear Creek valley, are not always well defined.

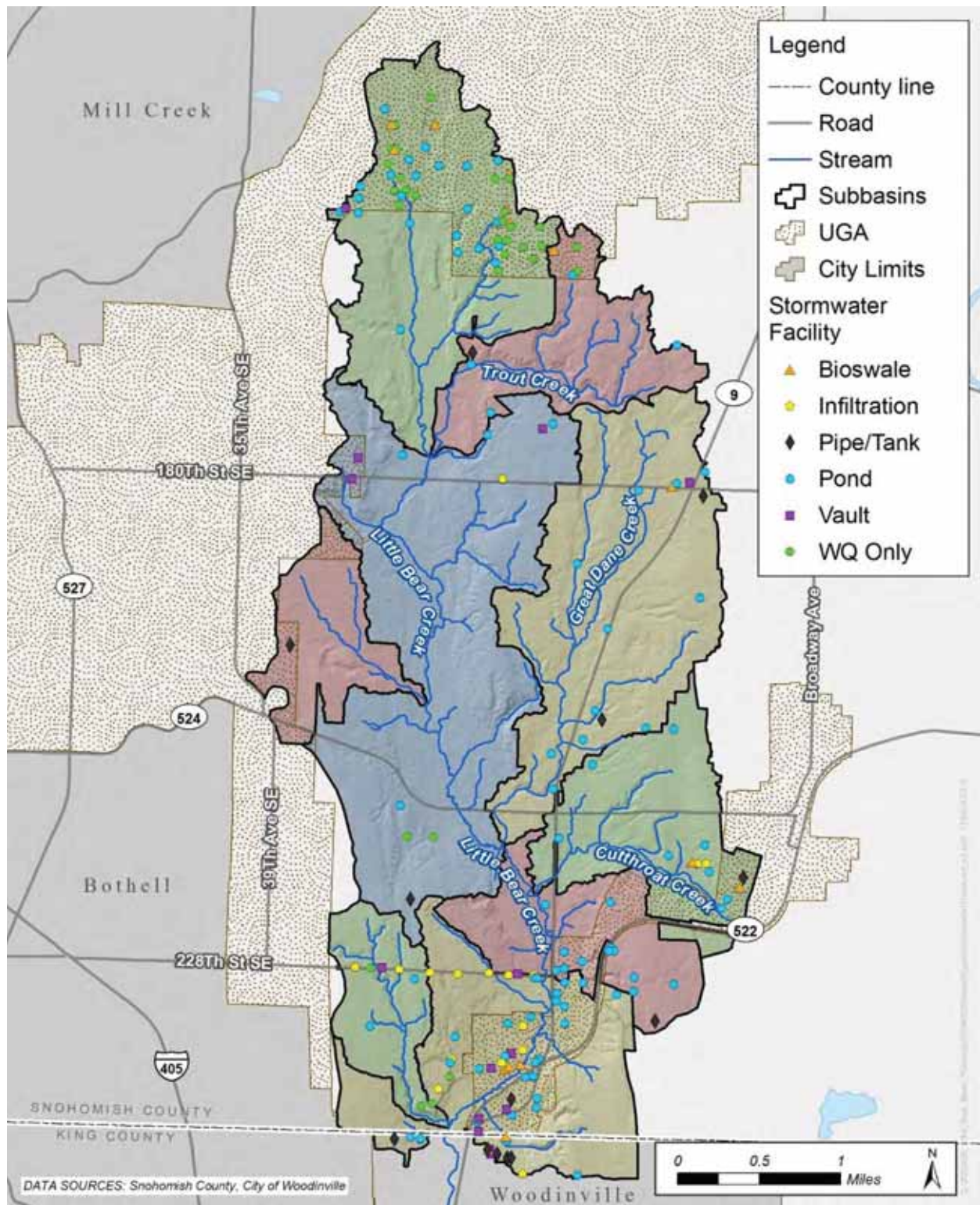
### 2.4.2 Constructed Drainage Systems/MS4s

Constructed stormwater drainage systems falling under NPDES permits are referred to as municipal separate stormwater sewer systems (MS4s). These systems encompass enclosed pipe and open ditch conveyance systems, as well as stormwater treatment facilities (discussed separately in the following section). Ditch and culvert systems are the most prevalent constructed stormwater conveyance systems in the Little Bear Creek study area basin. Enclosed pipe systems are present in the Silver Firs/Snohomish Cascades developments, newer subdivisions, and in some of the commercial/industrial complexes in the SR-522 corridor. Based on drainage inventory data from Snohomish County and the City of Woodinville, there are about 50 miles of ditch and culvert system and 45 miles of enclosed pipe system in the study area basin.

### 2.4.3 Stormwater Facilities

A preliminary assessment by the County identified approximately 170 stormwater treatment facilities in the study area in unincorporated Snohomish County (Figure 6). About half were identified as private facilities, 25 percent as public (Snohomish County, WSDOT, and King County [Brightwater]), and the remaining 25 percent undefined. GIS data provided by the City of Woodinville show an additional 14 facilities that drain into Snohomish County; ownership information was not available for the Woodinville facilities. Table 6 summarizes the stormwater treatment facilities by general type. Each type category encompasses a range of specific facility elements and treatment functions, e.g. the Pond category includes facilities labeled as detention ponds, wet ponds, constructed wetlands, etc. The Water Quality (WQ) Only category includes tree wells, media filters, and catch basin pollution control. This consolidation was necessary for the purposes of summarization and display.





**Figure 6. Existing Stormwater Facilities**

**Table 6. Stormwater Facility Types by Jurisdiction**

General Facility Type <sup>1</sup>	Snohomish County <sup>2</sup>	WSDOT	King County (Brightwater)	Woodinville
Bioswale <sup>3</sup>	13	1	--	2
Pond	66	12	10	4
Pipe/Tank	8	--	--	5
Vault	12	--	--	2
Infiltration	16	--	--	1
WQ Only <sup>4</sup>	31	--	--	--
<b>Total</b>	<b>146</b>	<b>13</b>	<b>10</b>	<b>14</b>
<sup>1</sup> Categories are consolidations including multiple specific facility types.				
<sup>2</sup> Includes public and private facilities located in unincorporated Snohomish County				
<sup>3</sup> Includes bioretention and biofiltration				
<sup>4</sup> Water quality specific treatments including tree filters, media filters, and catch basin pollution control.				

As shown in Figure 6, facilities are concentrated in the residential developments in the Little Bear Upper drainage basin and south of 228<sup>th</sup> Street SE in the Little Bear Lower (228<sup>th</sup> and CL) subbasins and Rowlands Creek. Approximately 70 percent of the known facilities are located within combined County and City UGA boundaries.

Stormwater treatment standards have become increasingly stringent over the last several decades, such that the level of treatment (both detention and water quality) can vary significantly depending on the regulations in effect when the facilities were designed. The following paragraphs provide a summary of the evolution of treatment requirements under the Snohomish County Drainage Manual.

- *Pre-1979 Snohomish County Drainage Procedures Manual* – Prior to the *1979 Snohomish County Drainage Procedures Manual*, the County primarily applied the Rational Method for conveyance sizing. Stormwater detention was generally not required.
- *1979 to September 1998 – 1979 Snohomish County Drainage Procedures Manual* – The County officially required the Rational Method, but the Yrjanainen & Warren (Y&W) method was also used to size stormwater detention on many projects. The intent of this method was to match a project's pre-development runoff rates. It is now understood that the Y&W method tended to over-predict predevelopment runoff and did not provide adequate storage. (From 1992 to 1998, the flow control and stormwater treatment standards of the 1992 Department of Ecology Stormwater Management Manual were applied to a number of projects in Snohomish County, although those standards were not adopted as County regulation until 1998. See discussion below of standards in the 1998 Snohomish County Drainage Manual.)
- *September 1998 to June 2006 – September 1998 Snohomish County Drainage Manual* – In September 1998, the County adopted the 1992 Department of Ecology Stormwater Manual, with an addendum that added some BMPs and some conditions of use to other BMPs, but retained the fundamental flow control and treatment standards of the 1992 Ecology Manual. Detention storage was calculated using a unit hydrograph method and required that: 1) post-



development runoff from the 2-year storm peak flow matched half of the pre-development 2-year storm peak flow and 2) post-development peak flow rates matched pre-development peak flow rates for the 25-year and 100-year storms. Projects were required to provide runoff treatment for the water quality design storm, defined as the 6-month, 24-hour storm, with a priority to infiltrate as much of the water quality design storm as possible. The manual included several water quality treatment BMP options. Ecology deemed this manual and the underlying County stormwater regulations “equivalent” to the content of its 1992 Stormwater Manual, pursuant to requirements of the 1995 NPDES Phase I municipal stormwater permit.

- *June 2006 to August 2008 – Amended September 1998 Snohomish County Drainage Manual* – Replaced Volume II (Erosion and Sediment Control) with Volume II from the 2005 Department of Ecology Stormwater Manual. Volumes I, III, IV, and V were unchanged from the September 1998 Snohomish County Drainage Manual.
- *August 2008 to October 2009 – Amended September 1998 Snohomish County Drainage Manual* – Replaced Volume IV (Source Control BMPs) with a new Snohomish County Volume IV. Volumes I, II, III, and V were unchanged.
- *October 2009 to September 2010 – Amended September 1998 Snohomish County Drainage Manual* – Amended stormwater facility maintenance standards in Volume III (Flow Control) Chapter 3. No changes to any other volumes.
- *September 2010 to January 2016 – September 2010 Snohomish County Drainage Manual* – This was the first stand-alone Snohomish County Drainage Manual, i.e., it did not adopt by reference a Department of Ecology manual. The Snohomish County manual was fundamentally based on the 2005 Ecology Stormwater Management Manual for Western Washington. Pursuant to requirements of the 2007 NPDES Phase I municipal stormwater permit, Ecology deemed this manual—and the underlying County stormwater regulations—equivalent to requirements in that permit and in the Ecology 2005 Stormwater Manual. This was the first County manual to require flow duration control to pre-development forested conditions using continuous hydrologic modeling, which results in significantly larger stormwater detention facilities. It also required higher levels of treatment for source control and water quality treatment BMPs and set forth requirements for on-site stormwater management in single-family residential development projects.
- *January 2016 Snohomish County Drainage Manual* – This manual was fundamentally based on the 2014 Ecology Stormwater Management Manual for Western Washington and significantly expanded requirements for on-site stormwater management and associated low impact development (LID) techniques. It changed the standards for protecting wetlands from stormwater discharges and changed the methodology by which wetland impacts are determined. It also established the use of an updated hydrologic model (WWHM 2012) and set forth requirements related to use of that model. Pursuant to requirements of the 2012 NPDES Phase I municipal stormwater permit (modified in 2015), Ecology deemed this manual and the

underlying County stormwater regulations equivalent to requirements in that permit and in the Ecology 2014 Stormwater Manual.

Since most of the identified facilities in the study area are located in areas that developed prior to 2000, the large majority of treatment facilities in the study area—especially detention facilities—can be expected to provide significantly less treatment than would be required by current Snohomish County regulations.

#### **2.4.4 Existing Stormwater Facility Assessment**

To help characterize current stormwater management conditions in the Little Bear Creek study area, an assessment of existing stormwater control facilities was conducted as part of the basin planning project. For the purpose of this assessment, existing stormwater facilities include public and private stormwater facilities within Snohomish County generally constructed over the last 40 years for the purpose of mitigating site development or roadway improvements. The facilities were generally intended to mitigate for runoff quantity, water quality, or both. The assessment was performed to improve understanding of the level of current stormwater runoff control and treatment within the basin. The stormwater facility assessment consisted of “desktop” review of database information, GIS data, record drawings, and available drainage reports for more than 130 facilities and field reconnaissance of 51 of the larger facilities to assess current conditions and confirm that facility size and configuration approximately matched record drawings.

The following information was available for this assessment:

- Snohomish County database of existing facilities within the Little Bear Creek study area. This spreadsheet database provided general information on the stormwater facilities, such as type of facility, name of development, approximate volume, and year constructed.
- As-Built records and/or design drawings, and associated drainage reports for some facilities.
- GIS data, including the drainage system and facility location shapefiles and facility attributes.

The site reconnaissance and observations helped to qualitatively assess the current operation and conditions of the facilities, primarily for project modeling purposes.

#### **Desktop Review**

Table 7 lists the known existing facilities in the Little Bear Creek study area. The table identifies the facility number, name, type/treatment provided, approximate year designed, and dead and live storage volumes. WSDOT and King County (Brightwater) facilities are indicated by IDs beginning with “WS” and “BW”, respectively. The information in Table 7 is based on best available information at the time of the assessment, but there may be additional facilities of which the County is not aware. Facility locations are shown in Figure 6.

Table 7. Summary of Stormwater Facilities in Study Area

ID	Facility Name	Type of Facility <sup>1</sup>	Approx. Design Year <sup>2</sup>	Dead Volume (CF) <sup>3</sup>	Max. Live Volume (CF) <sup>3</sup>	Total Storage Volume (CF) <sup>3</sup>	Performed Site Assessment
1962	180th St. Se & Snohomish Ave Intersection	Detention Pond - No WQ	2009	1,735	12,034	13,769	
3279	180th St. SE and Interurban Blvd.	Detention Pond - WQ	2012		51,757	51,757	Yes
3280	180th St. SW and Interurban Blvd.	WQ Only	-- <sup>4</sup>				
2704	21820 87TH AVE SE aka Kalmus Engineering	Detention Pipe - No WQ	1993		1,001	1,001	
3267	228th Street SE 39th Ave SE to S.R. 9	WQ Only	-- <sup>4</sup>				
3268	228th Street SE 39th Ave SE to S.R. 9	WQ Only	-- <sup>4</sup>				
3266	228th Street SE 39th Ave SE to S.R.9	WQ Only	-- <sup>4</sup>				
3265	228th Street SE 39th Avenue to S.R. 9	Detention Vault - No WQ	2011		13,024	13,024	
A3366	228th Street SE 39th Avenue to S.R. 9	Detention Vault - No WQ	2011		8,800	8,800	
3395	228th Street SE 39th Avenue to S.R. 9	Detention Vault - No WQ	2011		6,795	6,795	
3262	228th Street SE 39th Avenue to S.R. 9	WQ Only	-- <sup>4</sup>				
3263	228th Street SE 39th Avenue to S.R. 9	WQ Only	-- <sup>4</sup>				
3264	228th Street SE 39th Avenue to S.R. 9	WQ Only	-- <sup>4</sup>				
3265	228th Street SE 39th Avenue to S.R. 9	WQ Only	-- <sup>4</sup>				
3269	229th Street SE 39th Ave SE to S.R. 9	WQ Only	-- <sup>4</sup>				
2919	49th Ave SE 236th PL to 228th St. SE (RC#)	WQ Only	-- <sup>4</sup>				
2512	57th Ave SE_236th Place SE to 228th St. S	WQ Only	-- <sup>4</sup>				
BWA021	Brightwater Treatment Plant	Detention Pond - WQ	2006		222,156	222,156	Yes
BWA024	Brightwater Treatment Plant	Detention Pond - WQ	2006		178,596	178,596	Yes
BWA020	Brightwater Treatment Plant	Detention Pond - WQ	2006		143,748	143,748	Yes
BWA022	Brightwater Treatment Plant	Detention Pond - WQ	2006		143,748	143,748	Yes
BWA023	Brightwater Treatment Plant	Detention Pond - WQ	2006		108,900	108,900	Yes
BWA026	Brightwater Treatment Plant	WQ Only	2006	73,480		73,480	Yes
BWA025	Brightwater Treatment Plant	WQ Only	2006	47,980		47,980	Yes
BWA028	Brightwater Treatment Plant	WQ Only	2006	39,340		39,340	Yes
BWA029	Brightwater Treatment Plant	Detention Pond - No WQ	2006		25,850	25,850	
BWA027	Brightwater Treatment Plant	Detention Pond - WQ	2006		23,780	23,780	Yes
2720	C & H Enterprise Building	Detention Pipe - WQ	1998		15,375	15,375	
693	Cedar Lane East	Detention Pipe - No WQ	1995		4,930	4,930	
2305	Cedar Meadows	Detention Pond - WQ	2004	23,603	35,490	59,093	Yes
1158	Clearview Creek Estates	Infiltration Facility - WQ	1997	3,400		3,400	
0751	Donegal Park	Detention Pond - WQ	1998	87,000	219,209	306,209	Yes
2259	Everett Elementary #17	Detention Pond - WQ	2006	17,100	17,130	34,230	
2260	Everett Elementary #5 (Gateway Middle School)	Detention Pond - No WQ	1991		18,632	18,632	
3511	Everett Middle School No. 2, Dist. No. 5	Detention Pond - WQ	2006		107,526	107,526	
3258	Fairfield	Detention Vault - WQ	2012	4,256	33,367	37,623	
3290	Fairfield Lane aka Thornberg Addition	Detention Vault - No WQ	2013		11,560	11,560	
2261	Fernwood Elementary School	Detention Pipe - WQ	2010		2,222	2,222	

ID	Facility Name	Type of Facility <sup>1</sup>	Approx. Design Year <sup>2</sup>	Dead Volume (CF) <sup>3</sup>	Max. Live Volume (CF) <sup>3</sup>	Total Storage Volume (CF) <sup>3</sup>	Performed Site Assessment
1235	Fithen Meadows	Detention Pond - No WQ	1997		8,700	8,700	
1549	Fordham Meadows	Detention Vault - No WQ	1998		8,620	8,620	
0167	Halo Hills Regional Pond	Detention Pond - No WQ	1986		36,000	36,000	Yes
3235	Heath Short Plat	Detention Pond - No WQ	2008		1,253	1,253	
208	Highland Park Estates	Infiltration Facility - No WQ	1978		6,400	6,400	
1106	Highland Park Estates	Infiltration Facility - No WQ	-- <sup>4</sup>				
1107	Highland Park Estates	Infiltration Facility - No WQ	-- <sup>4</sup>				
778	Highland Vista	Detention Pipe - No WQ	1991		6,060	6,060	
0509 2	Highland Vista Estates	Detention Pond - No WQ	1996		73,110	73,110	
0904	Highland Vista Estates	Detention Pond - WQ	1996	7,680	59,530	67,210	Yes
0710	Highland Vista Estates	Detention Pond - No WQ	1996		59,530	59,530	Yes
0793	Hyde Park (fka Brummett)	Detention Pond - No WQ	1996		26,400	26,400	Yes
2639	Lambert, Dennis SP (96-104260)	Detention Pond - WQ	1998		3,940	3,940	
3100	Lincolnshire	Detention Pond - WQ	2007	39,160	74,671	113,831	Yes
2939	Maltby Joint Venture	WQ Only	-- <sup>4</sup>				
2938	Maltby Joint Venture	Bioretention/biofiltration - WQ	-- <sup>4</sup>				
2522	Maple View Div 1 PRD	Detention Vault - WQ	2005	18,816	14,691	33,507	
2321	Maple View Div 2	Detention Pond - No WQ	2005	13,529	28,176	41,705	Yes
332	Morris Place	Detention Pond - No WQ	1990		9,942	9,942	
331	Morris Place	Detention Pipe - No WQ	1990		2,827	2,827	
341	North Canyon Park Estates	Detention Pond - No WQ	1978		3,550	3,550	
2723	Northshore Elementary School No 20	Detention Pond - No WQ	1992		21,800	21,800	
2721	OPUS Northwest, LLC	Detention Pond - WQ	1999	40,612	57,520	98,132	Yes
1594	Pacific Topsoils - Maltby	Detention Pond - No WQ	1999		79,384	79,384	Yes
3064	Project Andrea	Infiltration Facility - WQ	2010	28,794	47,318	76,112	Yes
2690	PSM Corporation	Detention Pond - WQ	2003	120,000	131,416	251,416	Yes
2687	Reliance Manufacturing	Detention Pond - No WQ	1999		10,900	10,900	
3302	Restaurant Depot - Woodinville	Detention Pond - WQ	2012		38,651	38,651	
A3301	Restaurant Depot - Woodinville	WQ Only	-- <sup>4</sup>				
3303	Restaurant Depot - Woodinville	Bioretention/biofiltration - WQ	-- <sup>4</sup>				
3304	Restaurant Depot - Woodinville	Bioretention/biofiltration - WQ	-- <sup>4</sup>				
442	Rockhaven Ranch	Detention Pond - No WQ	1988		9,800	9,800	
2722	Roof Truss Supply, Inc.	Detention Pond - WQ	1995		4,381	4,381	
2044	Seattle Glass Block	Detention Vault - WQ	2000		12,852	12,852	
780	Silver Firs Div #7	Detention Pond - WQ	1996	20,300	245,984	266,284	Yes
779	Silver Firs Div #7	Detention Pond - No WQ	1992		138,780	138,780	Yes
0781	Silver Firs Div #7	Detention Pond - WQ	1992		110,643	110,643	Yes
0477	Silver Firs Div 6B	Detention Pond - WQ	1996		47,890	47,890	Yes
0479	Silver Firs Div No 6A-2	Detention Pond - No WQ	1991		23,193	23,193	Yes

ID	Facility Name	Type of Facility <sup>1</sup>	Approx. Design Year <sup>2</sup>	Dead Volume (CF) <sup>3</sup>	Max. Live Volume (CF) <sup>3</sup>	Total Storage Volume (CF) <sup>3</sup>	Performed Site Assessment
1290	Silver Firs Div No 8-A & B & Silver Firs	Bioretention/biofiltration - WQ	-- <sup>4</sup>				
1294	Silver Firs Div No 9A & B	Bioretention/biofiltration - WQ	-- <sup>4</sup>				
2656	Silver Firs Sect 2 Div No 9C	Bioretention/biofiltration - WQ	-- <sup>4</sup>				
1297	Silver Firs Sect 4 Div No 10 A	Detention Pond - WQ	1998		122,400	122,400	Yes
1299	Silver Firs Sect 4 Div No 10B & C & Sect	Detention Pond - No WQ	1998		86,200	86,200	Yes
1304	Silver Firs Sect 4 Div No 10 A	Detention Pond - WQ	1998	244,900	1,482,000	1,726,900	Yes
0478	Silver Firs, Div. No. 6A-1	Detention Pond - No WQ	1991		17,601	17,601	
730	Snohomish Cascade Sect II Div I PH II	Detention Pond - WQ	1992		11,600	11,600	
1201	Snohomish Cascade Sector II Div II	Bioretention/biofiltration - WQ	-- <sup>4</sup>				
0927	Snohomish Cascade Sector II, Div III, Ph. I	Detention Pond - WQ	1994		245,322	245,322	Yes
1199	Snohomish Cascade Sector II, Div. I Phase	Bioretention/biofiltration - WQ	-- <sup>4</sup>				
0786	Snohomish Cascade Sector II, Div. II	Detention Pond - WQ	1993		99,290	99,290	Yes
1203	Snohomish Cascade Sector II, Div. II	Bioretention/biofiltration - WQ	-- <sup>4</sup>				
0785	Snohomish Cascade Sector II, Div. III, P	Detention Pond - WQ	1995		245,322	245,322	Yes
1036	Snohomish Cascade Sector II, Div. III, P	Detention Pond - WQ	1992		157,710	157,710	Yes
1866	Snohomish-Woodinville Rd RC#1079	Detention Pond - WQ	2005	14,000	38,350	52,350	Yes
1589	Spectrum Glass Expansion	Detention Pond - No WQ	1995	9,212	6,809	16,021	
WS0564	SR 9: SR 522 to 212th St Widening	Detention Pond - WQ	2005	20,785 <sup>5</sup>	113,895 <sup>5</sup>	134,680 <sup>5</sup>	Yes
WS0563	SR 9: SR 522 to 212th St Widening	Detention Pond - WQ	2005	17,920 <sup>5</sup>	92,566 <sup>5</sup>	110,486 <sup>5</sup>	Yes
WS0889 (or 3282)	SR 9: SR 522 to 212th St Widening	Detention Pond - No WQ	2005	14,859 <sup>5</sup>	63,047 <sup>5</sup>	77,906 <sup>5</sup>	Yes
WS0280	SR522: SR9 to Paradise Lake Road	Detention Pond - WQ	1999 (AB) <sup>2</sup>	65,631 <sup>5</sup>	185,391 <sup>5</sup>	251,022 <sup>5</sup>	Yes
WS0147	SR522: SR9 to Paradise Lake Road	Detention Pond - No WQ	1999 (AB) <sup>2</sup>	24,621 <sup>5</sup>	140,688 <sup>5</sup>	165,309 <sup>5</sup>	Yes
WS0144 (or 1572)	SR524, SR524 Vic To SR522, JTC York Rd	Detention Pond - No WQ	1997	0 <sup>5</sup>	3,249 <sup>5</sup>	3,249 <sup>5</sup>	
WSU011	SR9: 212th St SE to 176th St SE Stage 3 Widening	Detention Pond - WQ	2011	56,912	116,248	173,160	Yes
WSU012	SR9: 212th St SE to 176th St SE Stage 3 Widening	Detention Pond - WQ	2011	18,750	44,345	63,095	Yes
WSU010	SR9: 212th St SE to 176th St SE Stage 3 Widening	Detention Pond - No WQ	2011	0 <sup>5</sup>	41,850 <sup>5</sup>	41,850 <sup>5</sup>	Yes
WSA010	SR9: 212th St SE to 176th St SE Stage 3 Widening	Bioretention/biofiltration - WQ	-- <sup>4</sup>				
WS0146	SR9: SR522 / SR9 Interchange Modification - Stage 1A	Detention Pond - No WQ	1995	7,627	9,428	17,055	
WS0281	SR9: SR522 / SR9 Interchange Modification - Stage 1A	Detention Pond - No WQ	1995	5,635	5,619	11,254	
WS0152	SR9: SR522 / SR9 Interchange Modification - Stage 1A	Detention Pond - No WQ	1995	3,926	4,052	7,978	
832	Strickland's Addition	Infiltration Facility - WQ	1995	1,555	1,555	3,110	
0849	Summer Ridge	Detention Pond - WQ	1998		112,320	112,320	Yes
0848	Summer Ridge	Detention Pond - WQ	1998		31,104	31,104	Yes
2697	Teufel Nursery Inc.	Detention Pond - WQ	2000		35,289	35,289	
2743	Texaco Refining and Marketing	Detention Vault - No WQ	1998		1,800	1,800	
517	Timbercrest	Detention Pond - No WQ	1973		4,000	4,000	
1338	Turner's Crossing	Detention Pond - WQ	1997	27,663	183,754	211,417	Yes
1337	Turner's Crossing	Detention Pond - WQ	1997	19,671	56,635	76,306	Yes
2698	Underwood Gartland 9	Detention Vault - WQ	2006		33,100	33,100	

ID	Facility Name	Type of Facility <sup>1</sup>	Approx. Design Year <sup>2</sup>	Dead Volume (CF) <sup>3</sup>	Max. Live Volume (CF) <sup>3</sup>	Total Storage Volume (CF) <sup>3</sup>	Performed Site Assessment
2709	Vangemert, John & Weaver-Vangemert, Amy	Detention Pond - No WQ	1998		5,800	5,800	
2237	Waste Management Northwest - Woodinville	Detention Vault - WQ	2011	11,580	58,640	70,220	
A2237	Waste Management Northwest - Woodinville	WQ Only	-- <sup>4</sup>				
2085	Wellington Hills Park LLC	Detention Pond - No WQ	2005		65,850	65,850	Yes
1799	Windrose	Detention Pond - WQ	2002	20,441	26,942	47,383	Yes
570	Windsor Park	Detention Pond - No WQ	1988		15,700	15,700	
2001	Woodin Valley Baptist Church	Infiltration Facility - WQ	2009	6,022	7,910	13,932	
2691	Woodinville Church of Christ	Detention Pond - WQ	2003	11,390	14,515	25,905	
3498	Woodinville Costco SR-9	Detention Pipe - WQ	2005	18,295	265,280	283,575	Yes
1936	Woodinville Costco SR-9	Detention Pipe - WQ	2005	4,939	52,124	57,063	Yes
0589	Woodlane	Detention Pond - No WQ	1978		17,815	17,815	
<p><sup>1</sup> Type of Facility was categorized by the general type and whether it incorporated a water quality feature/component. See <b>Table 8</b> and text for types of BMPs categorized as WQ only.</p> <p><sup>2</sup> AB denotes As-Built. For instances where the design date was not available, the As-Built date is listed if available.</p> <p><sup>3</sup> The volume information was obtained from either As-Built, Design Drawings, or Drainage Reports.</p> <p><sup>4</sup> Reliable information unavailable.</p> <p><sup>5</sup> Facility volume provided by WSDOT.</p> <p>Disclaimer: The information contained within this document is a historical compilation that contains legacy data from old sources and may be out of date. While this information was carefully reviewed, it may have errors. No warranty is expressed or implied. The potential user of this data is responsible for verifying the accuracy of any information used.</p>							



Table 8 provides a summary of the number of facilities classified per type and function. For this breakdown, the facility classification defined by “water quality only” included wetponds without detention storage and smaller water quality systems such as pervious pavement and tree filters that filter stormwater.

**Table 8. Distribution of Reviewed Stormwater Facilities by Type and Function**

Facility Type	Flow Control Only	Water Quality Only	Flow Control and Water Quality
Bioretention/biofiltration	--	--	10
Detention Pond	33	--	41
Detention Pipe	4	--	4
Detention Vault	6	--	5
Infiltration Facility	3	--	4
WQ Only	--	17	--
Based on best available data. There may be additional facilities not listed. For this classification, water quality only facilities included wetponds without detention, pervious pavement, and tree filter treatment systems.			

As discussed in the previous section, stormwater treatment standards for development projects have become increasingly stringent over the past several decades. Facilities within the Little Bear Creek study area were mostly designed under the applicable Snohomish County stormwater treatment requirements (described in the previous section), though WSDOT facilities fall under separate standards. WSDOT facilities are designed in accordance with WSDOT’s Highway Runoff Manual (HRM) (M31-16) and Hydraulics Manual (HM) (M23-03). As with Snohomish County, the WSDOT design standards have become more stringent over time. Based on design year, the WSDOT facilities in Little Bear Creek would fall under varying manuals. HRM and HM revision history and links to applicable manuals are available on WSDOT’s HRM and HM webpages, respectively.

Table 9 summarizes the number of facilities in the study area based on the design year, which is generally indicative of the applicable standard, and facility ownership. Only facilities for which design year could be reliably estimated are included in the table. There were 19 facilities (15%) included in the assessment that were designed before 1992, which is prior to the time when water quality treatment was typically required.

**Table 9. Summary of Facility by Design Year and Facility Ownership**

Design Year	Private Commercial	Private Residential	Public, Snohomish County	Public, King County (Brightwater Regional Wastewater Facility)	Public, WSDOT	Total by Period
Pre 1990		3	3			6
1980-1991	2	6	5			13
1992-1997	6	27	3		4	40
1997-2006	12	6	2	10	5	35
2006-2007		2				2
2008-2010	2		1			3
2011-2015	7	2	15		4	28
<b>Total by Type</b>	<b>29</b>	<b>46</b>	<b>29</b>	<b>10</b>	<b>13</b>	<b>127</b>
Based on best available data. There may be other additional smaller facilities not included in this summary.						

### Field Assessment

As noted above, the assessment included site reconnaissance for 51 of the larger facilities to qualitatively observe facility size and condition, primarily for project modeling purposes. The specific facilities visited are noted in Table 7. The site assessments were conducted between August 5th, 2015 and September 17th, 2015 and were not associated with formal County facility maintenance inspections. Data collection methods included visual observations and a few hand measurements, but no GPS or surveying equipment was used. Control structure and detention facility access lids were opened for visual assessment, but catch basin lids were generally not opened. The field reconnaissance also provided an opportunity to note potential facility retrofit opportunities, which could be a part of basin planning solutions to enhance stormwater treatment. Collectively, the 51 observed facilities represent about 95 percent of the storage provided by stormwater facilities within the study area.

For each site, observations were compiled on field data sheets. The information collected included:

- Qualitative verification of apparent volume, depth, slopes, emergency overflow, maintenance access, outlets, and inlet.
- General observation of facility conditions including level of maintenance, signs of sedimentation and erosion, accumulated solids or debris, short-circuiting, vegetation, water quality description (e.g. turbidity, odors, eutrophication, oils, etc.).
- Identification of potential retrofit opportunities for hydromodification and/or water quality improvements.

The resulting data sheets are in a separate backup to this report.

The following paragraphs summarize key field observations regarding facility conditions and related potential performance issues. Observations characterize the facility conditions at the time of the



summer 2015 site visits; this did not allow for direct observation of facility performance during storms. Table 10 provides a general summary of observed maintenance conditions.

Thirteen (25 percent) of the facilities were observed to have some facility feature that did not appear to match record drawings. In some instances, hydraulic performance would be affected. Examples of these situations included: control overflow risers not matching the design elevation or dimension; missing control structures (two ponds); pond footprint areas smaller than the record drawings so that they were providing less storage volume; and an improperly constructed control orifice that was partially blocked.

Approximately 30 percent of the ponds appeared to lack routine maintenance and some showed no signs of maintenance. Several ponds were overgrown, with trees growing in the storage areas and along pond banks. The likely outcome of an overgrown condition is accumulation of sediment over time, loss of water storage volume, and an increased potential for blockage of outlet controls.

Five of the facilities (10 percent) had had treatment trains consisting of a pond followed by an under-vegetated bioswale. Dense vegetation canopy appeared to have prevented grass growth in the swales. Without vegetation, bioswales would be expected to provide less water quality treatment than intended.

Eight of the older pond facilities (16 percent) are located within native growth protection areas (NGPAs). These (sometimes relatively narrow) facilities are located within existing ephemeral channels obstructed by young woodlands, downed limbs and trunks, and other organic debris. Because they are located in NGPAs, maintenance activity is limited to ensuring facility function (e.g. checking control structures and manually clearing pipe inlets/outlets). Removal of native vegetation is restricted and equipment and machinery is not permitted. Over time, it is likely that these types of facilities could lose some of their original detention storage volume. It was also noted that many of these facilities lacked trash racks or screens below the bottom of the control risers to help prevent debris clogging. Screens, in particular, were not typically included in older facilities because they were not part of the standard designs at the time.

At least seven ponds (14 percent) had standing water with moderate to dense algal growth during the late summer visits. It is uncertain to what extent this may be affecting stream water quality, as dense algal growth could contribute to low dissolved oxygen. The conditions where dense algal growth were observed were variable.

**Table 10. Summary of Observed Maintenance Conditions**

Condition Observed in 2015	Number of Facilities
No issues observed	18
Facility appeared to have some feature inconsistent with record drawings that could affect hydraulic performance (e.g., control risers not matching record drawings, missing control structure, or smaller pond bottom footprints)	13 <sup>1</sup>
Facility showed general lack of maintenance (e.g., excess tree growth, pond bottoms filled in with sediment).	11 <sup>2</sup>
Facility with under-vegetated bioswale (often due to excess tree canopy limiting grass growth)	5
Facility in NGPA easement that limits maintenance activities	8 <sup>3</sup>
Facility with moderate to dense algal growth	7 <sup>3</sup>
<sup>1</sup> Facility with missing control structure has been resolved. <sup>2</sup> Since the time of the data collection, maintenance occurred on two facilities. Three facilities have maintenance scheduled. The remaining six facilities are private non-regulated facilities and owners will receive notification of the maintenance needs. <sup>3</sup> The observed condition does not imply the facility is not functioning as designed.	

### 3 HYDROLOGIC/GEOMORPHIC CONDITIONS

#### 3.1 Introduction

The following sections describe the current understanding of hydrologic and geomorphic conditions in the Little Bear Creek watershed. Compared to many other urban and urbanizing streams in the region, Little Bear Creek has experienced less dramatic changes to several watershed characteristics strongly linked to hydrologic impacts of urbanization. Forest remains the predominant land cover outside of designated UGAs and dominates the riparian corridors of Little Bear, Trout, and Cutthroat Creeks. Frequent road crossings have interrupted the stream corridors, but in most of the study area, constructed drainage systems are fairly disconnected, reducing the effect of extending the natural drainage network. Also, because constructed systems outside the UGAs are largely ditch and culvert, they are less efficient than highly connected pipe drainage systems, which helps to retard and attenuate flows. Preserved riparian wetlands in the Little Bear Creek valley also help to attenuate increased peak flows associated with impervious runoff.

#### 3.2 Precipitation

Figure 7 shows the locations of precipitation gaging stations in and around the Little Bear Creek basin. Snohomish County has been collecting precipitation data at the Silver Lake Water District Office (Silver Lake) continuously since the late 1980s, the longest record in the area. Several other stations operated by Snohomish and King Counties have periods of record ranging from about seven to twenty years, as

summarized in Table 11. A precipitation gage at 180<sup>th</sup> Street and Interurban was installed in 2014 by Snohomish County for purposes of the Little Bear Creek basin planning study.

**Table 11. Precipitation Stations Near Little Bear Creek**

Station Name	Agency	Available Timestep	Period of Record
Silver Lake	Snohomish Co	15-minute	11/1987 - present
Willis Tucker Park	Snohomish Co	1-hour	2/2008 - present
180 <sup>th</sup> at Interurban	Snohomish Co	15-minute	7/2014 - present
Brightwater (BW_rain)	King Co	15-minute	10/2005 - present
Little Bear I&I (BEAR)	King Co	15-minute	10/2000 - present
Cottage Lake (02w)	King Co	15-minute	11/1992 - present
North Creek Maltby I&I (MNCR)	King Co	15-minute	10/2000 - present
Bothell I&I (BOTH)	King Co	15-minute	10/2001 - present
Martha Lake I&I (MCSN)	King Co	15-minute	11/2000 - present

Regional mapping of annual precipitation normals (PRISM, 2015) shows a west-to-east increasing precipitation gradient across the Little Bear Creek basin, with annual precipitation increasing by about 10 percent across the watershed (from 41 inches to 45 inches). However, a distinct gradient is not apparent from analyzing individual gage records in the area. Figure 8 shows a scatter plot of daily rainfall for various gages versus daily rainfall at Silver Lake, where the County has a long-term record. Points for all gages fall close to the one-to-one line (red line in figure). Linear trend lines for the individual gages (not shown) suggest that other gages come in slightly lower than Silver Lake—counter to the regional mapping—though within a couple percent.

Figure 9 shows a cumulative precipitation plot for the same gages for the period from March 2008 through June 2015, when data for all five gages were available. The cumulative plot shows all but the Little Bear I&I gage tracking quite consistently; North Creek Maltby drops lower in spring 2011 but then resumes a consistent trajectory with the other three gages. The Little Bear I&I gage totals are distinctly higher than the other gages, including Brightwater, which is within half a mile. It is not clear why cumulative totals are higher at this site, but the result seems to be an anomaly given the otherwise fairly consistent totals in the area and the close day-to-day tracking with Silver Lake seen in Figure 8. Based on analysis of area gages, precipitation appears to be fairly consistent over the Little Bear watershed, though spatial patterns for individual storms vary.

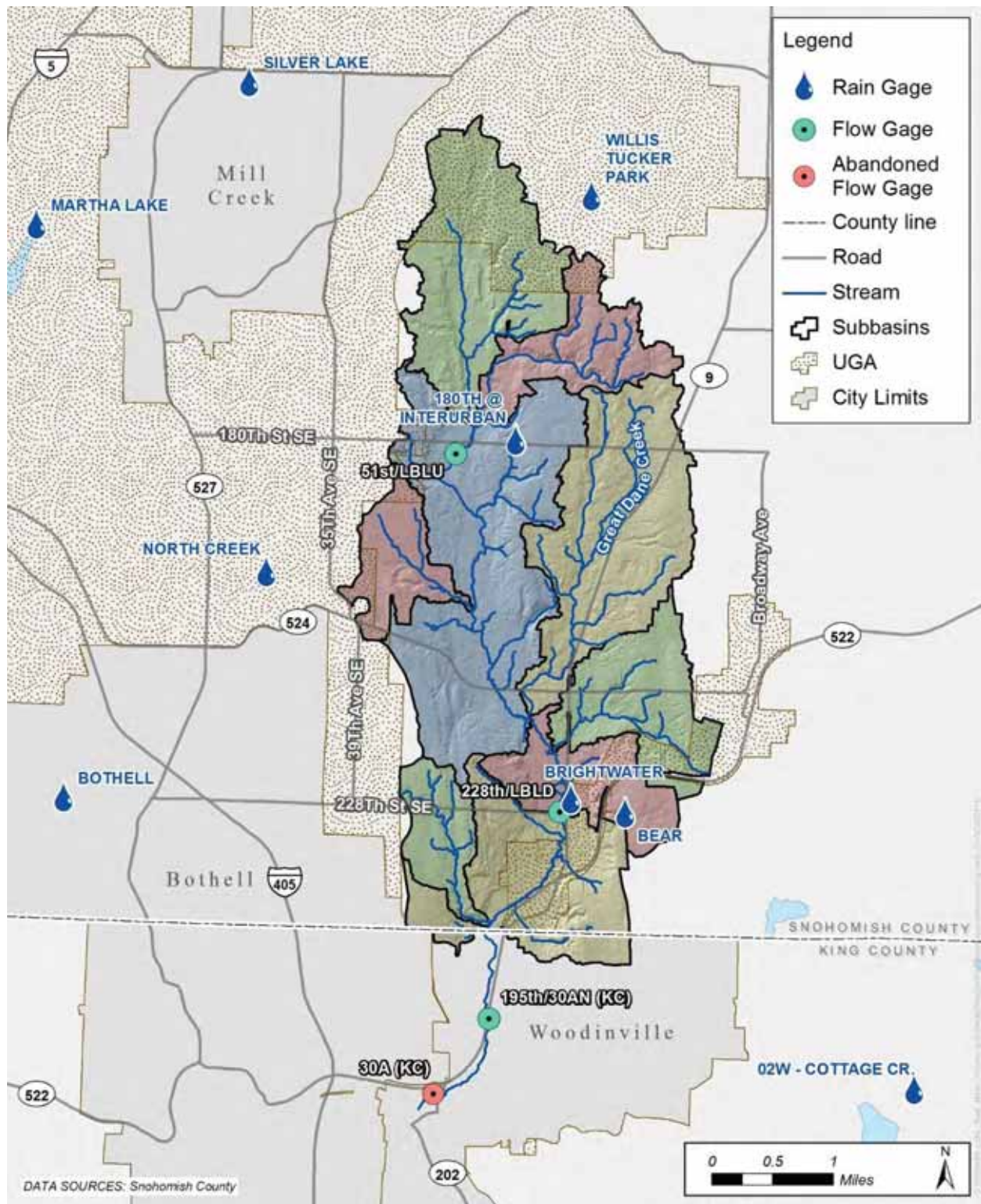


Figure 7. Hydrometric Monitoring Stations in Little Bear Creek Vicinity

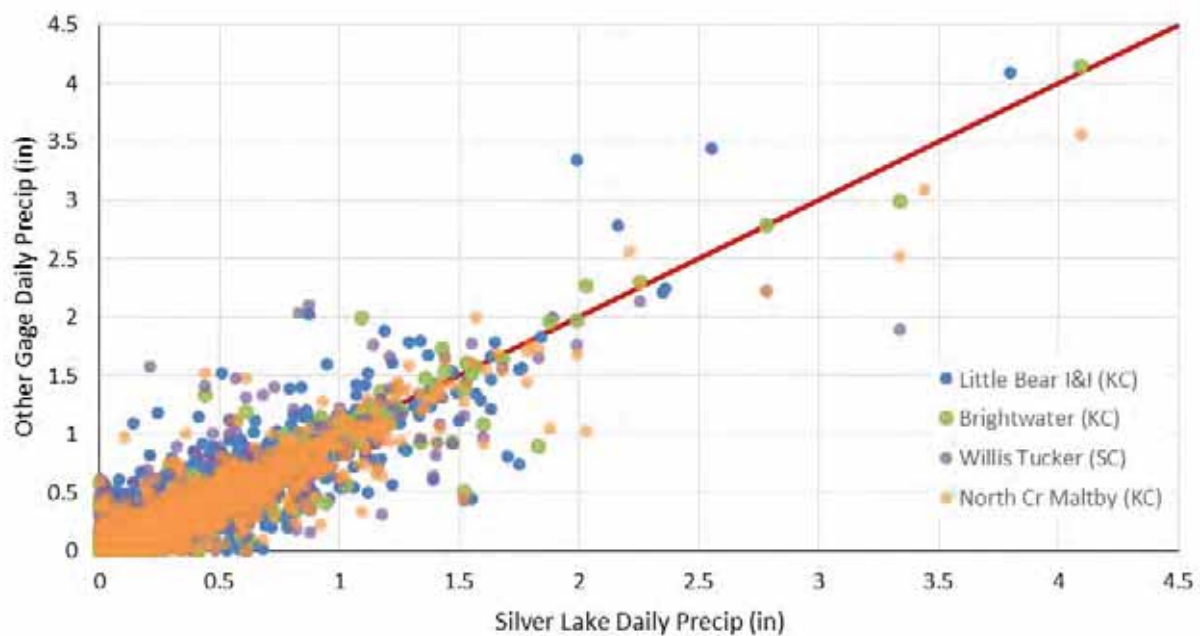


Figure 8. Daily Precipitation Comparison of Little Bear Area Gages to Silver Lake

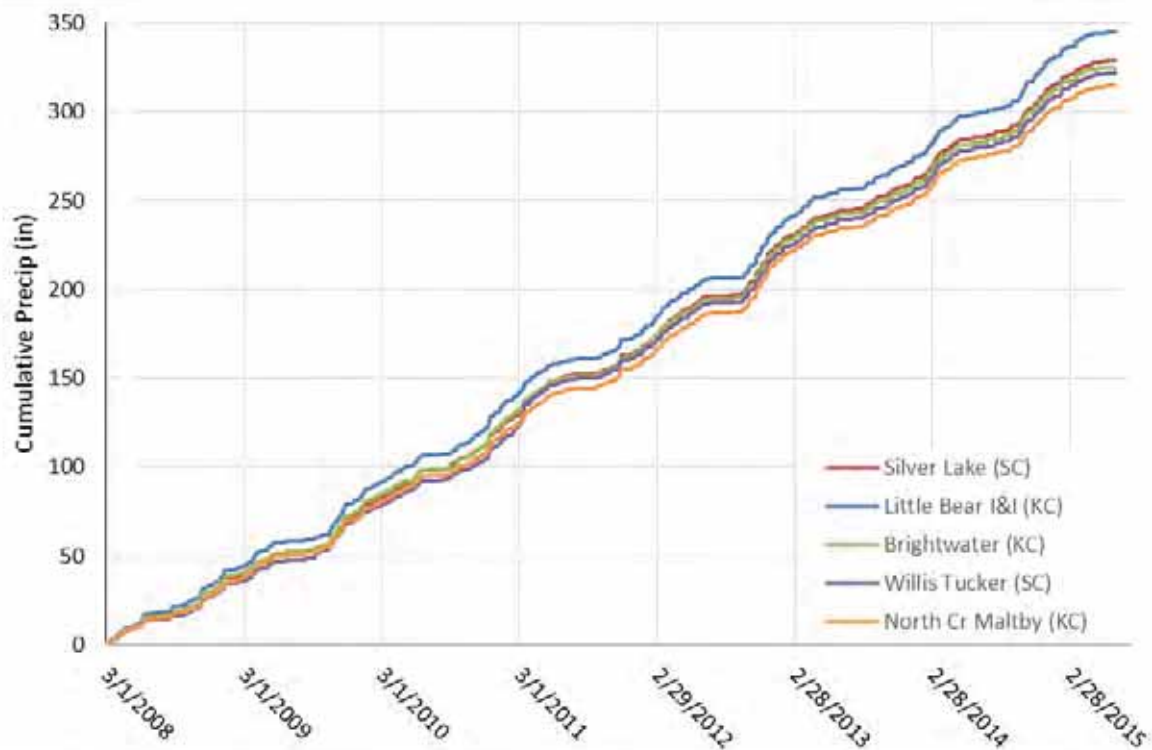


Figure 9. Cumulative Precipitation (2008-2015) for Little Bear Area Precipitation Gages



### 3.3 Streamflow

Streamflow on Little Bear Creek has been monitored continuously by King and/or Snohomish County since the late 1990s. Snohomish County has monitored streamflow on Little Bear Creek at 51<sup>st</sup> Avenue SE and 228<sup>th</sup> Street SE for more than 15 years. King County monitored streamflow at SR-202 near the mouth of Little Bear Creek (30A) from 1998 through 2007 when the station was relocated upstream to NE 195<sup>th</sup> Street (30AN) in 2013. Current and recent gage locations are shown in Figure 7 and Table 12 lists the available stream gage records. Table 13 summarizes flow statistics for these gages over their respective periods of record (through water year 2015).

**Table 12. Little Bear Creek Streamflow Gages**

Gage Location	County	Period of Record	Drainage Area (sq mi)
51 <sup>st</sup> Ave SE	Snohomish	2000-present	3.5
228 <sup>th</sup> St SE	Snohomish	2000-present	11.3
NE 195 <sup>th</sup> St (30AN)	King	2013-present	14.1
SR-202 (30A)	King	1998-2007	15.1

**Table 13. Comparison of Selected Streamflow Statistics**

Gage Location	Drainage Area (sq mi)	Mean Annual Flow		Mean Summer Flow <sup>1</sup>		Mean Annual Peak		Analysis Period (WY)
		(cfs)	(cfs/sq mi)	(cfs)	(cfs/sq mi)	(cfs)	(cfs/sq mi)	
51 <sup>st</sup> Ave SE	3.5	4.0	1.1	1.8	0.51	46	13	2001-2015
228 <sup>th</sup> St SE	11.3	16.5	1.5	6.0	0.53	257	23	2001-2015
NE 195 <sup>th</sup> St (30AN)	14.1	20.7	1.5	8.4	0.60	n/a <sup>2</sup>	--	2013-2015
SR-202 (30A)	15.1	22.0	1.5	8.7	0.68	287	19	1998-2007
<sup>1</sup> July – September								
<sup>2</sup> Period of record too short								

Table 13 shows that the flows per unit drainage area are notably lower for the upper basin gage (51<sup>st</sup> Ave SE) despite extensive residential development concentrated above the 51<sup>st</sup> Avenue gage. This difference is consistent for both peak flows, related to storm event response, and mean flows, which are more characteristic of longer-term runoff volumes. Relatively low runoff contribution to Little Bear Creek from this area is most likely associated with a regional groundwater divide (discussed further in Section 3.5) that diverts groundwater from a large percentage of the gage tributary area out of the basin to the Snohomish River.

Streamflow monitoring is being conducted at additional locations as part of the Little Bear Creek basin plan project. This information is anticipated to improve understanding of relative runoff contributions from different areas of the basin and to support hydrologic model calibration.

### 3.4 Wetlands

There are 872 acres of wetlands in the Little Bear Creek study area, shown in Figure 10. Nearly 60 percent of this area (over 500 acres) lies in a connected wetland complex in the Little Bear Creek valley extending from just south of 156<sup>th</sup> Street SE to the Great Dane Creek confluence. This large wetland complex is intersected by multiple road crossings, however, which may impact overall wetland quality. The Cutthroat Creek corridor is also characterized by a 55-acre band of wetlands extending upstream from SR-9. The remaining wetland area occurs in scattered upland wetlands and disconnected riparian wetlands along lower Little Bear Creek.

### 3.5 Groundwater

Snohomish County originally designated Critical Aquifer Recharge Areas (CARA) in 2000. The purpose of this designation was to identify and protect sensitive groundwater recharge areas and to further protect quality and quantity of groundwater water supplies in unincorporated County areas (Golder, 2000). Figure 10 shows areas within the Little Bear Creek study area that have been designated as CARAs. Much of the Little Bear Creek valley, as well as the Cutthroat Creek corridor, are designated as having medium aquifer sensitivity. High sensitivity areas are designated along the Little Bear Creek channel from approximately Cutthroat Creek to Howell Creek, and in the vicinity of the Rowlands Creek confluence just upstream of the county line.

The Vashon advance outwash layer (Qva) is the primary aquifer in Little Bear Creek as it is in much of the Puget Sound lowlands. The advance outwash layer is typically 20 to 100 feet below ground level in much of the Little Bear Creek basin (Golder, 2005). It surfaces in places along Little Bear Creek and where tributaries cut into the Little Bear Creek valley (see Figure 2), and these areas would be expected to be particularly susceptible to groundwater quality impacts from stormwater. On the tributaries, springs and seeps commonly occur where the advance outwash surfaces—in several areas marking the transition point between ephemeral and perennial flow. Spring locations observed during streamwalks conducted as part of this project (see Section 3.6.2) are also shown on Figure 10. On the tributaries, much of the baseflow observed during the summer streamwalks emerged at these spring locations. Cross Valley Water District's Woodlane Well (shown on Figure 10) taps in to the Qva aquifer within the Little Bear Creek basin, and there are dozens of smaller private wells within the watershed (Golder, 2005).

Hydrogeologic studies of the area dating back to a countywide USGS assessment in 1996 (Thomas et al., 1997) indicate a groundwater divide crossing the northeast portion of the basin, with groundwater flow to the north and east of the divide going to the Snohomish River. The location and angle of the divide through Little Bear Creek vary between sources (King County, 2005 (Appendix 6-B); Golder, 2005), so there is some uncertainty in terms of how much of the Little Bear Creek basin is affected. For purposes of hydrologic modeling, a divide location was assumed based on available mapping and calibration to streamflow data. Additional groundwater analysis or modeling is not planned for the current study.

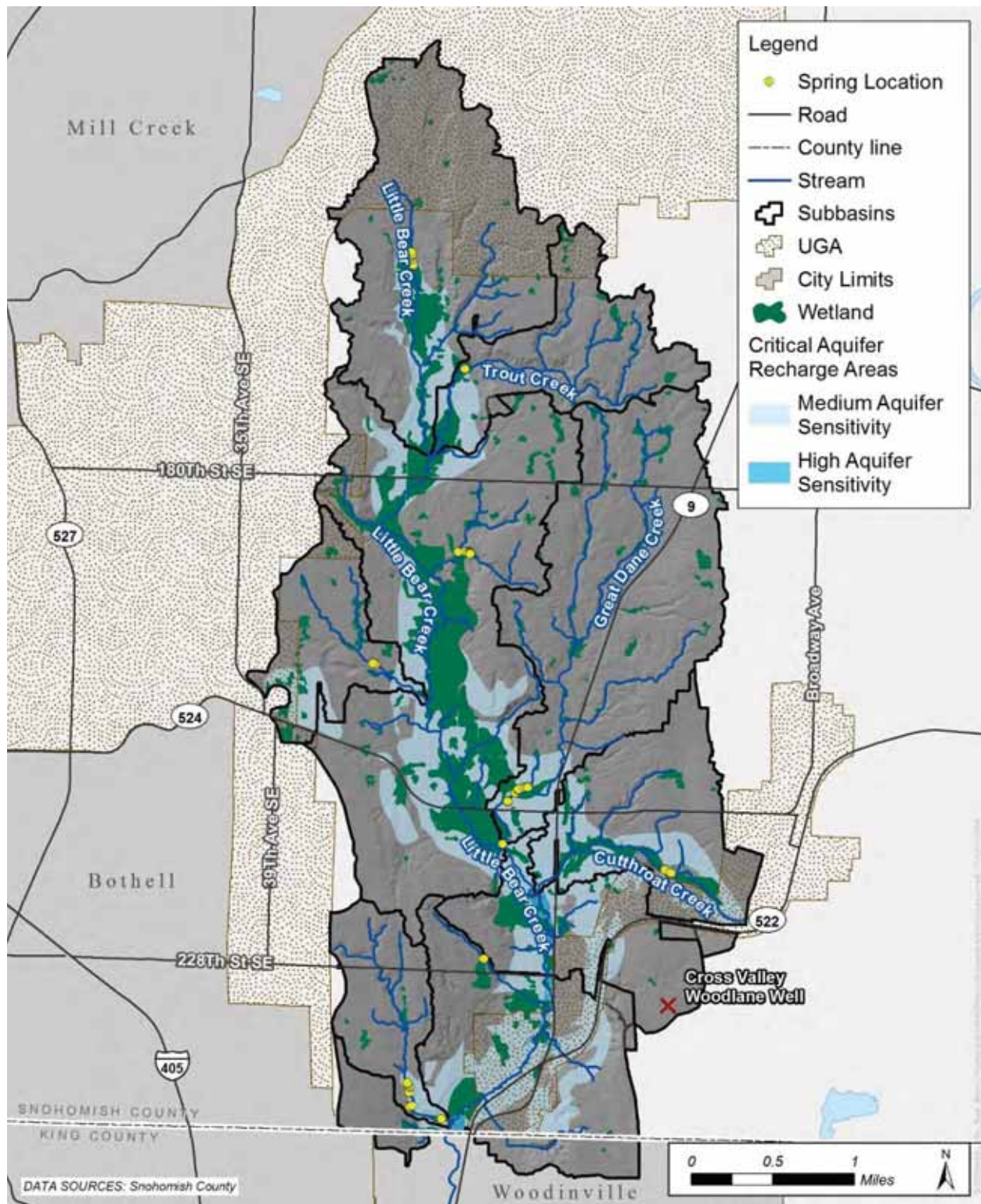


Figure 10. Wetland and Groundwater Features

## 3.6 Geomorphology

### 3.6.1 Previous Studies

Prior to this project, there had been little direct study of geomorphic conditions in the Little Bear Creek basin. Habitat studies conducted by King County (2001a) and the City of Woodinville (2002) included some observations of bank and channel conditions related to salmonid habitat assessment by NMFS's Matrix of Pathways and Indicators (NMFS, 1996). However, the Woodinville study did not extend north into Snohomish County.

King County (2001a) found that channels in Little Bear Creek were generally quite stable, as indicated by bankfull width to depth ratios. Only the segment between 228<sup>th</sup> Street SE and Great Dane Creek showed indications of over-widening (bankfull width to depth greater than 10). Bank stability was also high, with all reaches upstream of SR-524 (the study extended to 180<sup>th</sup> Street SE) reported as stable. Armoring and bank erosion were present between the county line and SR-524, though interspersed with stable reaches except downstream of 58<sup>th</sup> Avenue SE.

### 3.6.2 Geomorphic Assessment (Streamwalks)

Geomorphology, particularly as related to channel stability and sediment transport, is inextricably linked to hydrology and can impact water quality and biological conditions. To better understand this component of the Little Bear Creek system, a geomorphic assessment of reaches throughout the watershed was conducted as part of this project.

The existing geomorphic condition of stream channels and adjacent floodplains and hillslopes provides an indication of the geologic and current balance of sediment, flow, and vegetative conditions having an impact on the channel. Understanding these conditions can aid in interpretation of the history of flow conditions in the basin, processes governing channel response to flow changes, and sensitivity of the channel to potential future changes in the flow.

This assessment focused on modern channel conditions and fluvial processes active in Little Bear Creek. The Pleistocene glacial history, which is described in Section 2.2.1, shaped most of the basins topography and geomorphic structure, providing both the initial topography and sediment sources for the modern creeks. For example, much of the length of Little Bear Creek is underfit (*sensu* Dury, 1964, 1965) with respect to the creek valley. The larger valley was formed by glacial outwash flows that dwarf the present flow regime, so modern alluvial processes do not control the valley width or gradient. Elsewhere in the basin, tributaries are actively eroding through Pleistocene glacial deposits to enlarge their current valleys.

### Methods

As part of the Little Bear Creek Basin Planning project, field observations of geomorphic conditions in stream channels were collected at 60 reaches spread throughout the study area from the headwater streams down to the lowest reach of Little Bear Creek at the Snohomish/King County line (Figure 11).



Note that, as shown on the figure, many surveyed reaches were on unnamed tributaries. Unnamed streams in the Little Bear Creek network were assigned tributary IDs (letter or letter/number designations) for the purpose of reporting and reference in this analysis. In addition, it is important to note that river mileages referenced in figures and text in the following discussion are defined as distance along the flow path from the point of interest downstream to the outlet of Little Bear Creek. The locations of these reaches were selected to maximize the spatial coverage of the field data collection effort, within constraints defined by property access. Data were collected in wadeable streams, based on an approach modeled extensively on Snohomish County's habitat survey protocol (Rustay et al., 2008). Depending on type, data were collected continuously or at regularly spaced intervals along assessment reaches.

Reach-average slopes were estimated from stream cross sections extracted from the LiDAR topography and field-measured channel length. Channel bankfull widths and depths were determined (in order of priority) from an existing hydraulic model of Little Bear Creek and major tributaries, field survey, or bank height measurements at interval locations and photos of the stream. In an alluvial channel, the bankfull stage corresponds to the top of alluvial stream banks and the corresponding level of adjacent floodplain surfaces, if present (Osterkamp in Goudie, 2004 p. 52; Osterkamp, 2008). Flows above this elevation will inundate the floodplain, while flows below this level are confined to the channel. In an alluvial channel where channel size and shape are adjusted to current flow and sediment regimes, bankfull stage usually corresponds to a flood with a recurrence interval between about one and three years (Petit and Pauquet, 1997; Castro and Jackson, 2001). In areas of non-alluvial channels, the top of bank features were identified by a break in slope, if present, between the valley wall and channel boundary, or by ordinary high water indicators, such as edge of perennial vegetation. Approximate contributing drainage area for each reach was estimated using stream-channel drainage-enforced LiDAR topography, but not including flow contributions or diversions from infrastructure.

Data were aggregated into 200- to 400-foot long stream intervals, with interval length depending on the bankfull width of the stream (i.e. smaller streams used shorter intervals). Data were normalized, as appropriate, to stream length, area, and bankfull width to facilitate comparison and are summarized in Appendix B (Tables B1 through B5).



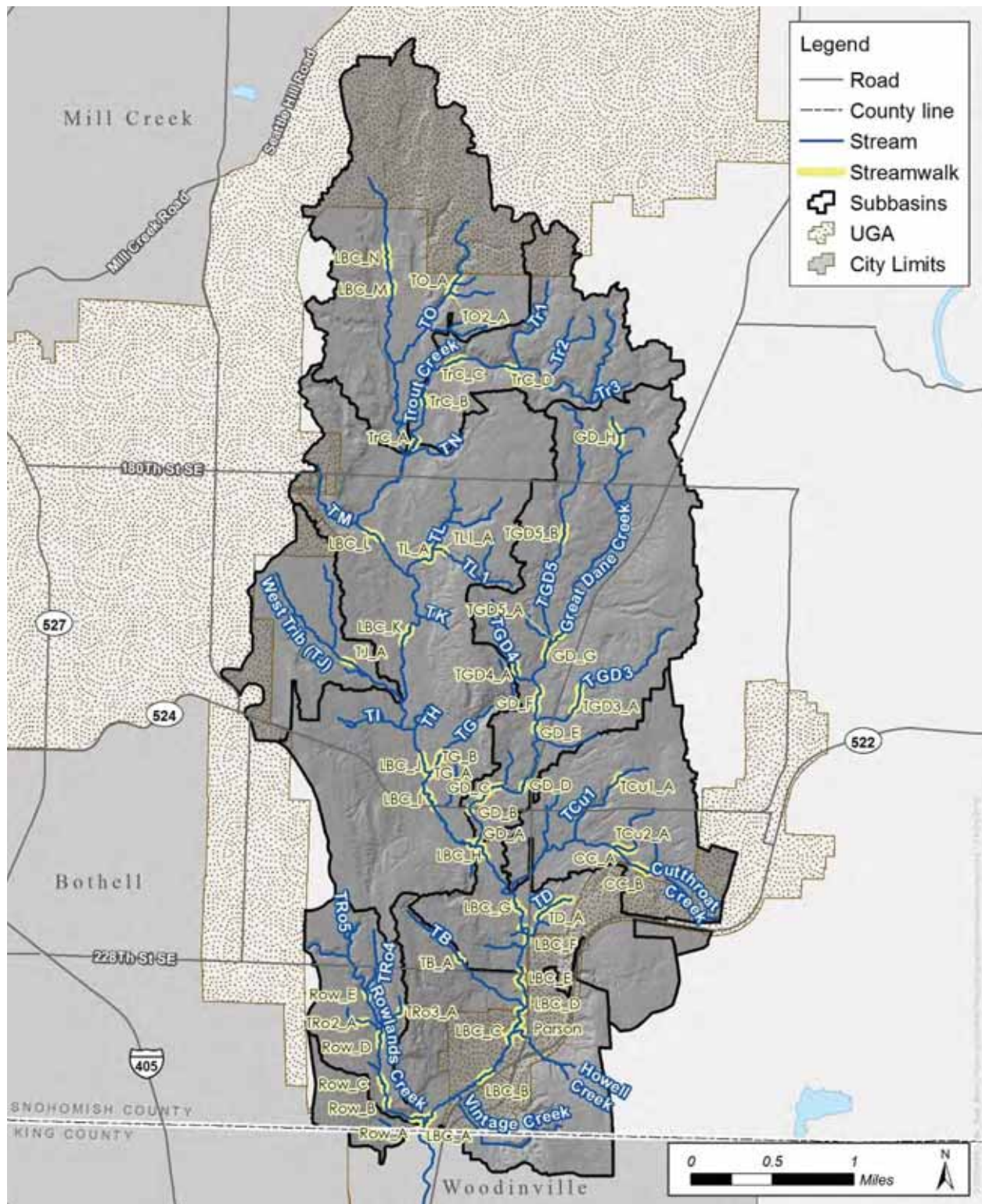


Figure 11. Locations of the Little Bear Creek stream network surveyed following the streamwalk protocol.

Key data describing conditions along the channels were plotted in a series of stacked graphs (presented as Figure 14 through Figure 18 later in this section) that depict both controlling factors—defined by topography, aerial photos, and surrounding geology—and channel conditions. In each set of plots, the top plot shows the channel profile and change in contributing area. The next three plots are strip plots depicting geological material surrounding the channel, channel morphology, and bank vegetation. Dominant channel morphology for each surveyed reach is categorized as colluvial, step pool, wood-forced step pool, plane bed, pool riffle, and dune ripple conditions following the approach of Montgomery and Buffington (1997). The remaining plots are bar and proportional bar charts showing the proportion of total bank length that is revetted (protected by riprap, constructed wood features, gabion baskets, or similar) or eroding, the proportion of the total area occupied by various types of geomorphic units (described below), large wood abundance, and the distribution of dominant substrates (channel bed materials). Geomorphic units were categorized in the field following the definitions given in Appendix B. Dominant substrate is defined as the single most abundant particle size class on the bed, which is not necessarily greater than 50 percent. Boulder, cobble, gravel, and sand follow standard (Wentworth, 1922) size breaks. Fines refers to both silt and sand.

## Channel Conditions

### *Small tributaries and channel-head locations*

In many places, the stream channel mapping used to define field survey locations extended above the extent of channelized flow. Locations without channelized flow were identified in the field and not surveyed in detail. Areas above the channel head are places where the current surface flow is not sufficiently capable of eroding the ground surface to initiate channel formation. The land surface at these sites was often vegetated, which provided an added layer of resistance to channel formation. It is not until the flow from the drainage area has increased to become sufficient to erode the vegetation cover, or that cover is otherwise disturbed, that the subsurface soil or sediment can erode to develop into a channel form. Small tributaries and headwater segments below the channel head typically had bankfull widths of two to five feet, and less than one square mile of contributing basin area.

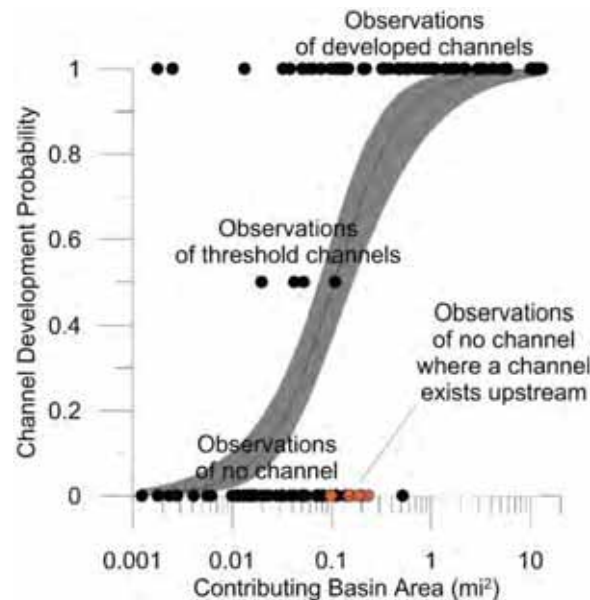
The location of channel initiation is important, because field observations suggest that this is an area particularly sensitive to changes in flow regime. Well-developed channels down-valley can adjust to changes in flow regime by coarsening of bed material or slight increases in channel width and sinuosity. Far up-valley of channel heads, historic surface flow has not been capable of significantly eroding surface soils or underlying sediment, and the incremental change from existing and historic conditions required to reach this threshold is much greater. In contrast to these more stable areas of the stream network, in the vicinity of channel heads, stability of the soil surface is contingent on the added strength of vegetation roots concentrated in the shallowest portion of the soil profile (e.g. Figure 12). Once the power of the flow is sufficient to erode through the surface of the soil (which is stabilized by the vegetation roots) it substantially exceeds the shear stress required to mobilize any underlying soil and sediment. Thus, concentration of flows at or above the location of the channel head can trigger major erosion and downcutting and extend the channel up-valley, increasing drainage density and flow conveyance efficiency.





**Figure 12. Photos illustrating the important role of plant roots in stabilizing the soil surface near channel-head locations.**

Figure 13 summarizes observations used to infer channel head locations and shows the results of a logistic regression<sup>1</sup> that predicts the probability of channel development by the contributing basin area. Although there is substantial overlap in the region of observed developed channels and observed absence of channels, the significant logistic regression ( $X^2 = .122$ ,  $df = 1$ ,  $p < 0.00001$ ) and observed threshold channels both indicate that most channels form around 0.1 square mile of contributing area, although some form at much smaller basin areas and channels may not be present at larger basin areas. Thus, it was possible to define the approximate drainage area where channelization typically begins in the Little Bear Creek study area basin.



**Figure 13. Observations of channel presence/absence and logistic regression predicting probability of channel presence. Gray shaded region represents the 95 percent confidence bounds for the results of the regression.**

Variable hydrologic response due to impervious surfaces, soil conditions, and underlying geology likely accounts for most of this scatter, although riparian land cover in areas near the threshold of channel development is also important. There are several locations where channels disappear from upstream to downstream with increasing drainage area (shown in brown in Figure 13). These areas consistently have underlying outwash soil that is highly permeable and are immediately downstream of a till soil, where infiltration through the soil column is restricted by a low permeability hardpan layer, typically within a couple of feet of the ground surface. This spatial correlation suggests that flow leaving the till-based channel is infiltrated into the outwash and continues down-valley as subsurface flow.

<sup>1</sup> Logistic regression is a statistical tool used to predict a binary outcome from continuous, overlapping data. Here the method of Pezzullo (2014) was applied.



### *Little Bear Upper*

The Little Bear Upper subbasin extends from the headwaters of the stream, where it emerges from a series of stormwater control ponds just north of 156<sup>th</sup> Street SE at RM 10.9 and continues downstream to the confluence with Trout Creek at RM 8.4. Most observations in this area were from the most upstream reach (Figure 14).

No flow was observed at the 156<sup>th</sup> Street SE crossing. However, significant flow was present in the highest surveyed interval (LBC\_N4 in Figure 11) approximately 600 feet downstream. Five springs were observed in this upstream-most reach, and the stream gained substantial flow from upstream to downstream. A local landowner indicated that the amount of flow and extent of saturated ground around the springs had increased since stormwater ponds were constructed up-valley. The bankfull width in the reach is about five feet. The slope decreases from approximately 3 percent to 0.3 percent across the highest surveyed stream interval, and the bed material transitions from gravel- and cobble-dominated upstream to sand with a minor amount of gravel downstream.

In the next surveyed segment, about 600 feet downstream, Little Bear Creek flows through a large wetland with a very low slope. Bed material in the wetland is dominated by organic material, mud and some sand.

No streamwalk data were collected over a long segment of the stream between the area described above and downstream of the Trout Creek confluence, but supplemental observations were possible at road crossings. At the West Interurban Boulevard crossing of the stream (RM 8.9) the bed was sand-dominated with some gravel, and areas observable from the road right-of-way that were outside of the immediate culvert influence had plane-bed morphology. The confluence between Little Bear and Trout Creek occurs in a large wetland influenced by both a road embankment and beaver activity that extends downstream from RM 8.6 to 180<sup>th</sup> street (RM 8.3).

The only surveyed tributary in Little Bear Upper subbasin was Tributary O. The surveyed reach of this tributary lies just downstream of the transition in surface geology from till to outwash. The surveyed reach was generally stable, with some scour downstream of a private driveway culvert. The tributary flows through sandy outwash-derived soil, which could be susceptible to significant erosion at higher flows. A downstream segment of Tributary O was visited but not surveyed because there was no defined channel.



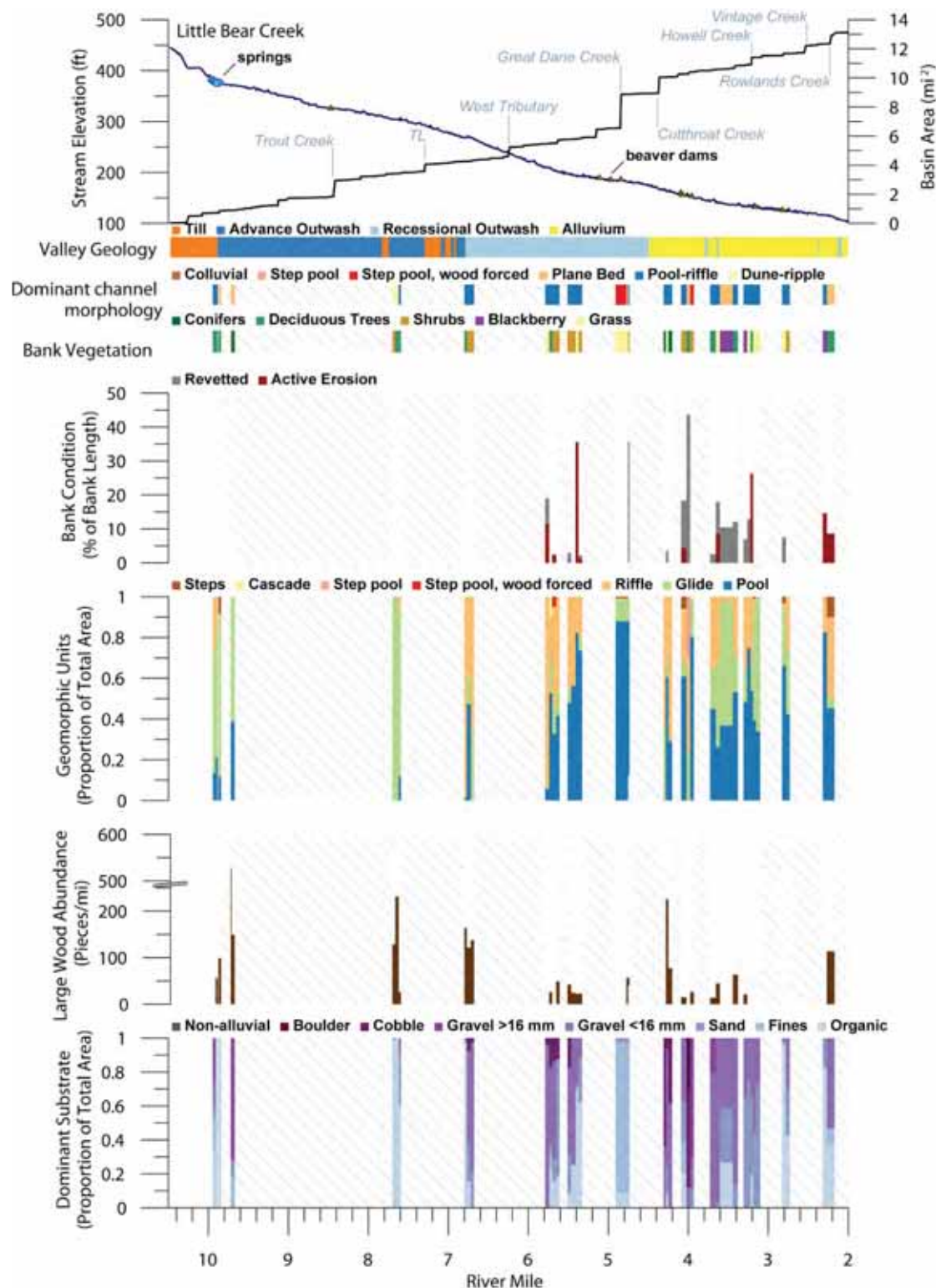


Figure 14. Stacked series of plots summarizing observed geomorphic conditions along Little Bear Creek. No systematic observations following the stream walk protocol were collected in dashed areas, while blank zones indicate no observations of that class collected in the reach.

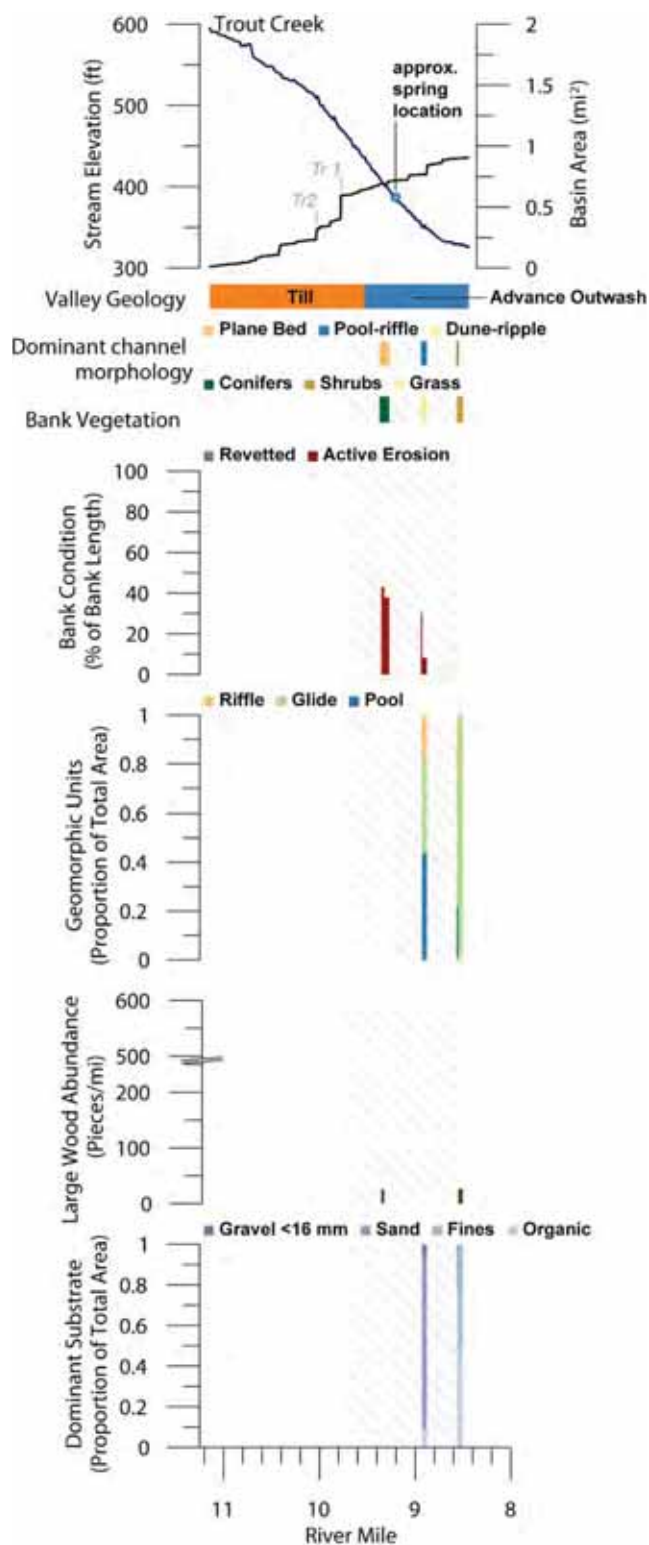
## Trout Creek

Four reaches of Trout Creek were surveyed (see Figure 11), with contributing basin areas ranging from approximately 0.4 to 1 square mile. In addition, several road crossings upstream of surveyed reaches were visited. At one planned survey reach upstream of the surveyed reaches, no developed channel was observed.

The most upstream surveyed reach (TrC\_D in Figure 11) has incised one to two feet into weathered till soils sometime in the past several decades, as indicated by the presence of channel-spanning tree roots. Mature riparian forest around the creek is intact. Because the creek is incising through more erosion-resistant till, bank positions are quite stable. A large volume of angular gravel was present at the confluence of Trout Creek and tributary Tr1, indicating an upstream sediment source somewhere on tributary Tr1, which was not surveyed.

The next surveyed reach downstream (TrC\_C) occurs just below the boundary between till and advance outwash in underlying materials. The channel in this reach is incising into outwash sediment and expanding laterally. As the bed and banks are eroded, gravels are added to the channel.

The two furthest downstream surveyed reaches on Trout Creek (TrC\_A and TrC\_B) cross an alluvial fan. Local residents indicated that a perennial spring supplies water to the creek at a location near the head of this fan. The creek's gradient and bed material size decrease with distance from upstream to downstream over the alluvial fan, transitioning from cobble- and gravel-dominated at the W Interurban Boulevard crossing (RM 9.0) to fine sediment and organic-dominated where the stream flows into the large beaver-dam formed wetland at its confluence with Little Bear Creek. As gravel and cobble is deposited in the channel along the alluvial fan, the channel shifts laterally, eroding a combination of poorly-graded alluvial (or recessional outwash) gravel underlying alluvial sand and silt.



**Figure 15. Stacked series of plots summarizing observed geomorphic conditions along Trout Creek.**

### *Little Bear Middle – Trout Creek to Great Dane Creek*

The profile of this segment of Little Bear Creek (see Figure 14) is characterized by a knickzone, that is, a reach that is locally steeper than those upstream or downstream. The result is a channel with bed slope that increases with distance downstream in the upstream portion of the reach and then flattens out in the downstream portion. The reach begins at the confluence of Little Bear and Trout Creek, which occurs in the large beaver-dammed wetland that extends downstream to RM 8.3. From there, observations from the road right of way at the upper 51<sup>st</sup> Avenue SE road crossing (RM 8.0) and surveyed reach LBC L (RM 7.6-7.7) indicate the bed material in the upper portion of this reach is dominated by sand, with small areas of exposed gravel that do not appear to have been mobile during recent flows. As the gradient increases downstream, gravel comprises a greater proportion of the channel bed surface. The source of the high sand content on the bed was not identified. It most likely comes from local bank erosion along Little Bear Creek between the 180<sup>th</sup> Street SE crossing and the observation sites and/or Tributary TM, where no survey occurred. The LBC L reach had among the highest large wood loads of any of the reaches surveyed, with 100 to 200 pieces of large wood per mile and stable banks.

Surveys along the lower portion of this segment (RM 7.3 to Great Dane Creek confluence at RM 4.8), where the gradient is declining in the downstream direction, show that this is an area of gravel and cobble deposition. Bed surface sediments change with distance downstream, from cobble- and gravel-dominated upstream to predominantly sand, fines, and organic material as the slope decreases. Deposition of gravel and cobble as bars in the channel has shifted channel flow toward the banks, causing bank erosion. As a result, particularly in reaches LBC J and I, up to 40 percent of the total bank length in surveyed reaches is eroding. Bank erosion in this area typically mobilizes gravel and sand at the bank toe and fine overbank alluvial or wetland deposits over most of the bank height, thus contributing mostly fine-grained sediment to the stream. By the time the creek reaches the Maltby Road (SR-524) crossing, it has deposited nearly all of the gravel and coarser bed load from upstream and carries primarily sand. Downstream of Maltby Road, the creek flows into a beaver-dammed wetland complex that was not surveyed in detail. Bed material in this area is dominated by sand, fines, and organics, and the channel is virtually flat between elevation drops at beaver dams. In reach LBC I, some properties have lawns maintained to the edge of the creek, replacing native vegetation that adds greater bank strength. In one case bank erosion has exposed a network of buried pipes which may be related to a drain field.

In addition to the West Trib (tributary J in the streamwalk naming convention), three small tributaries (F, G, and L) were surveyed in the Little Bear Middle subbasin. These streams were similar to other small tributaries throughout the basin (see small tributaries discussion above), with the following notable local conditions:

- A large pond approximately 100 feet upstream of Little Bear Creek Road intercepts nearly all sediment transported by Tributary G. Immediately downstream of the pond, the creek is eroding into fine sediment and peaty organic material. However, within 100 feet downstream of the pond outlet no incision was observed. By the time the tributary reaches with Little Bear

Creek, the tributary appears to be very stable with a consolidated bed of fine and medium gravel.

- The channel bed along Tributary L, and particularly Tributary L1, has both a steep slope and high sand content with very little bed surface armoring. This combination of factors suggests that the bed material is anomalously mobile and that significant erosion is occurring somewhere upstream of the surveyed reach. Relatively high bank instability and lateral channel migration were also observed in the surveyed reach; in several locations this migration impinges on the valley margins, resulting in erosion of material interpreted to be heavily weathered till. Nonetheless, physical habitat conditions along the lower surveyed segments (Intervals TL A1 and TL A2) appeared quite good, with abundant LWD and pools.
- A private culvert just downstream of the surveyed reach of Tributary L creates an apparent fish passage barrier, with a drop of about 1.8 feet between the culvert outfall and the 1.5-foot deep scour pool beneath it.

### *West Trib*

Only one reach was surveyed along the West Trib (also labeled as TJ in Figure 11). Observed conditions in this reach were similar to other small tributaries in the basin. The surveyed segment reach had a riparian area dominated by coniferous trees and abundant in-channel wood creating wood-forced step-pool and pool-riffle and dominated morphology. The substrate is cobble-gravel dominated with high embeddedness and abundant overlying sand and fines.

### *Great Dane Creek*

Eight reaches of Great Dane Creek were surveyed, with contributing basin areas ranging from approximately 0.1 to 2.3 square miles. Most of the upper portion of the creek and its tributaries flow through broad, relatively poorly defined valleys that are underlain by glacial till. At approximately RM 5.9, between reaches GD E and GD D, the creek valley cuts through the till mantle. Here it abruptly enters a ravine, formed in the outwash, that extends downstream to approximately RM 5.3, where Great Dane Creek enters the broad Little Bear Creek valley. At the edge of the main Little Bear Creek valley (between RM 5.3 and 5.2), the creek incises slightly into an erosional (strath) terrace underlain by clayey deposits interpreted to be transitional outwash beds. Multiple springs were observed in this location, where the channel intersects groundwater flow along this relatively impermeable layer. At RM 5.2, the creek emerges onto an alluvial fan that extends into the Little Bear Creek Valley. Higher bed elevations at the Little Bear Creek confluence associated with this fan are the likely reason for the relatively low gradient of Little Bear Creek upstream of the Great Dane confluence, (described in the previous section).

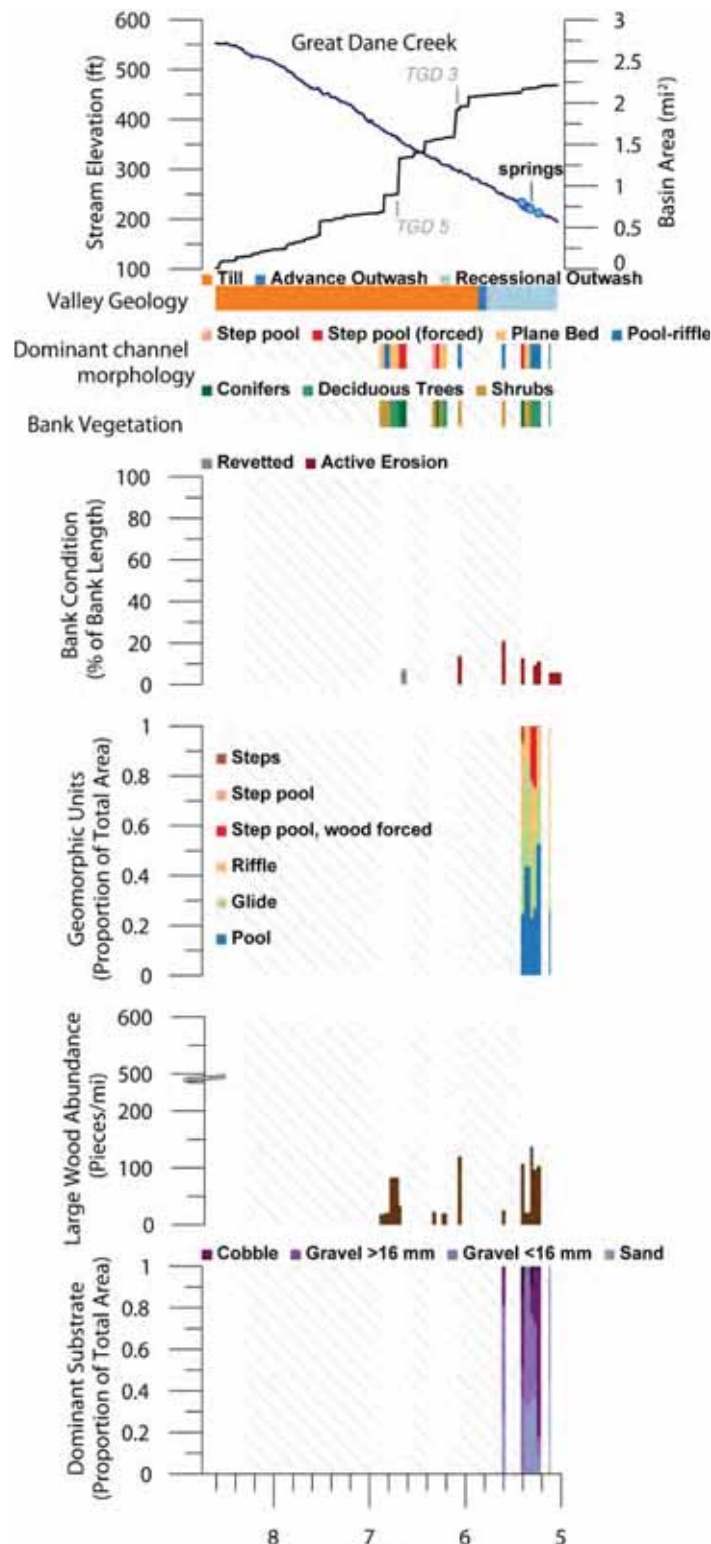
The upstream-most observed location along Great Dane Creek was at approximately RM 8.35, where unchanneled wetland areas alternated with a very small (approximately two-foot bankfull width) channel.



Observations around the confluence of Great Dane Creek and Tributary TGD5 (the other main headwater channel in the Great Dane subbasin) at RM 6.7 suggest that the increase in flow across the confluence has destabilized the channel downstream. Upstream of the tributary confluence, the general channel grade appeared to be stable. Downstream of the confluence, persistent channel bed erosion was apparent. The channel bed was characterized by exposed till and large steps between locations where the grade is locally controlled by tree roots or large wood. Downcutting in this area is mobilizing coarse sediment from the bed and widely graded material from the patchily exposed till.

Observations along the next surveyed reaches downstream (GD F RM 6.19-6.35 and GD E RM 6.04-6.08) suggest that these reaches are vertically stable. This is likely because the reaches downstream of RM 6.4 have a much lower slope (1.5 percent) than the unstable reach upstream (3.1 percent), are surrounded by dense riparian vegetation, and are stabilized by the presence of in-channel wood. Local instability occurs at the downstream edge of reach GD E, where an extremely wide culvert was installed in 2007. With no vegetation within the culvert to provide tensile strength, the channel banks are prone to erosion and the channel is widening within the culvert itself.

The channel of Great Dane Creek is unstable from where it cuts through the till mantle downstream through the alluvial valley incised through outwash. This instability is consistent with the local geological controls: 1) the slope increases slightly (to about two percent) below the knickzone at the edge of the outwash and 2) bank materials become more erodible. Instability was observed in Reach GD D (RM 5.58-5.62) and locally upstream (RM 5.72-5.79) where the creek was observed from private culvert crossings and the SR-9 right-of-way. In this area, lateral channel instability (and possible downcutting) has eroded a large volume of outwash cobble, gravel and sand. At RM 5.75, the channel has eroded the fill



**Figure 16. Stacked series of plots summarizing observed geomorphic condition along Great Dane Creek.**



supporting the shoulder of SR-9 and a nearly vertical bank extends to the guardrail.

The creek transitions from the confined eroding outwash valley towards its alluvial fan as it crosses reach GD C (RM 5.21-5.42). A deposition zone was noted just upstream of the surveyed reach. This occurs at a site where the valley bottom width increases and just upstream of a constriction formed by a private culvert. Between RM 5.38 and 5.42, groundwater emerging from many springs along the channel banks contributed nearly all of the creek's baseflow. This reach corresponded to a location where outwash overlies an area of thinly laminated clay and silt observed on the streambed (but not indicated at the surface in existing geological maps). This material is interpreted to be the advance outwash transitional beds mapped cropping out along the east valley wall to the south (Minard, 1985). One bank mass failure was noted in this area, consistent with Minard's observation that the unit is prone to instability because of high moisture content and plasticity.

As the creek crosses the alluvial fan (RM 5.21 and downstream), channel gradient decreases and surface bed material becomes smaller. By the time Great Dane Creek reaches the confluence with Little Bear Creek, its bed is composed nearly entirely of sand and finer material.

#### *Little Bear Lower 228th – Great Dane Creek to 228<sup>th</sup> St SE*

Immediately downstream of the Great Dane Creek confluence, the Little Bear Creek floodplain contracts from the 200- to 600-foot widths characteristic of upstream reaches to approximately 150 feet, and slope increases from nearly flat to approximately 1.1 percent. The bed material coarsens from sand and finer to cobble and gravel material. Given that coarse bed material was not observed in the reaches of Little Bear and Great Dane creeks immediately upstream of this location, the bed coarsening is not attributable to upstream supply. This would suggest that either the coarse material is relatively immobile or that the channel is downcutting. Because there are no indications of downcutting in this area, the bed material must be very stable. Aerial photos and LiDAR topography indicate the creek has intact mature riparian forest and exhibits a similar slope and narrowed floodplain from its confluence with Great Dane Creek to its confluence with Cutthroat Creek at RM 4.38.

The first surveyed reach downstream of Great Dane Creek begins about 300 feet downstream of the confluence with Cutthroat Creek (RM 4.4) and extends downstream to RM 4.20. A large portion of this reach is revetted with hard bank protection features to protect homes built adjacent to the creek. The reach has pool-riffle morphology, abundant wood, and a bed surface dominated by cobble and gravel.

The downstream-most surveyed reach in this area (LBC F) shows a strong influence from beaver activity. Most of the drop occurs at three or four separate beaver dams, the most upstream of which impounds a very large pond. At this large pond, flow spills over the crest of the dam and into a broad area where new channels are eroding through silt and sand overlying gravel. In addition to the beaver dams, a significant break in the grade occurs where the creek abuts SR-9. Riprap along the highway embankment has formed a grade control feature over which water cascades.

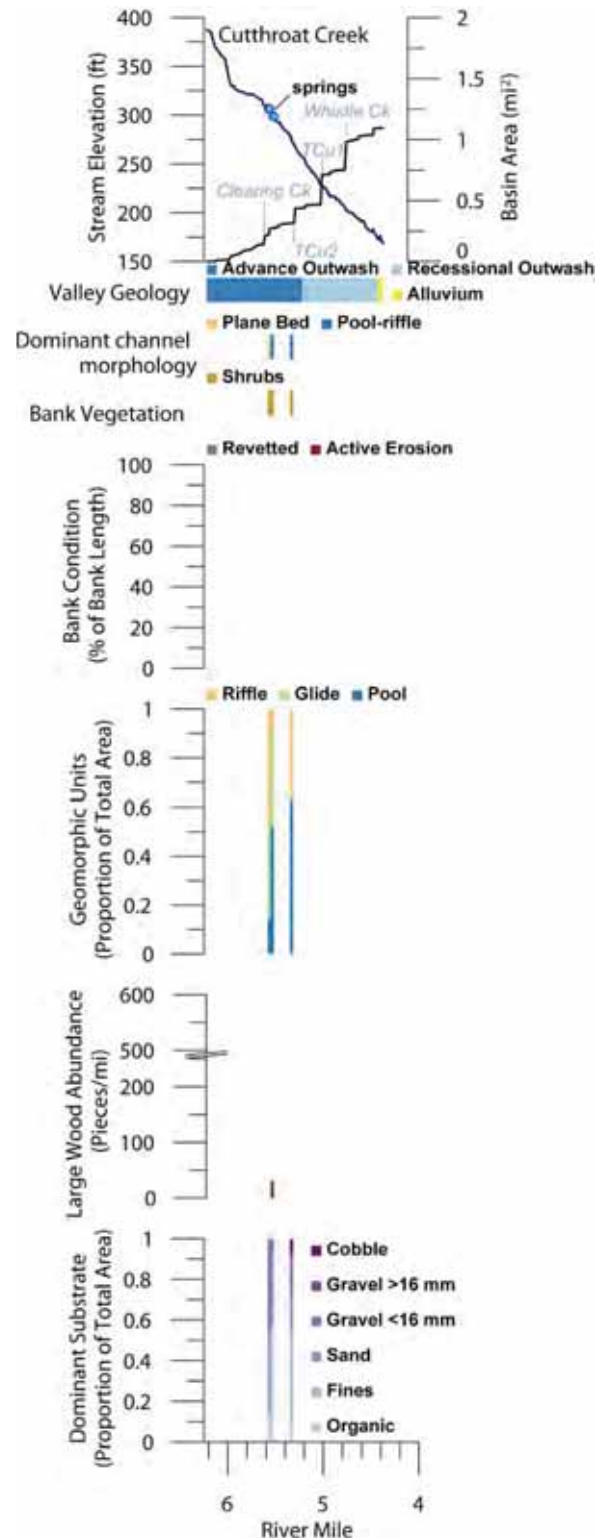
In addition to Cutthroat Creek (described below) two other significant tributaries enter this reach:

- Nearly the entire length of Tributary D was surveyed. This tributary has a steep slope (three to five percent). The upstream portion of the tributary is downcutting through outwash, eroding substantial volumes of gravel and sand. The downstream portion of the tributary has been reconstructed through the north end of the Brightwater Wastewater Treatment Plant property. It flows through two large ponds and then through a culvert under SR-9 into Little Bear Creek. These ponds are intercepting much of the sediment generated upstream, which may have been previously delivered to Little Bear Creek. Flow from Tributary D into Little Bear Creek was notably warm (19°C) at the time of survey (7:55 AM on August 21, 2015).
- An unmapped tributary enters the channel in the lower portion of reach LBC F. Here, substantial flow exits a large constructed wetland that is presumably groundwater fed because there is no upland valley associated with the tributary.

### *Cutthroat Creek*

Cutthroat Creek flows almost entirely through a valley bounded by outwash sediment; near its mouth, it crosses alluvium deposited by Little Bear Creek. Although obscured by fill in the eastern headwaters, the combination of mapped underlying geology and extremely wide valley relative to the size of the creek suggests that Cutthroat Creek follows the course of a much larger relict outwash channel that once connected the Little Bear Creek Basin to the adjoining Crystal Lake Basin.

Only two reaches of Cutthroat Creek were surveyed, both of which are relatively close to the stream's headwaters. Both reaches have natural riparian conditions dominated by wet deciduous forest with a thick understory of mostly vine maple and salmonberry. Bed material is gravel- and sand- dominated with some cobble. Large wood in the active channel is relatively sparse. The narrow channel width means that most large wood spans the small creek channel. No areas of revetment or



**Figure 17. Stacked series of plots summarizing observed geomorphic condition along Cutthroat Creek.**

significant active erosion were noted along the surveyed reaches of the creek, except in the immediate vicinity of a culvert replacement, where the grade is adjusting upstream and eroding a small amount of bed material.

Two tributaries were also surveyed:

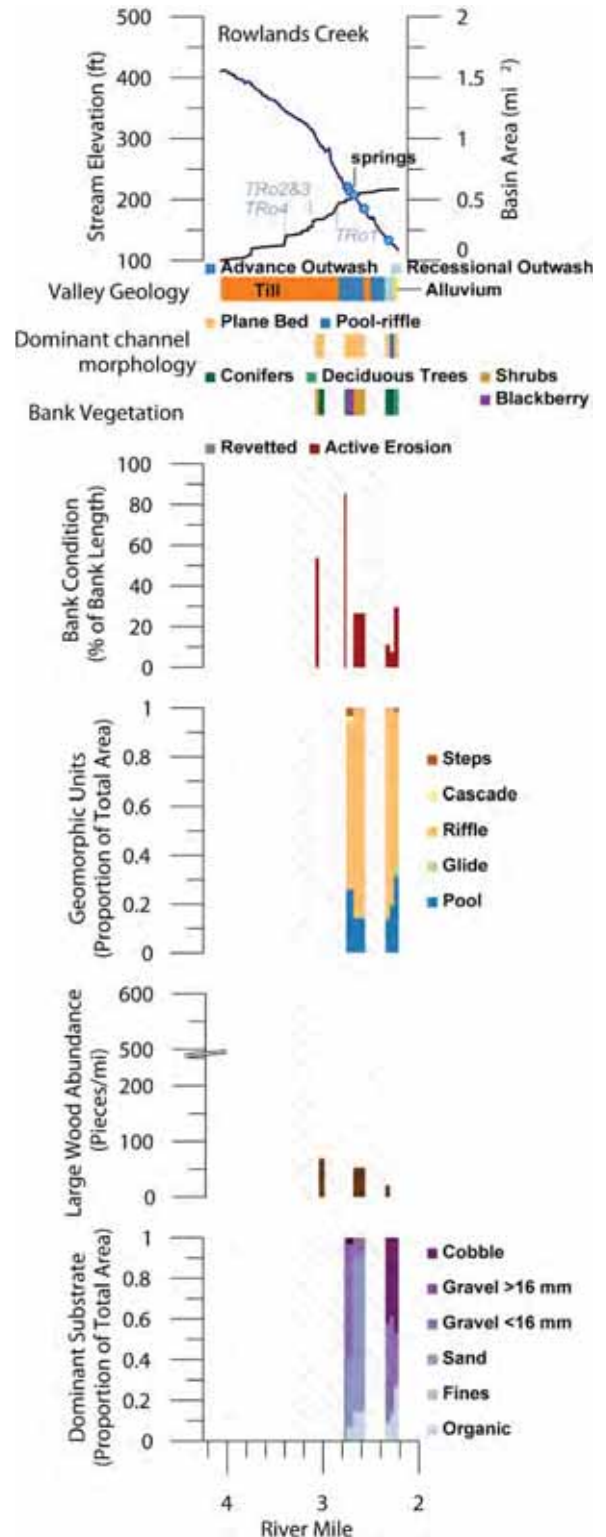
- A site relatively far upstream along TCu1 (RM 5.56, 0.13-square mile contributing area) showed signs of incipient channel development, with local areas of surface erosion on the valley bottom. Much further downstream (RM 5.25, 0.18-square mile contributing area), no channel was present. The valley topography indicates that valley bottom material has transitioned from till to outwash at the downstream site, suggesting that stormwater infiltrates into the ground between the two sites.
- Major erosion was observed on TCu2. The channel has downcut through outwash soil up to three feet below the historic valley bottom (see Figure 12).

### Rowlands Creek

A large proportion of the total Rowlands Creek profile flows through a valley carved by glacial meltwater slightly incised into till, and most of the basin area is underlain by till. At about RM 3, the creek plunges into a ravine deeply incised through advance outwash. At the base of the ravine, the creek emerges onto a small alluvial fan extending into the Little Bear Creek Valley.

The farthest upstream surveyed reach on Rowlands Creek is just downstream of the confluence of TRo4 and the Rowlands Creek mainstem. Above the confluence, a couple of observations at road crossings suggested that the creek alternates between stable and downcutting segments. Below the confluence, two- to three-foot high vertical banks and large steps at locations stabilized by wood and roots indicate that the creek is downcutting through heavily weathered and relatively easily erodible glacial till.

The most concentrated area of erosion observed anywhere in the Little Bear Creek study area occurs on Rowlands Creek just below the transition from till to outwash geology. At the transition (Row D RM 2.99-3.08), the creek is very steep (seven



**Figure 18. Stacked series of plots summarizing observed geomorphic condition along Rowlands Creek.**



to ten percent slope) with little stabilization from wood and riparian tree roots. High banks suggest the channel is aggressively downcutting. The creek then passes through a long culvert, which provides vertical grade control. Immediately below this culvert (in an unsurveyed reach viewed from an adjoining property), the channel has downcut six to ten feet, eroding a large volume of sand and gravel.

Approximately half a mile downstream, (Row C, RM 2.68-2.78), the vertical profile of the creek appears to be more stable, but meanders eroding the edge of the incised valley are undercutting the adjacent hillslope, initiating landslides, and indirectly mobilizing yet more gravel and sand (Photo 1). This reach is also the location where perennial springs feed the creek. The remainder of the ravine is quite steep (approximately four percent grade), relatively lacking in wood, and dominated by plane-bed morphology; that is long channel segments without distinct local changes in slope associated with pools and bars. Significant erosion is occurring in all reaches surveyed within the ravine, mobilizing both outwash sand and gravel and finer silt and sand deposited more recently as overbank alluvium.



**Photo 1. Lateral migration and vertical bank erosion at Row C.**

The entirety of the creek's alluvial fan was surveyed as a part of reach Row A (RM 2.21-2.35). Here the slope is slightly less (about three percent). Anomalously fine bed material in this reach indicates high bed



**Photo 2. Example of bed material aggradation on log weir in lower Rowlands Creek.**

material transport rates, consistent with the abundant sediment supply observed upstream. There were local areas of channel incision and bank erosion, and significant aggradation of bedload was observed during habitat surveys (Photo 2). The downstream-most surveyed interval passes through a constructed, locally grouted, step-pool channel immediately above the confluence with Little Bear Creek.

Observations were also collected on four tributaries to Rowlands Creek:

- Tributary Ro 1 was not surveyed but observed from a driveway crossing. This tributary joins the creek in the reach that has downcut six to ten feet. The local decrease in bed elevation has induced erosion up the tributary to the culvert from above which it was observed. The slope of the channel has decreased as it downcuts, and so the depth of downcutting on the tributary was greater than in Rowlands Creek.
- Short segments of tributaries Ro2 and Ro 3 were surveyed. Both were near the threshold for channel development and appeared stable.
- Tributary Ro 4 was not surveyed, but was observed above its confluence with Rowlands Creek. This channel was a grass-bottomed swale. Aerial photos show at least two ponds along the tributary between 228<sup>th</sup> Street SW (RM 3.57) and the confluence with Rowlands Creek (RM 3.40). A local landowner noted that flows and sediment transport in the tributary both decreased after one of these ponds was constructed.

#### *Little Bear Lower County Line – 228<sup>th</sup> St SE to County Line*

This segment of Little Bear Creek flows through alluvium and has a fairly constant slope of about 0.4 percent. It is dominated by pool-riffle channel morphology, with some areas of plane bed. The bed material is composed dominantly of small gravel (2-16 mm), with substantial amounts of sand and finer sediment. Except for the most downstream reach, which flows through mature coniferous forest and has abundant large wood, there is limited riparian area with grassy or blackberry-dominated vegetation and little instream wood. There are numerous areas of bank erosion along the outside of meander bends. In these areas, the stream erodes gravelly material from the bank toe and silt and sand over most of the bank height.

Beaver dams are present in this reach but have limited influence on channel grade. The dams are typically contained within the bankfull channel area and do not impound large ponds or wetland areas, suggesting they may wash out during significant floods.

The channel downstream of the 244<sup>th</sup> Street SE culvert appears to have downcut substantially since the culvert was installed in the 1930s. The culvert outlet is perched about a foot above the plunge pool water surface, and the culvert is free of sediment due to high-velocity flow, potentially acting as a barrier to fish passage.

Two tributaries to this downstream-most reach of Little Bear Creek were also surveyed:

- Howell Creek (aka Parsons Creek) flows through an entirely constructed channel downstream of SR-522. The channel between SR-522 and SR-9 was recently constructed as a part of the Brightwater Wastewater Treatment Plant project. There is an area of significant erosion near a stormwater outfall that feeds the channel, but the sediment appears to drop out in a constructed wetland above the culvert under SR-9. The channel downstream of SR-9 was



realigned between 1994 and 2002 and flows across the creek's alluvial fan. It appears generally stable.

- The surveyed segment of tributary B was quite stable, with bank stability enhanced by riparian plants.

### 3.6.3 Summary

The irregular profile of Little Bear Creek and its tributaries (Figure 14 through Figure 18) testify to the dominance of glacial and paraglacial geomorphic processes in forming the topography of the Little Bear Creek valley. The modern streams have not been able to redistribute enough sediment through the post-glacial Holocene period to form a graded profile connecting sediment transport from upstream to downstream. Rather, throughout the system, sediment transport occurs in short, disconnected steps. Material is locally eroded along steeper channel segments, transported a short distance, and then deposited in areas with lower gradient.

In environments with strong discontinuity of geomorphic processes along the channel profile, a helpful tool to generalize observations is the concept of geomorphic process domains. Geomorphic process domains (e.g. Montgomery, 1999) are spatially discrete areas characterized by distinct suites of geomorphic processes. In the case of streams in the Little Bear Creek system, process domains can be defined by underlying geological materials, topography, and contributing basin area (which is a proxy for flow magnitude).

- Colluvial - The principal characteristic of this process domain is that surface flow has been insufficient to excavate clearly defined alluvial channels. In the natural state of the landscape, the soil is stabilized by roots and a framework of fallen trees and is protected from erosion by surface flow. If vegetation is removed from the landscape, Colluvial areas become sensitive to erosion from local runoff.
- Transitional - This process domain occurs at the upstream-most extent of channelized flow, at the threshold between colluvial and fluvial-dominated geomorphic processes (see Figure 12). These areas have a very high potential for significant geomorphic response.
- Till Bound - This process domain occurs where developed channels have cut through overlying soil and weathered till and reached erosion-resistant hardpan. These channels are typically entrenched and erosion-resistant with low potential for geomorphic response.
- Outwash Gully - This process domain is characterized by flow through steep, confined channels bounded by outwash deposits. These channels are particularly sensitive to flow increases and are observed to have very high potential for geomorphic response, with areas of major bank erosion and channel downcutting, as observed in the lower portions of Trout, Great Dane, and Rowlands creeks (see Photo 1).

- Alluvial - Channels in this process domain are self-forming, flowing through deposits of sediment that have accumulated as a result of fluvial processes. Alluvial channels have several degrees of freedom to adjust to changes in flow or sediment supply, including lateral migration, channel width, change in bed texture, and downcutting.
- Underfit - Channels in this process domain flow through broad valleys originally carved by glacial meltwater. The combination of low valley gradient and low stream discharge (relative to channel-forming discharge) results in insufficient stream power to convey bed material delivered from upstream. Beaver dams and beaver-dam meadows are common features of channels in the Underfit process domain.
- Alluvial Fan – This process domain occurs where an abrupt reduction in slope, confinement, or (typically) both results in deposition of bedload delivered from upstream. Geomorphic response is similar to Alluvial channels; however, Alluvial Fan channels are more sensitive to the ratio of the change in flow and sediment supply. Increased flow without corresponding increase in sediment supply can drive channel downcutting, while increased flow with increased sediment supply can drive rapid lateral migration and/or avulsions.

Figure 19 shows the observed process domain in surveyed reaches and inferred process domain for mapped streams throughout the Little Bear Creek study area basin. In unsurveyed reaches, process domains were inferred from topography, geology, contributing basin area, and conditions in adjoining surveyed reaches and observed locally at road crossings. Classifications for inferred reaches should be confirmed with site observations before being used as the basis for specific projects or stream actions.

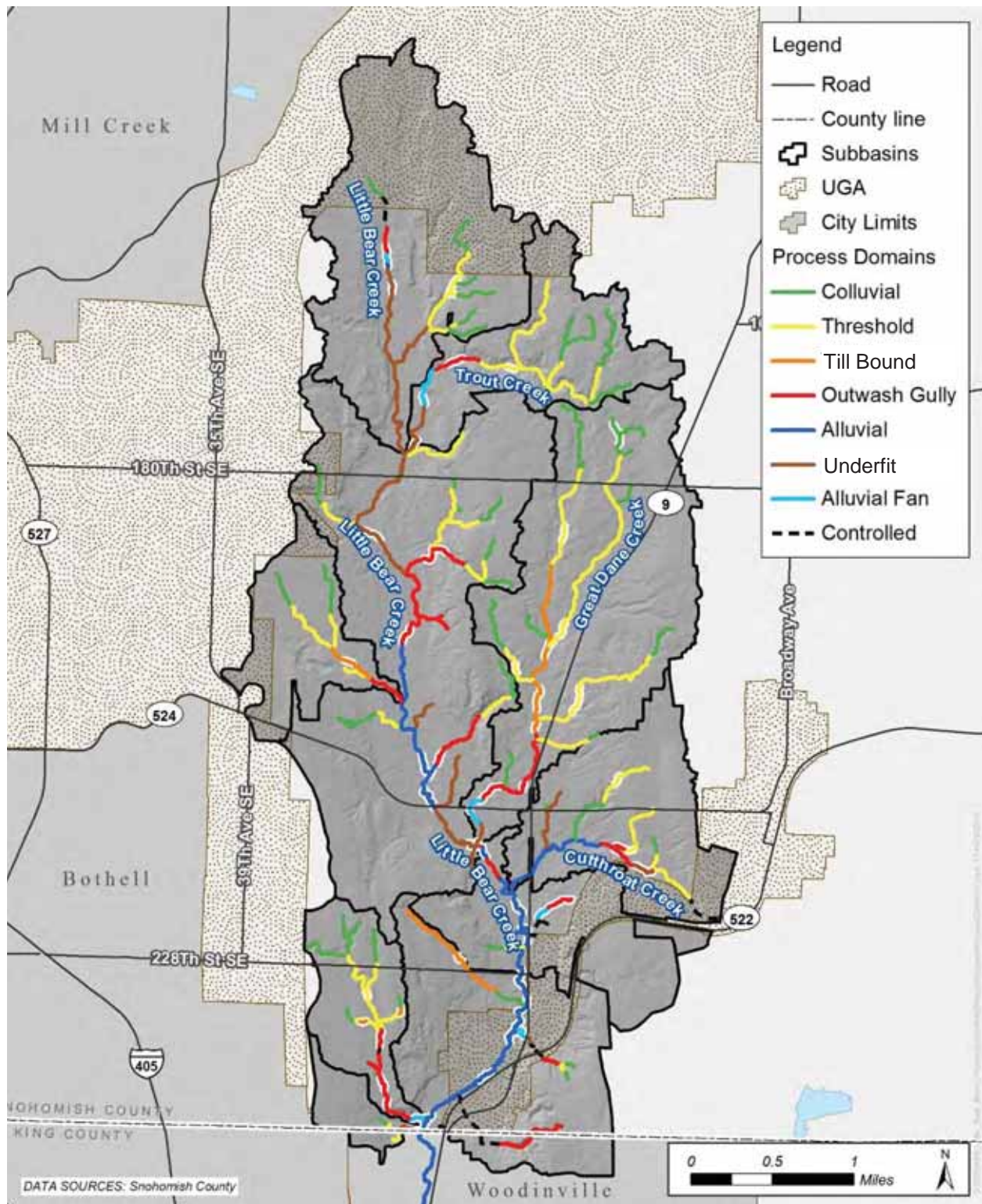


Figure 19. Observed (highlighted in white) and inferred geomorphic process domains through the Little Bear Creek study area basin. “Controlled” segments are areas with extensive human modification.

### 3.7 Known Problems

Although hydrologic data are not available for the period prior to development of the Little Bear Creek watershed, it is reasonable to assume that widely-observed impacts of development on hydrology and stream channels have affected conditions in the study area basin. These include increased runoff volume, higher storm flows, and flashier hydrographs, which typically lead to increased channel erosion and channel instability, particularly in steep headwater channels.

Creek flooding is not a widespread problem in the Little Bear Creek study area, though several locations have experienced repeated road overtopping or property flooding. Flooding within constructed drainage systems, particularly at driveway culverts, is much more common, however. NHC (2013) reported flooding problems in the study area identified from County Drainage Rehabilitation and Investigation (DRI) records and the Little Bear Creek Drainage Needs Report (DNR) update (Snohomish County, 2006). Two-thirds (16 of 24) of the drainage complaints and investigations were related to maintenance issues or local/private property drainage. These included blocked culverts and ditches, private drainage system overflows, and local yard and basement flooding. Remaining drainage complaint investigations are summarized in Table 14. The most significant flooding issue as identified by the County is at the confluence of Rowlands Creek and Little Bear Creek near the Snohomish/King County line (DRI 20080003). This location has had numerous complaints directly related to overflow from the creeks, including repetitive loss claims to FEMA.

**Table 14. Little Bear Creek Drainage Investigation Summary**

DRI ID	Issue	Notes
20050289	Crushed culvert entrance	Identified as possible fish barrier, potential culvert replacement candidate
20060074	Pond overtopping and flooding house	Pond drains to Little Bear Cr and backs up due to blocked/damaged private drainage systems.
20070260	Road runoff causing driveway/garage flooding	Seasonal stream that should receive runoff noted as choked with vegetation
20080003	Little Bear 244 <sup>th</sup> St SE culvert backwaters at high flows and floods property at Rowlands confluence	Numerous complaints from large flood events
20110284	Modified culvert backing up	Replaced as part of related County project
20120015	Failing culverts at 59th Ave SE	Culverts scheduled to be replaced in 2014
20120324	Private property flooding from road runoff	Damaged/insufficient private drainage system
20120342	Private berm redirecting runoff on to road	Resolved by removing portion of berm

The County's 2006 DNR update used hydrologic and hydraulic modeling to identify 44 problem locations with existing conditions flooding frequency estimated at 25-year or more frequent. In almost all cases, flooding is caused by insufficient culvert capacity, due to either undersized culverts or sediment blockages. Many of these problems have since been investigated and addressed, including several culvert replacements and referral of blocked ditches and culverts to County maintenance. Outstanding

flooding problem areas from the DNR update are listed in Table 15. Several of the stream culvert problems, including LB-LB-F-66, -67, and -74, are slated by the County and/or WSDOT for culvert replacements. Replacement of undersized culverts with fish-passable culverts required by current regulations can address flooding issues and remove fish passage barriers (see Section 5.3).

**Table 15. Flooding Problems Identified in 2006 DNR Update**

DNR Problem ID	Major Basin	Location	Problem Description	Flooding Frequency
LB-LB-F-16	LB Lower CL	Pipe on west side of 58 <sup>th</sup> Ave SE	Insufficient capacity of enclosed drainage system causes shoulder & potential roadway flooding	2-year
LB-LB-F-66	Cutthroat	Culvert under 73 <sup>rd</sup> Dr SE	Insufficient culvert capacity causes flooding of the roadway	10-year
LB-LB-F-67	Great Dane	Box culvert under Maltby Rd (WSDOT)	Insufficient culvert capacity causes flooding of the roadway	25-year
LB-LB-F-74	LB Upper	Culvert at private property access upstream of Interurban Blvd	Insufficient private culvert capacity causes flooding of the private property and roadway	10-year
LB-LB-F-76	LB Lower CL	Box culvert under 244 <sup>th</sup> St SE	Insufficient culvert capacity causes flooding of private property and house (same as DRI 20080003)	25-year

In addition to the locations identified above, the County has also documented road overtopping in the following areas. The source, nature, and extent of these overtopping problems have not been further explored.

- Puget Park Drive/54<sup>th</sup> Avenue SE – Upper Little Bear Creek
- West Interurban Boulevard – Trout Creek

Locations of erosion and sediment problems, aside from clogged culverts and ditches noted with some of the flooding problems above, have generally not been analyzed and catalogued for Little Bear Creek in previous studies. The geomorphic assessment and habitat surveys conducted as part of this project included identification of active channel erosion and near-channel sediment sources along the surveyed stream segments.

Figure 20 shows the extent of observed bank erosion and sediment sources noted during the streamwalks and habitat surveys. The most extensive channel erosion is occurring on steep gully reaches of Rowlands Creek and Great Dane Creek. Erosion was also observed on other tributary reaches in the Outwash Gully process domain. The process domains identified in the previous section (shown in Figure 19) provide some guidance regarding the sensitivity of the channel network to potential changes in flow. Channels in the Transitional and Outwash Gully domains are likely to have the highest sensitivity to flow increases, while geomorphic adjustments in channels flowing through larger Alluvial, Alluvial Fan, and Underfit domains would be expected to be much more subtle. Local conditions govern the response of areas in the Colluvial and Till Bound domains.



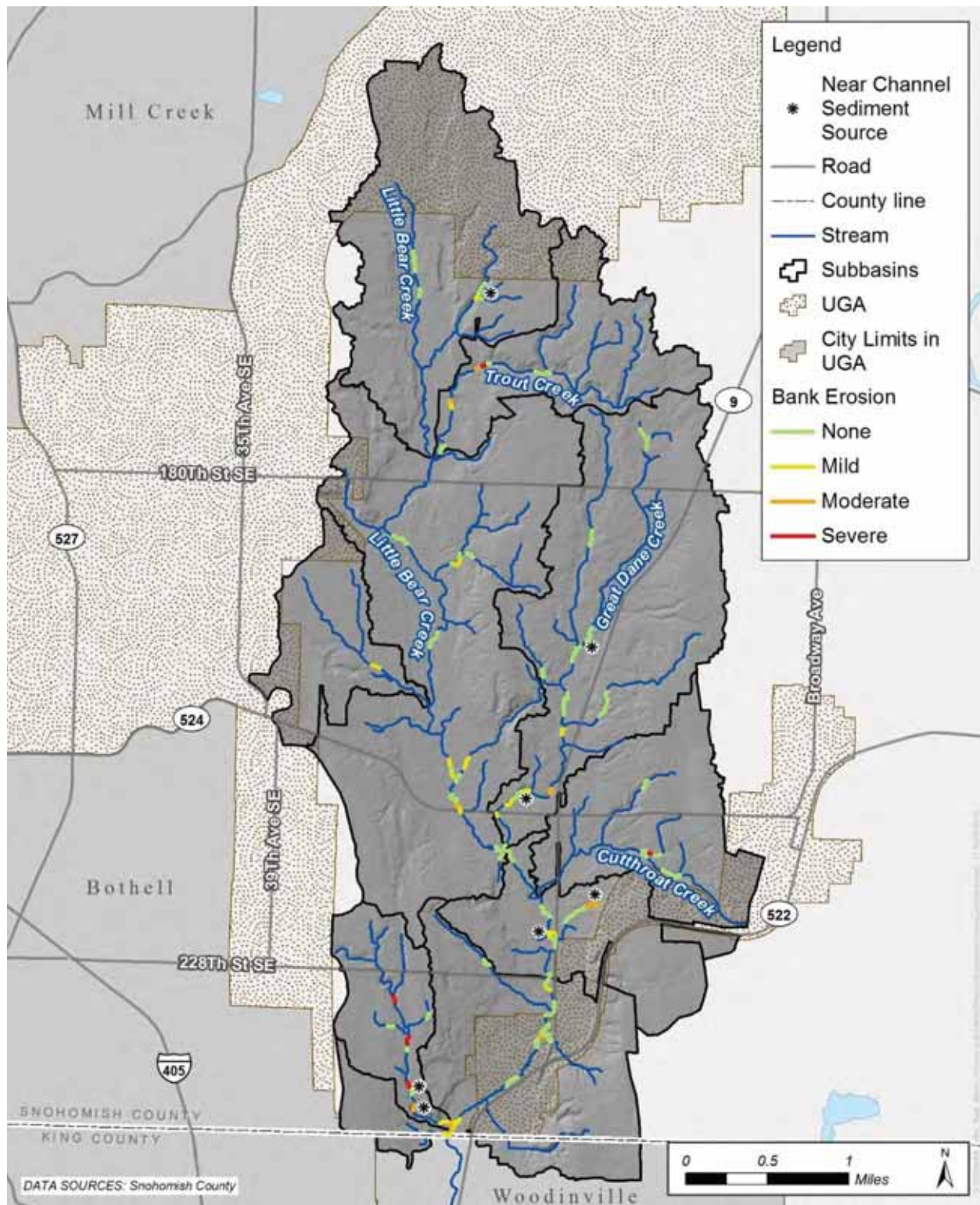


Figure 20. Observed bank erosion and near-channel sediment sources.

## 4 WATER QUALITY CONDITIONS

### 4.1 Introduction

The State of Washington's water quality standards, listed in WAC section 173-201A, provide useful metrics by which to evaluate many of the water quality constituents of greatest concern within the Little Bear Creek watershed. The criteria vary depending on the designated uses for a receiving water. Little Bear Creek has the following designated beneficial uses:

- Aquatic Life Uses: Core Summer Salmonid Habitat (in addition to spawning, rearing, and migration outside the summer season)
- Recreation Uses: Extraordinary Primary Contact
- Water Supply Uses: Domestic water, industrial water, agricultural water, and stock water
- Miscellaneous Uses: Wildlife habitat, harvesting, commerce/navigation, boating, and aesthetics

In addition to the designated use criteria, Little Bear Creek is also listed in the Supplemental Spawning and Incubation map publication (Ecology publication 06-10-038). The supplemental temperature criteria listed on this map for Little Bear Creek, 13°C from September 15 through May 15, is colder than the use-based criteria and overrides the other criteria.

WAC 173-201A lists parameters that are important metrics of the aquatic health of Little Bear Creek. Among these parameters, temperature, fecal coliform bacteria, dissolved copper, and dissolved zinc, (listed in Table 16 below) are the constituents required as per Section S5.C.5.c. of the Permit and are the primary constituents targeted in the Little Bear Creek basin planning study. Beneficial uses based on these constituents are defined quantitatively in WAC 173-201A. Portions of Little Bear Creek and its tributaries are included on the Washington State 2012 303(d) list of impaired water bodies for temperature, dissolved oxygen, bioassessment, and mercury (Howell Creek only). Inclusion on the list requires a Total Maximum Daily Load (TMDL) or other water quality improvement (WQI) project for those parameters. A TMDL was previously completed for Little Bear Creek for fecal coliform bacteria (Ecology, 2005). Although not specifically considered under this project, designated and beneficial uses may be characterized by narrative criteria which can be used for pollutants for which numeric criteria are difficult to specify, i.e., odor and color.

**Table 16. Water Quality Standards for Permit-Mandated Constituents**

Parameter	WAC Freshwater Water Quality Standard	Numeric Criteria
Fecal coliform bacteria	173-201A-200 (2)(b)	Extraordinary Primary Contact: geometric mean value < 50 colonies /100 mL, with < 10 % exceeding 100 colonies /100 mL
Temperature <sup>1</sup>	173-201A-200 (1)(c)	<ul style="list-style-type: none"> <li>Supplemental temperature criteria (Sept 15-May 15): maximum 7-day average of the daily maximum temperature (7DADMax) is 13°C (55.4°F)</li> <li>Core Summer Salmonid Habitat criteria (June 15-Sept 14): maximum 7-DADMax of 16°C (60.8°F)</li> <li>Spawning, Rearing, Migration criteria (May 16-June 14): maximum 7-DADMax of 17.5°C (63.5°F)</li> </ul>
Dissolved Copper (Cu)	173-201A-240	Acute <sup>2</sup> $(0.960)(e^{(0.9422[\ln(\text{hardness})] - 1.464)})$ Chronic <sup>3</sup> $(0.960)(e^{(0.8545[\ln(\text{hardness})] - 1.465)})$
Dissolved Zinc (Zn)	173-201A-240	Acute <sup>2</sup> $(0.978)(e^{(0.8473[\ln(\text{hardness})] + 0.8604)})$ Chronic <sup>3</sup> $(0.986)(e^{(0.8473[\ln(\text{hardness})] + 0.7614)})$
<sup>1</sup> Temperature (7DADMax) not to exceed the criteria more than once every ten years on average. <sup>2</sup> Acute criteria, 1-hour average concentration not to be exceeded more than once every three years on the average. <sup>3</sup> Chronic criteria, 4-day average concentration not to be exceeded more than once every three years on the average.		

## 4.2 Water Quality Monitoring Data

The parameters targeted by this study (fecal coliform bacteria, temperature, dissolved copper, and dissolved zinc) have been sampled under long-term ambient monitoring programs and short-term studies conducted by Snohomish County and King County. Ambient monitoring programs have collected monthly grab samples at six sites within the study area—LBHW, TROT, LBLU, S478 (King County), DANE, CUTT, and LBLD—and also at the SR-202 crossing downstream of the study area basin (LBCC/O478 (King County)), all shown in magenta in Figure 21. Long-term continuous temperature monitoring data were available at LBHW, LBLU, S478, and LBLD, as well as at LBCC/O478 downstream of the study area basin.



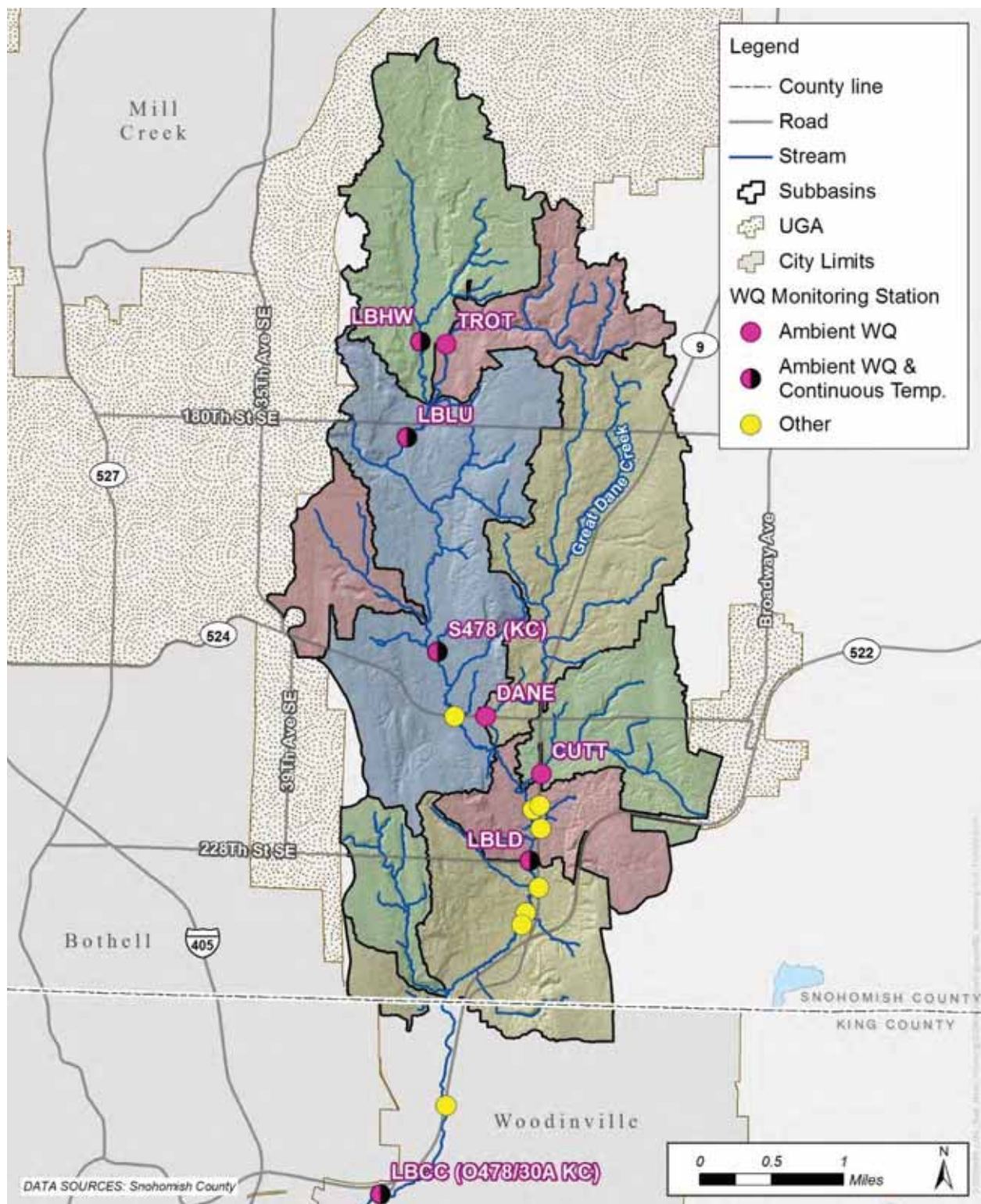


Figure 21. Water Quality Monitoring Stations

Reporting of ambient monitoring for metals was discontinued at all King County Little Bear sites in 2008 and all Snohomish County sites in 2009. In addition to ambient monitoring, short-term studies have included the SWAMP assessment (King County, 2003), the 2005 fecal coliform TMDL (Ecology, 2005), and the Brightwater Treatment Plant EIS (King County, 2005). An inventory of all of these sites is provided in the project Quality Assurance Project Plan (QAPP) (NHC, 2015). Data from King County and Snohomish County were used to assess the current water quality conditions of the study area basin. The County data have known QA/QC procedures, long periods of record, and were collected with the purpose of monitoring the overall condition of Little Bear Creek. Table 17 lists the sites in upstream to downstream order and summarizes the period of record used for each water quality monitoring site included in this section.

**Table 17. Ambient Water Quality Monitoring Locations**

Station ID	Location	Period of Record Used		
		Total Metals	Dissolved Metals	Fecal Coliform
LBHW	Little Bear Creek @ Interurban Blvd.	4/2000 – 10/2003	n/a	1/2010 – 12/2014
TROT	Trout Creek	4/2000 – 10/2003	n/a	1/2010 – 12/2014
LBLU	Little Bear Creek @ 51 <sup>st</sup> Ave SE	1/2000 – 12/2009	n/a	6/2006 – 12/2014
S478 (KC)	Little Bear Creek @ Little Bear Creek Road	11/2002 – 2/2008	11/2002 – 2/2008	6/2006 – 12/2014 <sup>1</sup>
DANE	Great Dane Creek	4/2000 – 10/2003	n/a	1/2010 – 12/2014
CUTT	Cutthroat Creek	4/2000 – 10/2003	n/a	1/2010 – 12/2014
LBLD	Little Bear Creek @ 228 <sup>th</sup> Street SE	1/2000 – 12/2009	n/a	6/2006 – 12/2014
LBCC/ O478 (KC) <sup>2</sup>	Little Bear Creek @ SR-202	Not used	2/2000 – 2/2008	Not used
<sup>1</sup> Extended gap in record.				
<sup>2</sup> Downstream of study area basin. Data used where study area basin data were limited.				

Snohomish County conducted an initial assessment in 2013 of water quality monitoring data needs for the modeling effort in the Little Bear Creek Basin Planning project, prior to the initiation of the project. While some of the ambient water quality data were determined to be usable for modeling purposes, the County determined that additional water quality monitoring data would be needed to support calibration of the continuous runoff model. As a result, the County implemented a short-term monitoring program at several continuous and grab sampling locations in the Little Bear Creek study area in 2014 and 2015.

### 4.3 Temperature

Although ambient temperature data exist for longer periods and multiple locations in the watershed, data collection and quality control methods vary. Only data collected and reviewed according to accepted Ecology methods were used to evaluate the state water quality temperature criteria. These

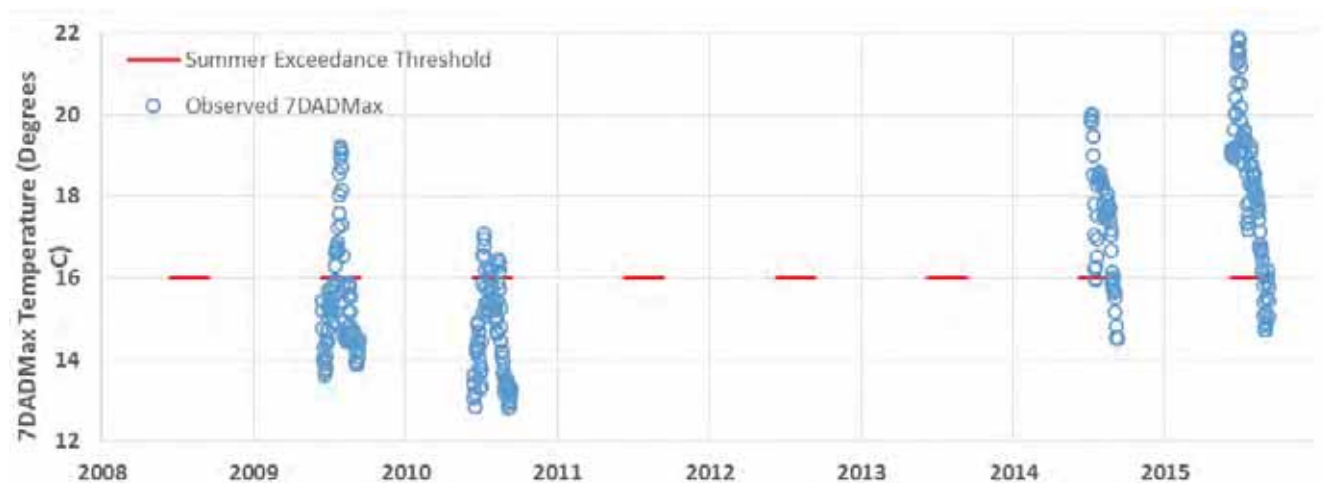


data have been collected for the critical summer period at four sites since 2008 or 2009. Temperature monitoring data from these four sites were used to evaluate the state water quality criteria applicable to Little Bear Creek. As described in Table 16, Little Bear Creek is subject to three separate temperature criteria, depending on time of year. The seven-day moving average of daily maximum temperatures (7DADMax) is compared to the applicable criteria to determine whether a temperature exceedance has occurred. The standard allows for one exceedance every ten years on average. Seasonal exceedances for the summer period for which data are available are summarized by site in Table 18.

**Table 18. Water Temperature Criteria Exceedances**

Station ID	Name	Years of Data	Core Summer Period June 15 – Sept 14 (16°C)	
			Days Criteria Exceeded	Average per Year
LBLU	Little Bear Creek @ 51 <sup>st</sup> Ave SE	4	164	41
DANE	Great Dane Creek	4	31	7.8
CUTT	Cutthroat Creek	4	64	16
LBLD	Little Bear Creek @ 228 <sup>th</sup> St SE	5	183	37

The summer temperature threshold was exceeded between 8 and 41 times per year on average. The number of exceedances was three to five times higher on the mainstem (LBLU and LBLD) than on the tributaries (DANE and CUTT). Time series plots in Figure 22 through Figure 25 show the 7DADMax temperature values computed from the observed data (in blue), and the exceedance thresholds representing the temperature criteria (in red). The highest observed 7DADMax temperatures occurred during the summers of 2009 and 2015. The summer 2009 7DADMax exceeded 20°C at the LBLD site and reached 18°C at the LBLU site. The summer of 2015 was warm and dry throughout the region, and high stream temperatures were common in many streams.



**Figure 22. Summer 7DADMax Temperature, Monitoring Site LBLU**

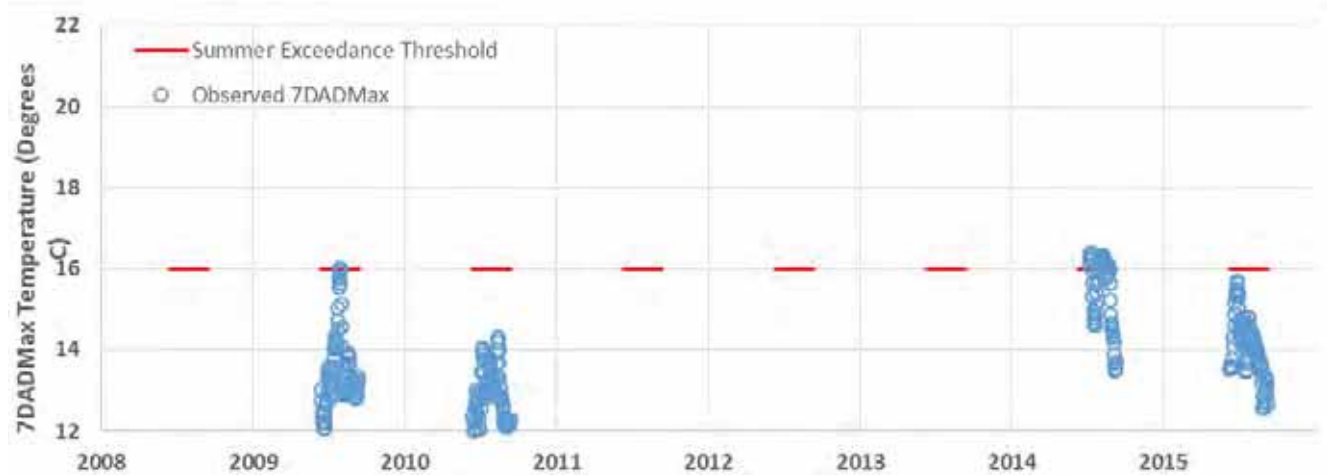


Figure 23. Summer 7DADMax Temperature, Monitoring Site DANE

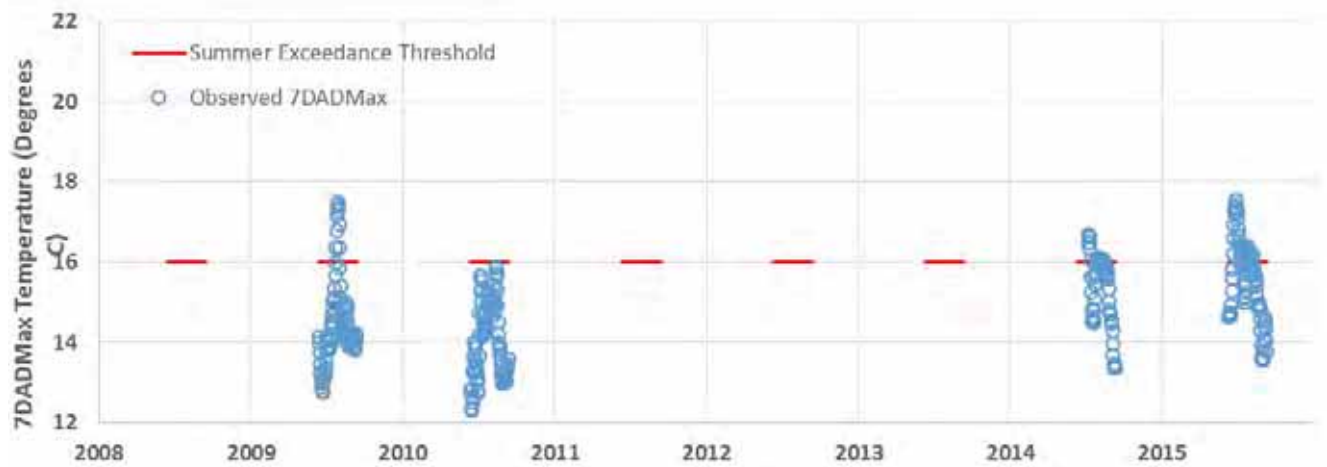


Figure 24. Summer 7DADMax Temperature, Monitoring Site CUTT



Figure 25. Summer 7DADMax Temperature, Monitoring Site LBLD

In addition to collection of temperature data for model calibration, new temperature data were collected as part of a stream metrics study conducted for the Little Bear Basin Planning project, providing additional locations for comparison of stream temperatures in 2014 and 2015. Summary results are plotted by year and location in Figure 26, displaying differences along the stream profile and between mainstem and tributary sites. Site LBLU at river mile 7.6 was the warmest among locations sampled in both years. The plot highlights that water temperature upstream from LBLU is relatively cooler before warming to the site. Then water temperature cools in a downstream direction to the middle portion of Little Bear Creek near Little Bear Creek Road. Tributaries are generally cooler overall and, except for one tributary at RM 5.5, did not increase in temperature as much as mainstem sites during the summer drought of 2015, either in degrees Celsius or relative percent difference.

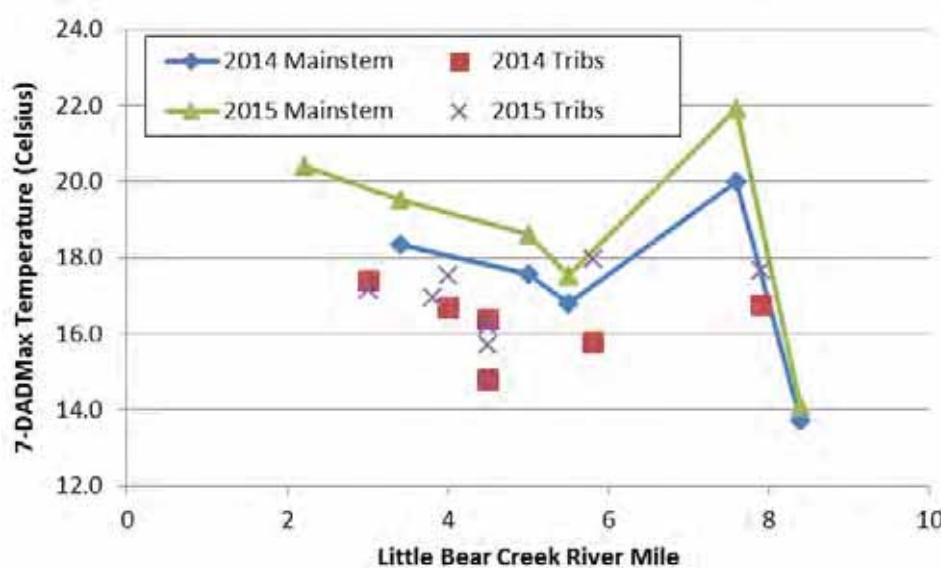


Figure 26. Stream temperature plotted as the summer maximum 7DADMax (°C) by river mile for mainstem and tributary locations. Tributary values are plotted based on the confluence location along Little Bear Creek and not the location sampled on the tributary.

## 4.4 Metals and Hardness

### 4.4.1 Hardness

The Washington State metals criteria vary as a function of hardness to account for its effect on dissolved metal toxicity. Hardness is a measure of the concentration of many dissolved ions in water, but principally calcium and magnesium. Metals toxicity generally decreases with increasing hardness (USGS, 2007). New methods for estimating bio-availability and metal toxicity, using Biotic Ligand Models (BLM) based on ten different water quality parameters, are being developed but have not yet been adopted in Ecology's criteria (Ecology, 2010). Hardness data have been collected at two locations in Little Bear Creek: LBLU and LBLD. Hardness values are similar at both sites, ranging from 32 to 66 and 34 to 57 mg

CaCO<sub>3</sub>/L, respectively. These minimum and maximum hardness values, shown in Table 19, were used to calculate the corresponding dissolved copper and dissolved zinc water quality criteria thresholds listed in Table 20.

**Table 19. Hardness Ambient Monitoring Statistics**

Parameter	Value Type	Station ID and Name			Both Sites
			LBLU Little Bear Creek @ 51 <sup>st</sup> Ave SE	LBLD Little Bear Creek @ 228 <sup>th</sup> St SE	
Hardness (mg CaCO <sub>3</sub> /L)	Observation	Minimum	32	34	32
		Maximum	66	57	66

**Table 20. Metals Standards Based on Observed Hardness**

Parameter	Value Type	Station ID and Name			Both Sites
			LBLU Little Bear Creek @ 51 <sup>st</sup> Ave SE	LBLD Little Bear Creek @ 228 <sup>th</sup> St SE	
Dissolved Copper (µg/L)	Chronic Standard	Minimum	4.3	4.5	4.3
		Maximum	8.0	7.0	8.0
	Acute Standard	Minimum	5.8	6.2	5.8
		Maximum	12	10	12
Dissolved Zinc (µg/L)	Chronic Standard	Minimum	40	42	40
		Maximum	73	65	73
	Acute Standard	Minimum	44	46	44
		Maximum	80	71	80

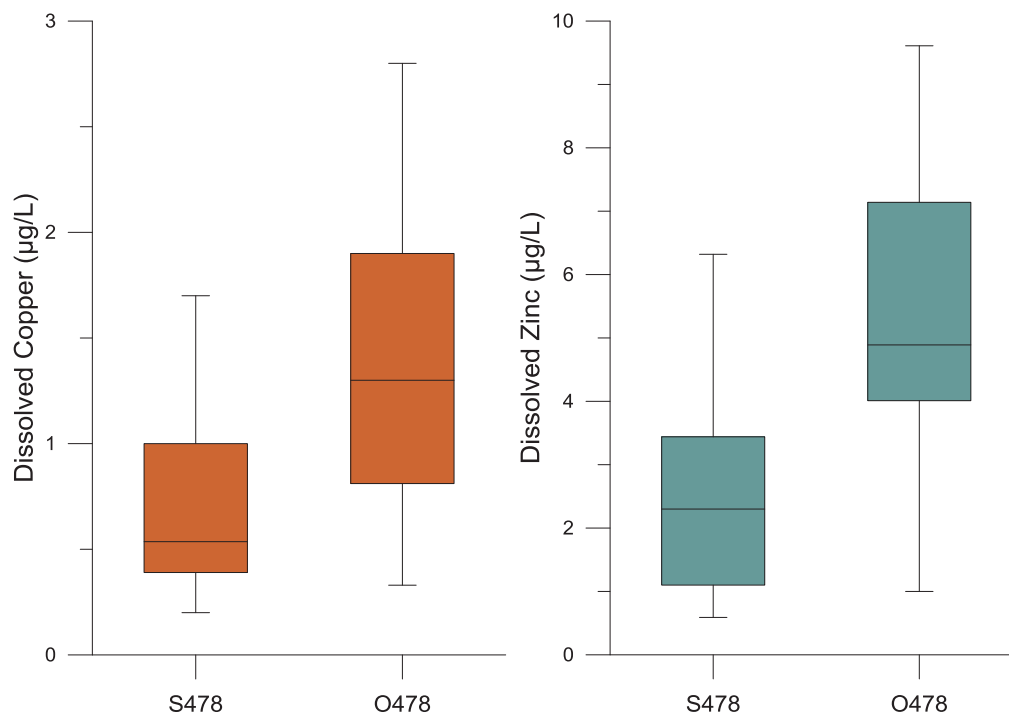
#### 4.4.2 Dissolved Metals

The only two Little Bear Creek ambient monitoring locations with dissolved metals data, S478 and O478, were operated by King County. Data from the two sites indicates that dissolved metals concentrations increase moving downstream, as shown in Table 21. This is consistent with urbanization and increased transportation and industrial uses in the southern portion of the study area basin. However, no exceedances of the state criteria have been observed at either site. Dissolved copper concentrations have not exceeded 2.8 µg/L—well below 4.3 µg/L, the lower end of the chronic copper criteria. Dissolved zinc concentrations have not exceeded 9.6 µg/L, which is well below the 40 µg/L lower end of the chronic zinc criteria. Box plots of dissolved copper and zinc concentrations are shown in Figure 27.

**Table 21. Dissolved Metals Ambient Monitoring Statistics**

Station ID	Name	Dissolved Copper (µg/L)				Dissolved Zinc (µg/L)			
		Mean	Median	Maximum	Samples	Mean	Median	Maximum	Samples
S478	Little Bear Creek @ Little Bear Road	0.7	0.5	1.7	19	2.6	2.3	6.3	19
O478	Little Bear Creek @ SR-202	1.4	1.3	2.8	50	5.1	4.9	9.6	48

From **Table 19**:  
Dissolved Copper Standards (µg/L), Chronic = 4.3 – 8.0, Acute = 5.8 – 12  
Dissolved Zinc Standards (µg/L), Chronic = 40 – 73, Acute = 44 – 80



**Figure 27. Dissolved Copper (left) and Dissolved Zinc (right)**

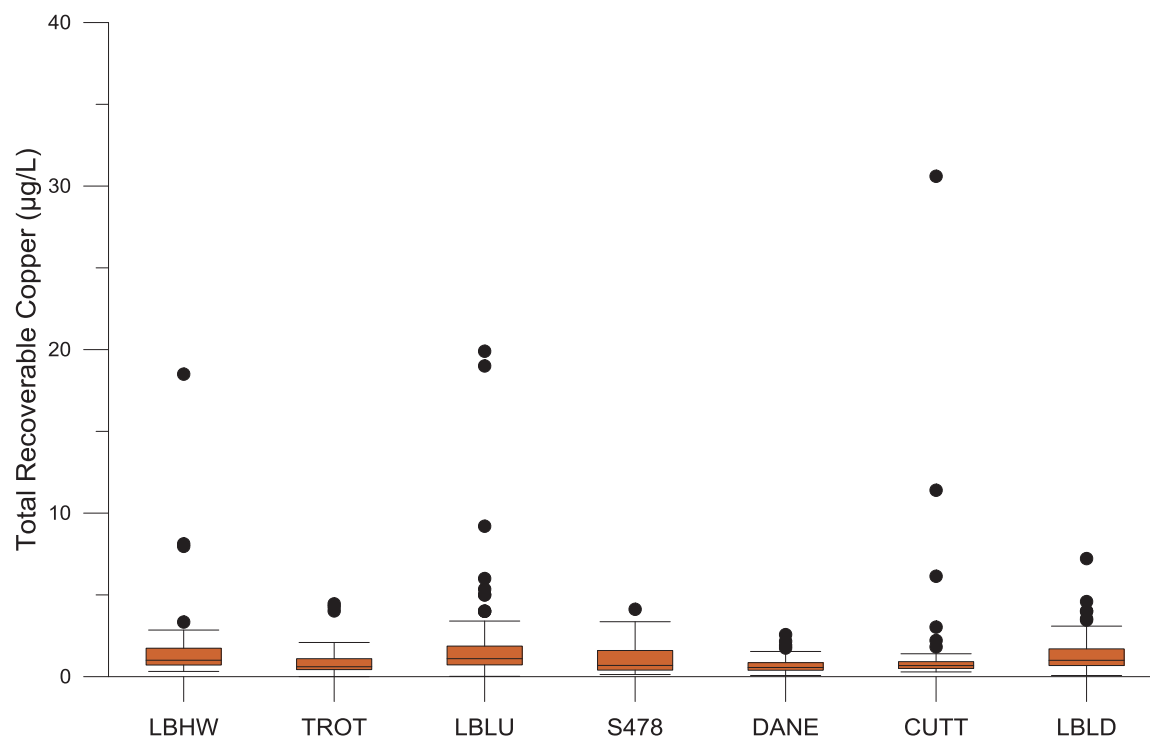
#### 4.4.3 Total Recoverable Metals

As is typical of most rivers and streams, total recoverable zinc concentrations were higher than those for copper. The data are summarized in Table 22 and box plots provided in Figure 28 and Figure 29.

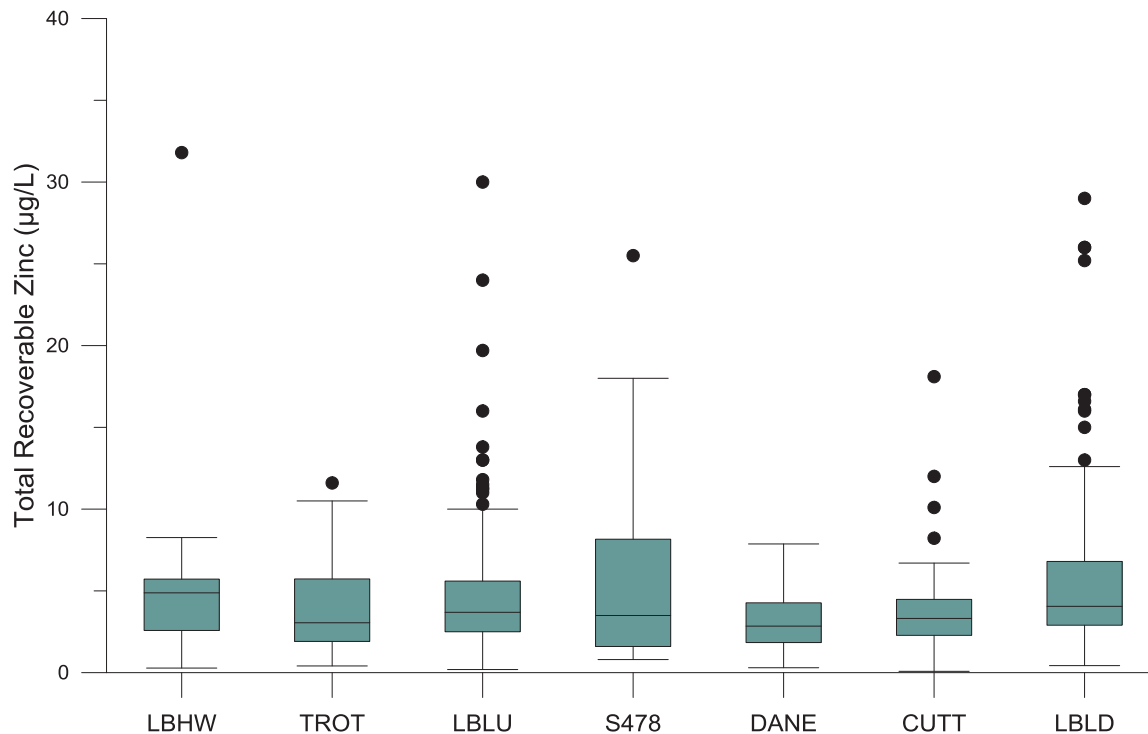


**Table 22. Total Recoverable Metals Ambient Data Statistics**

Station ID	Name	Total Recoverable Copper (µg/L)				Total Recoverable Zinc (µg/L)			
		Mean	Median	Maximum	Samples	Mean	Median	Maximum	Samples
LBHW	Little Bear Creek @ Interurban Blvd	1.9	1.0	19	42	5.0	4.9	32	42
TROT	Trout Creek	1.0	0.6	4.5	42	4.0	3.1	12	41
LBLU	Little Bear Creek @ 51 <sup>st</sup> Ave SE	1.6	1.1	20	163	4.7	3.7	30	165
S478	Little Bear Creek @ Little Bear Creek Rd	1.1	0.7	4.1	22	5.9	3.5	26	20
DANE	Great Dane Creek	0.7	0.6	2.6	42	3.2	2.8	7.9	42
CUTT	Cutthroat Creek	1.9	0.7	31	42	4.0	3.3	18	42
LBLD	Little Bear Creek @ 228 <sup>th</sup> St SE	1.3	1.0	7.2	157	5.8	4.1	29	168



**Figure 28. Total Recoverable Copper, Ambient Monitoring Sites**



**Figure 29. Total Recoverable Zinc, Ambient Monitoring Sites**

As with dissolved metals, the relative total recoverable metals concentrations are higher at stations closest to development. Station S478 had the lowest median concentrations of the mainstem Little Bear sites (median concentrations of 0.7 µg/L copper and 3.5 µg/L zinc), followed closely by LBLU, LBLD, and LBHW. The Trout Creek (TROT), Great Dane Creek (DANE), and Cutthroat Creek (CUTT) tributary stations have lower median total recoverable copper and zinc concentrations than stations on the mainstem of Little Bear Creek. However, the CUTT site had the highest maximum copper concentration (31 µg/L) in the study area. The CUTT site is within the UGA and a developed transportation corridor along the north edge of SR-522, where high copper loads would be expected.

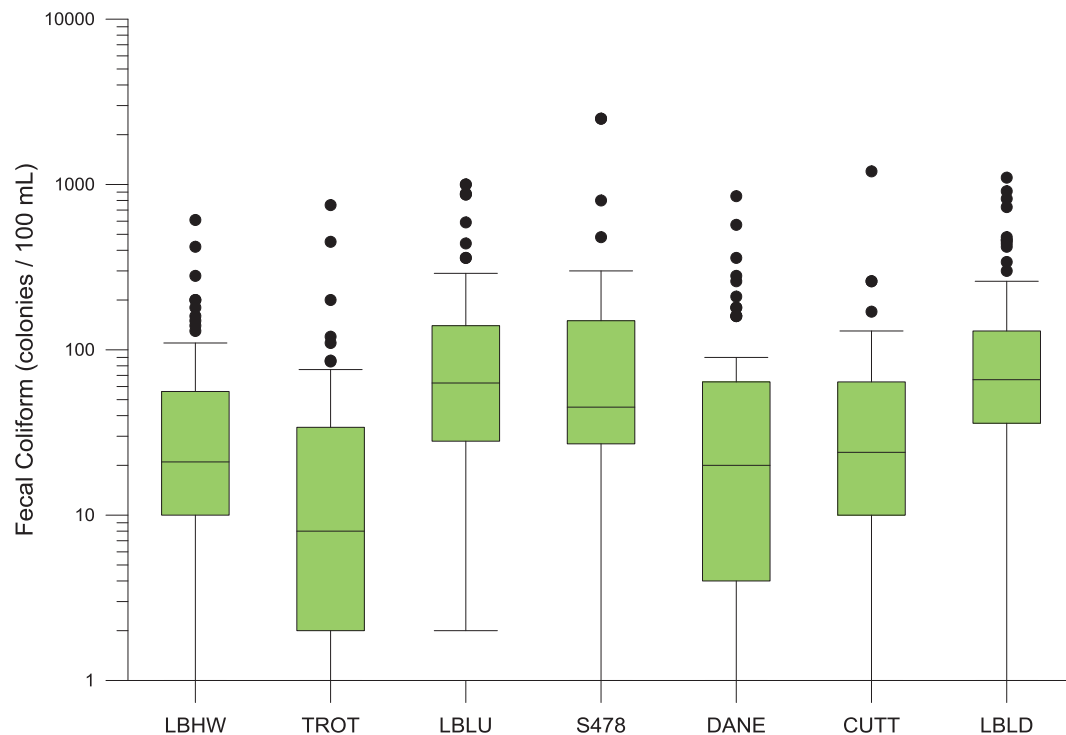
## 4.5 Fecal Coliform Bacteria

Fecal coliform bacteria are commonly used as an indicator of possible sewage contamination because they originate in human and animal feces. Although they are generally not harmful themselves, they indicate the possible presence of pathogenic (disease-causing) bacteria, viruses, and protozoans that also live in human and animal digestive systems. Therefore, their presence in streams suggests that pathogenic microorganisms might also be present and that swimming in or eating shellfish from these waters might be a health risk. Since it is difficult, time-consuming, and expensive to test directly for the presence of a large variety of pathogens, water is usually tested for coliforms and fecal streptococci instead. The two-part standard for fecal coliforms in an extraordinary primary contact stream such as Little Bear Creek (Table 16) specifies that the geometric mean concentration of fecal coliform samples not exceed 50 colonies per 100 mL (Part 1) and that less than 10 percent of samples have concentrations exceeding 100 colonies per 100 mL (Part 2).

Table 23 summarizes long-term fecal coliform bacteria concentration statistics for the period since 2006. The aggregated data for the ambient monitoring sites in the study area are shown in a box plot in Figure 30.

**Table 23. Fecal Coliform Bacteria Ambient Monitoring Statistics**

Station ID	Name	Part 1 Standard Geometric Mean (colonies / 100 mL) [Standard = 50]			%Exceeding Part 2 Standard [Standard = 100 colonies / 100 mL]			# of Samples	
		Dry	Wet	Annual	Dry	Wet	Annual	Dry	Wet
LBHW	Little Bear Creek @ Interurban Blvd	35	14	22	27%	11%	19%	30	28
TROT	Trout Creek	17	4	9	17%	0%	9%	30	28
LBLU	Little Bear Creek @ 51 <sup>st</sup> Ave SE	68	52	60	31%	35%	33%	48	46
S478	Little Bear Creek @ Little Bear Road (KC)	68	60	64	31%	43%	36%	26	21
DANE	Great Dane Creek	25	14	19	30%	7%	19%	30	29
CUTT	Cutthroat Creek	30	18	23	7%	17%	12%	29	29
LBLD	Little Bear Creek @ 228 <sup>th</sup> St SE	78	56	66	38%	30%	34%	48	47



**Figure 30. Fecal Coliform Bacteria, Ambient Monitoring Sites**

As shown in Table 24, the headwater and tributary sites (LBHW, TROT, DANE, and CUTT) pass Part 1 of the fecal coliform bacteria standard (geometric mean < 50 colonies/100 ml) in all monitoring years, but the three mainstem sites (LBLU, S478, and LBLD) fail the criteria in three or more years. Part 2 of the standard (< 10% exceeding 100 colonies/100 ml) was exceeded in at least one year at all sites, with more exceedances at the mainstem sites. Since statistics for comparison to standards are calculated on a water year basis, partial year data from 2006 and 2015 were excluded from this assessment.

**Table 24. Comparison of Ambient Fecal Coliform Data to Standard**

Station ID	Name	Part 1 Standard Exceeded in	Part 2 Standard Exceeded in
LBHW	Little Bear Creek @ Interurban Blvd	0 of 8 years	3 of 8 years
TROT	Trout Creek	0 of 8 years	1 of 8 years
LBLU	Little Bear Creek @ 51 <sup>st</sup> Ave SE	5 of 8 years	6 of 8 years
S478	Little Bear Creek @ Little Bear Road (KC)	3 of 3 years	3 of 3 years
DANE	Great Dane Creek	0 of 8 years	3 of 8 years
CUTT	Cutthroat Creek	0 of 8 years	2 of 8 years
LBLD	Little Bear Creek @ 228 <sup>th</sup> St SE	5 of 8 years	6 of 8 years

## 4.6 Known Problems

Review of ambient monitoring data identified that the stream exceeds state temperature and fecal coliform bacteria standards at multiple locations. Table 25 provides a summary of exceedances observed at each of the seven monitoring sites in the study area.

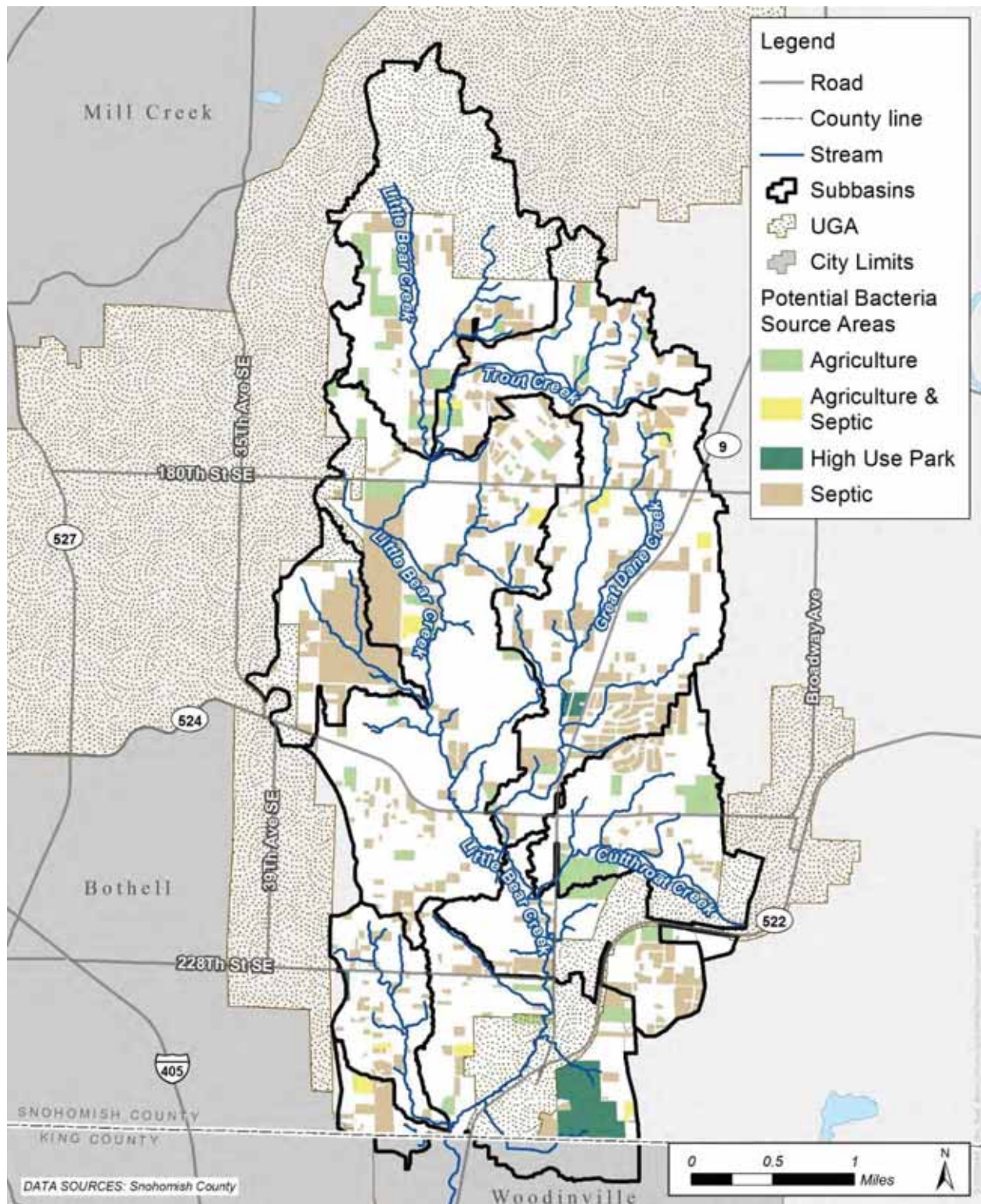
**Table 25. Summary of Little Bear Creek Water Quality Criteria Exceedances**

Station ID	Name	Temperature	Dissolved Copper	Dissolved Zinc	Fecal Coliform Part 1	Bacteria Part 2
LBHW	Little Bear Creek @ Interurban Blvd	n/a	n/a	n/a	Not Exceeded	Exceeded
TROT	Trout Creek	n/a	n/a	n/a	Not Exceeded	Exceeded
LBLU	Little Bear Creek @ 51 <sup>st</sup> Ave SE	Exceeded	Not Exceeded	Not Exceeded	Exceeded	Exceeded
S478	Little Bear Creek @ Little Bear Rd (KC)	Exceeded	n/a	n/a	Exceeded	Exceeded
DANE	Great Dane Creek	n/a	n/a	n/a	Not Exceeded	Exceeded
CUTT	Cutthroat Creek	n/a	n/a	n/a	Not Exceeded	Exceeded
LBLD	Little Bear Creek @ 228 <sup>th</sup> St SE	Exceeded	Not Exceeded	Not Exceeded	Exceeded	Exceeded

The Little Bear Creek fecal coliform bacteria TMDL (Ecology, 2005) provides guidance for residents and other basin stakeholders to reduce the loading of bacteria. Figure 31 shows agricultural uses (primarily animal-based in Little Bear Creek), septic system services areas, and high use parks in the study area, all of which can be potential sources of high levels of fecal coliform bacteria. Beavers, birds, and other wild animals can also contribute significant fecal coliform loads to stream systems.

In addition to fecal coliform and temperature, Little Bear Creek and/or its tributaries are included on the Washington State 2012 303(d) list for dissolved oxygen (Little Bear and Trout Creek) and mercury (Howell Creek). This suggests that, while not a Permit requirement for this basin planning project, future investigation of the levels and effects of these additional pollutants may be warranted to improve the existing and future aquatic health of Little Bear Creek. Little Bear Creek is also 303(d)-listed for bioassessment; biological conditions are discussed in the following section.





**Figure 31. Potential Bacteria Sources**

## 5 BIOLOGIC CONDITIONS

### 5.1 Introduction

With most of the study area basin outside of urban growth boundaries and zoned for rural land uses, the Little Bear Creek watershed has maintained approximately 50 percent forested land cover (see Table 5), a key supporting element of biological condition. Anadromous salmon and trout access almost all of this system, though there are some passage barriers to adults during periods of low stream water flows, and to juveniles during high flows (Kerwin, 2001). Table 26 lists level of occurrence of salmonid species and other species of concern in Little Bear Creek, as determined by Snohomish County staff in 2004 (unpublished data).

**Table 26. Species Occurrence in Little Bear Creek (Snohomish County, 2004)**

Species	Occurrence
Chinook Salmon	O
Coho Salmon	O
Sockeye Salmon	O
Kokanee Salmon	O
Steelhead Trout	P
Coastal Cutthroat Trout	O
Bull Trout/Dolly Varden	P
Pacific Lamprey	P
River Lamprey	P
Western Pearlshell Mussel	O
Western Toad	U
Northern Red-legged Frog	P
Bald Eagle	O
Olive-sided Flycatcher	O
Pileated Woodpecker	O
Great Blue Heron	O
Long-eared Myotis Bat	P
Pacific Townsend's Big Eared Bat	P
Occurrence Codes: O = Known to occur   P = Potential/Presumed occurrence based on suitability of habitat   U = Unknown	

### 5.2 Aquatic Community

The Little Bear Creek system is an important resource for fish and the following salmonid species are known to be present in the basin (see also Table 26): chinook (*Oncorhynchus tshawytscha*), sockeye (*O. nerka*), kokanee (*O. nerka*), and coho (*O. kisutch*) salmon. The WRIA 8 Chinook Salmon Recovery Plan notes that the estimated number of Chinook salmon spawning in Little Bear Creek averaged 11 fish for many years up to 1998. Coastal cutthroat trout (*O. clarki clarki*) and steelhead/rainbow trout (*O. mykiss*) have also been observed (Williams et al., 1975; WDFW, 1993). King County provides maps of known fish

use distribution (from data collected 1970-2000) on its Lake Washington/Cedar/Sammamish watershed website (King County, 2001b).

Although bull trout/Dolly Varden are not thought to be present in Little Bear Creek, they could potentially occur within the Cedar-Sammamish (WRIA 8) drainage. Similarly, it is not known whether Pacific lamprey or river lamprey occur within the Little Bear Creek watershed, though the potential for occurrence exists. Western pearlshell freshwater mussel are known to occur in Little Bear Creek.

In recent decades, a considerable body of research has shown that the overall quality of stream habitat to support fish and other aquatic species is well represented by the Benthic Index of Biotic Integrity (B-IBI), which is calculated from measurements of the species richness and abundance of benthic macroinvertebrates. The focus for Permit-required watershed planning is on the biotic integrity of streams, primarily as indicated by B-IBI. Therefore a detailed discussion of currently available B-IBI data in Little Bear Creek basin follows.

### 5.2.1 B-IBI

B-IBI has been investigated in Little Bear Creek since 1994 (May et al., 1997). Investigators have primarily included University of Washington graduate students, King County, and Snohomish County in the Snohomish County portion of the basin. Regionally, the condition of B-IBI has been primarily investigated in the context of land use and land cover characteristics, where the amount of impervious area in the drainage area upstream from B-IBI sites is used as an independent analysis variable (e.g. Booth et al., 2004). The land cover condition of the riparian buffer nearest to the B-IBI sample site has also been investigated as an explanatory variable, in addition to total drainage area land cover.

In Little Bear Creek, Morley (2000) observed that B-IBI was correlated with local land cover within one kilometer of the sample location. This scale of influence was consistent with the observation that B-IBI score decreased through a local area of riparian degradation but improved farther downstream where Little Bear Creek flowed through an extensive forested area again. Notably, King County, as part of its Normative Flow Study (Cassin et al., 2005), identified Little Bear Creek as an outlier in terms of higher B-IBI scores relative to modeled hydrologic flow metrics.

Based on surveys of past reporting and recent sampling, it is estimated that more than 30 individual sites in Little Bear Creek have been sampled over the years (Table 27 and Figure 32). Some sites have been sampled once in that time period, while others have been sampled in 13 years or more. B-IBI scores from nearly annual sampling since 2002 for seven long-term monitoring locations (upstream-to-downstream) are shown in Table 28 and correspond to sites labeled in Figure 32. B-IBI scores are color-coded by condition category (after Morley 2000) and sites do change category routinely from year to year. Among these long-term sample sites, the average B-IBI score condition is “fair,” and the 95 percent confidence interval of the average values ranges from 3.2-4.8 B-IBI points.

**Table 27. Little Bear Creek B-IBI sampling sites and scores. Long-term sites evaluated in this summary are shaded. No B-IBI sampling in 2004.**

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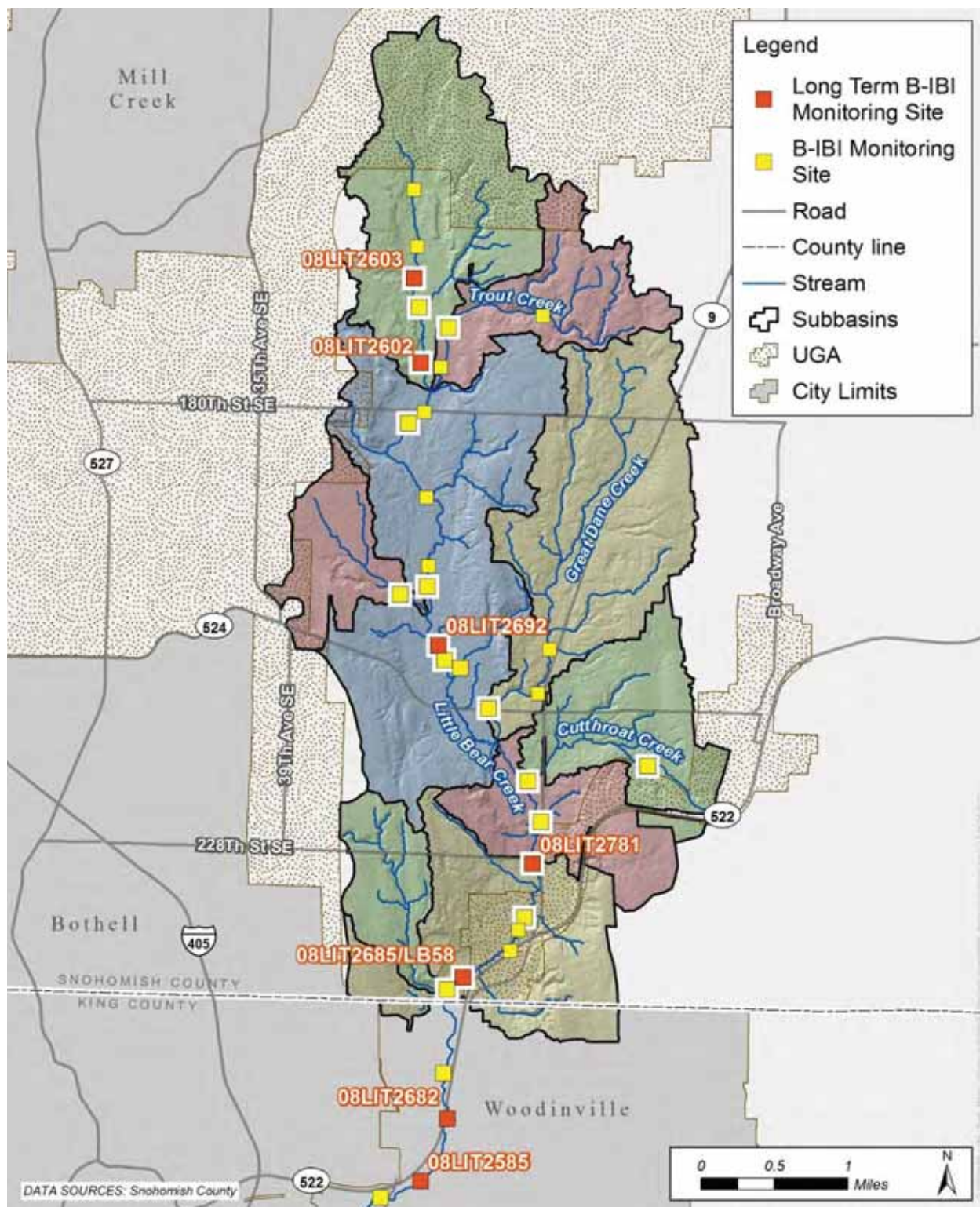


Figure 32. Little Bear Creek B-IBI sampling sites. Long-term (2002-2015) sites are labeled. White box around site indicates location of habitat survey.



**Table 28. B-IBI Scores and Biological Condition Category for Long-Term Little Bear Creek Sites**

Site/Year	08LIT2603	08LIT2602	08LIT2692	08LIT2781	08LIT2685	08LIT2682	08LIT2585
2002	20	26	30	34	28	28	24
2003	26	36	36	30	24	26	24
2005	36	30	36	34	22	24	22
2006	30	30	36	34	34	24	28
2007	24	38	36	36	28	24	30
2008	28	28	28	34	30	30	26
2009	32	30	40	36	26	34	26
2010	24	30	34	30	32	22	32
2011	28	26	28	30	26	32	32
2012	32	34	34	28	20	28	24
2013	32	30	30	30	28	26	30
2014	30	30	36	32	24	22	34
2015	33	26	30	27	30	32	26
<i>Site Statistics</i>							
Maximum	36	38	40	36	34	34	34
Minimum	20	26	28	27	20	22	22
Range (pts)	16	12	12	9	14	12	12
Average	28.8	30.3	33.4	31.9	27.1	27.1	27.5
Std Deviation	4.4	3.7	3.8	3.0	4.0	4.0	3.8
Coeff. of Var.	15.4	12.3	11.3	9.3	14.7	14.7	13.6
Std Error	1.23	1.03	1.05	0.82	1.10	1.10	1.04
95% CI +/-	2.4	2.0	2.0	1.6	2.1	2.1	2.0
Upper 95% CL	31.2	32.3	35.4	33.5	29.2	29.2	29.6
Lower 95% CL	26.4	28.3	31.3	30.3	24.9	24.9	25.5
B-IBI Score/ Condition Category	10-16 Very Poor	18-26 Poor	28-36 Fair	38-44 Good	46-50 Excellent		

Table 29 highlights the two highest (green shading) and lowest (red shading) B-IBI scores for each site among all years. Among sites, the highest and lowest scores did not align by year. Only one year, 2009, had high scores at more than two of the sites (with 3 out of 7 sites having high scores) with no observed low scores, but a maximum site score was observed at one or more sites in 9 out of 12 years. Likewise, a minimum score was observed at one or more sites in 9 out of 12 years. In most years, both a maximum score and minimum score were observed, reinforcing the lack of correlation among sites by year. Both maximum and minimum scores appear to track downstream over time, as suggested by the progression of shading down and to the right of low scores from 2002 to 2005 and 2011 to 2014 and of high scores from 2005 to 2010.

**Table 29. Variability of B-IBI scores by site and by year. Sites are listed in upstream to downstream order from left to right. The two highest (green) and lowest (red) scores for each site are indicated by shading.**

Year	08LIT2603	08LIT2602	08LIT2692	08LIT2781	08LIT2685	08LIT2682	08LIT2585	AVG
2002	20	26	30	34	28	28	24	27.1
2003	26	36	36	30	24	26	24	28.9
2005	36	30	36	34	22	24	22	29.1
2006	30	30	36	34	34	24	28	30.9
2007	24	38	36	36	28	24	30	30.9
2008	28	28	28	34	30	30	26	29.1
2009	32	30	40	36	26	34	26	32.0
2010	24	30	34	30	32	22	32	29.1
2011	28	26	28	30	26	32	32	28.9
2012	32	34	34	28	20	28	24	28.6
2013	32	30	30	30	28	26	30	29.4
2014	30	30	36	32	24	22	34	29.7
2015	33	26	30	27	30	32	26	29.1

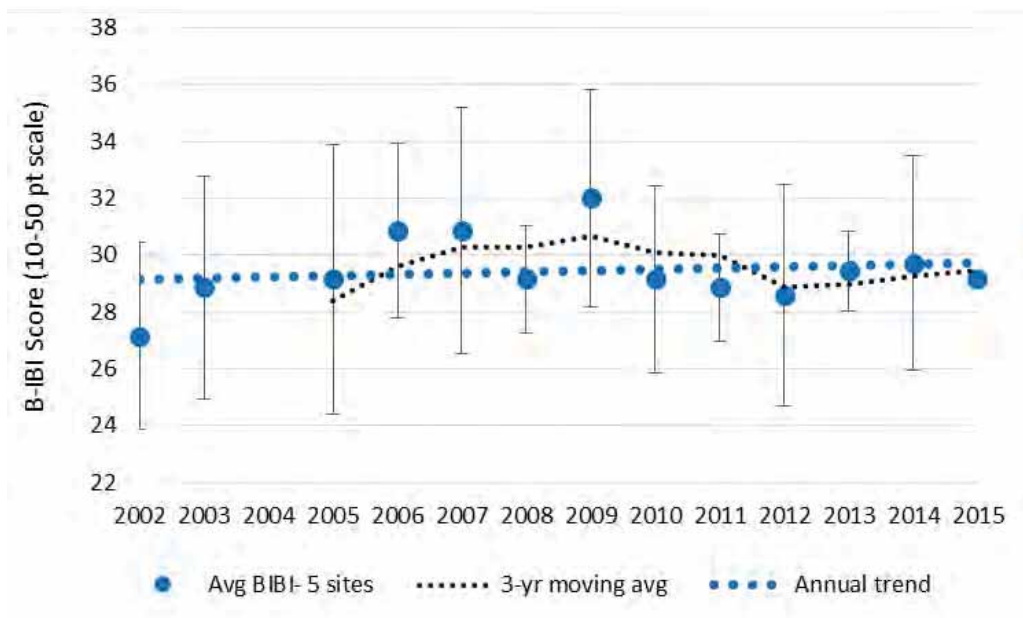
A correlation matrix for all sites for the 13 years is shown in Table 30. Among 21 site pair comparisons only one pair of sites, 2692 and 2602, were correlated across 13 years based on B-IBI scores. The correlation results suggest that site B-IBI scores are responding to different biotic or abiotic factors among these sites by year. Alternatively, the apparent downstream progressions over time noted in Table 29 suggest the possibility of a temporal and spatial lag where relatively higher (or lower) biotic integrity scores propagate downstream over time in sequential years. This possibility however, would require that the significance of relatively discrete (and presumably forceful) biotic or abiotic factors, such as large floods, drought, or population recruitment effects, persist for multiple years.

**Table 30. Correlation coefficients among sites based on B-IBI score.**

	08LIT2585	08LIT2602	08LIT2603	08LIT2682	08LIT2685	08LIT2692	08LIT2781
08LIT2585		-.0604 p=.844	-.2049 p=.502	-.2994 p=.320	.3270 p=.276	-.0922 p=.764	-.0785 p=.799
08LIT2602			-.0978 p=.751	-.4299 p=.143	-.3172 p=.291	.5829 p=.037	.1535 p=.617
08LIT2603				.1808 p=.554	-.3405 p=.255	.1931 p=.527	-.2045 p=.503
08LIT2682					-.0586 p=.849	-.3081 p=.306	-.0918 p=.766
08LIT2685						-.2413 p=.427	.1497 p=.625
08LIT2692							.4134 p=.160
08LIT2781							

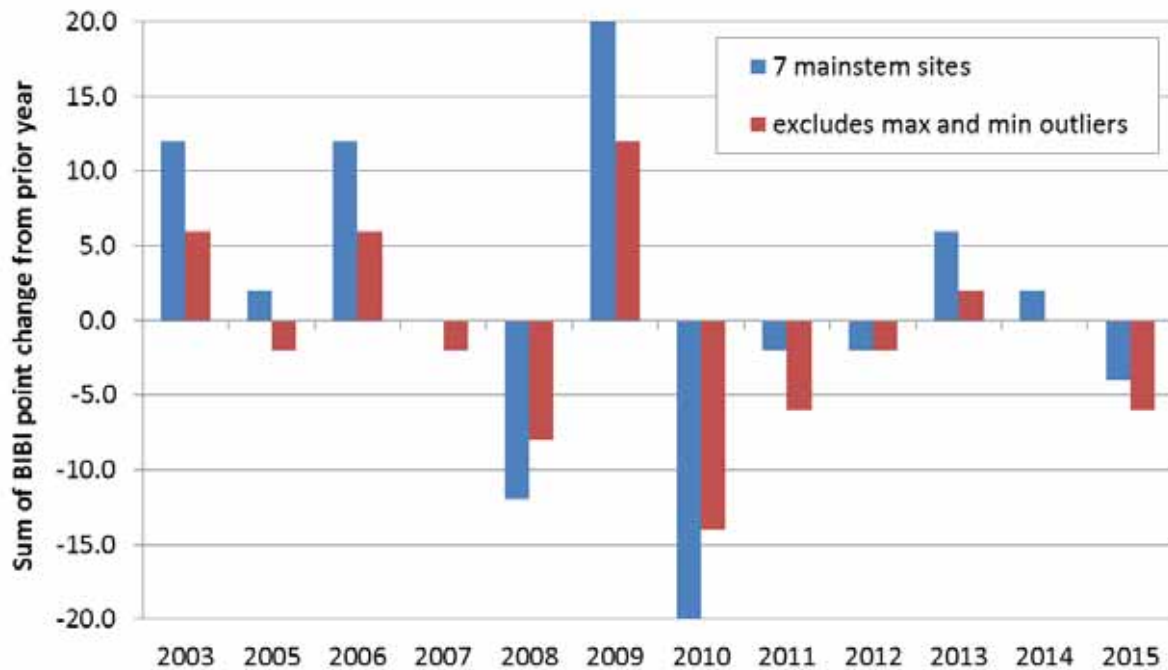
Marked correlations are significant at  $p < 0.05$ ,  $N=13$ . (Casewise deletion of missing data.)

Table 29 shows that the highest average B-IBI score in Little Bear Creek (for these seven sites) was in 2009, followed by 2007. The lowest average scores were observed in 2002 and 2003 (no data were collected in 2004). A plot of the average B-IBI score (and standard deviation) by year is shown in Figure 33. Scores increase on average between 2002 and 2007 and decrease on average between 2009 and 2013. The largest increase in average score between years is from 2008 to 2009. The largest decrease in average scores between years is from 2009 to 2010.



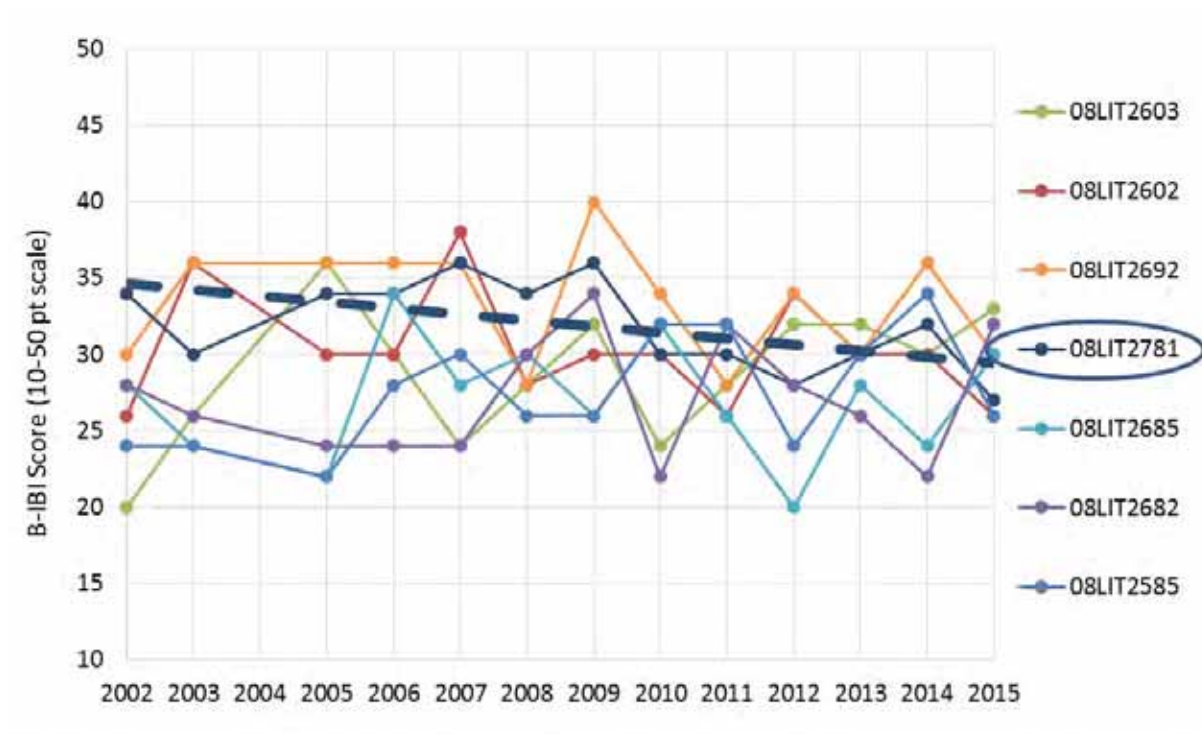
**Figure 33. Average B-IBI score by year for all sites (with standard deviation). The linear relationship is plotted as a 3-year running average.**

Figure 34 explores changes in site scores from year to year. For each of the same seven sites, the change in B-IBI point score (+/-) from the previous year was summed. The greatest observed changes were from 2007 to 2008 (negative sum), 2008 to 2009 (positive sum) and 2009 to 2010 (negative sum). Though individual site scores changed by up to  $\pm 12$  points between years, the sum of differences between these years was directionally compelling. Even when each of the largest positive and negative score changes per year were excluded from the analysis, the distinct shifts over this period were present. As a result, it may be worth investigating whether substantial differences in hydrology exist for this series of years (2008, 2009, and 2010) compared to any other series of three years.



**Figure 34. Year-to-year sum of B-IBI point change for seven sites. Values represent change from the previous year (i.e. 2008 value is the change from 2007 to 2008).**

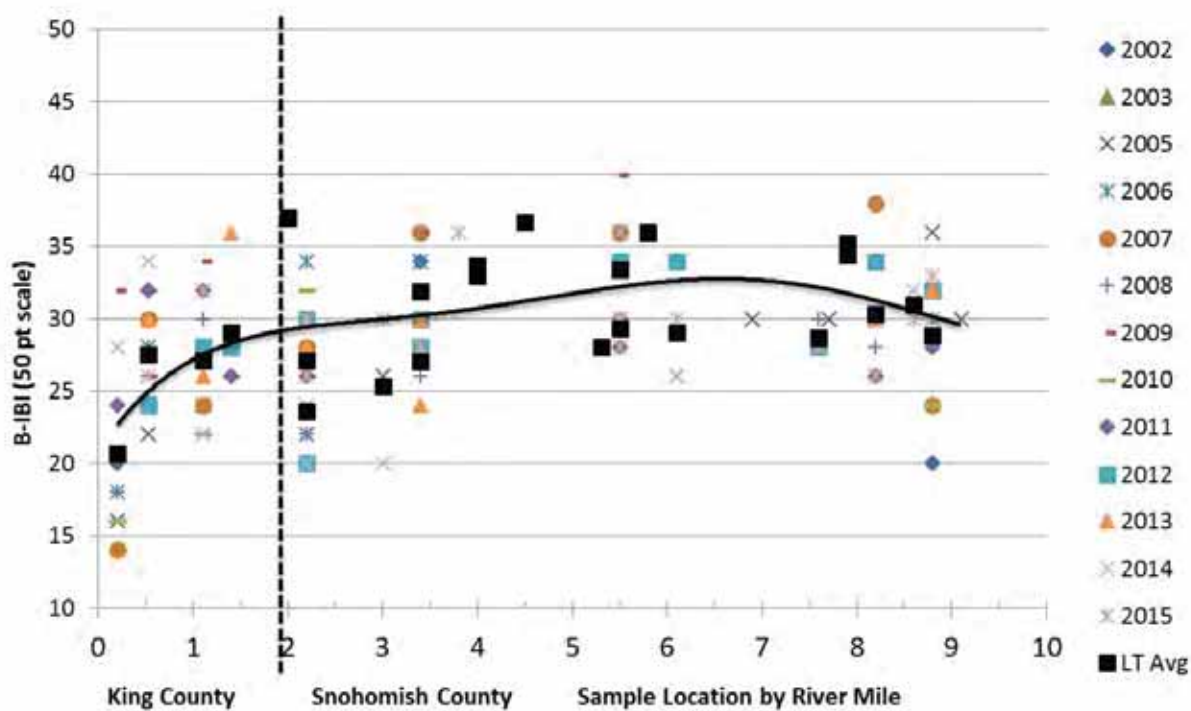
The data were tested for overall score trends among sites by year, despite the year-to-year variability. As highlighted by the line slope in Figure 35, only one site (circled legend item 08LIT2781) demonstrated either an increasing or decreasing score trend over time based on a simple test of the line slope ( $\alpha=0.05$ ). Even still, the significant negative slope is due to the decrease in B-IBI score in the final year in a range of years where increasing and decreasing score appears to be cyclical. Without the final year (2015), there is no significant line slope. The cyclical nature of increasing and decreasing B-IBI scores every few years (if persistent), suggests the statistically significant slope may not persist.



**Figure 35. Time series of site B-IBI scores. Statistically significant line slopes are shown with dashed regression line.**

There does appear to be a more distinct spatial pattern in B-IBI scores along Little Bear Creek. B-IBI scores for all mainstem sites since 2002 are shown longitudinally by river mile in Figure 36. The plot shows that B-IBI scores increase in a downstream direction starting from the upper sampling sites at approximately river mile 9 and continuing to river mile 5.5 at Little Bear Creek Road. From there, B-IBI scores generally decline in a downstream direction to near the mouth of Little Bear Creek in Woodinville. A break in the decreasing trend in B-IBI score is observed near the Snohomish-King County line (RM 2.0). This was also observed in previous studies (Morley, 2000; McBride, 2002) based on data collected prior to 2002. A downstream improvement in the forested buffer condition and the physical stream condition were noted by these authors.





**Figure 36. Longitudinal plot of all B-IBI scores (2002-2014) by river mile. Heavy dashed line represents Snohomish-King County line. Line fit through years is approximated to long-term average by site.**

Overall, biological condition in Little Bear Creek (as characterized by B-IBI) has been generally fair to good, with no area-wide temporal trends. Inter-annual variability at a site tends to be more substantial than spatial differences between sites, though there is a suggestion of some spatial trend with the best conditions found in unincorporated Snohomish County.

### 5.3 Habitat

The WRIA 8 Technical Committee identified the following salmonid habitat limiting factors within the Little Bear Creek watershed: fish access and passage barriers; loss of channel complexity and connectivity; altered hydrology and flow; increased sedimentation and altered sediment transport processes; degradation of riparian condition; and poor water quality (also see the Known Problems section below).

Fish passage barriers were one of the key limiting factors identified in the WRIA 8 Limiting Factors Report (Kerwin, 2001) that included Little Bear Creek. Barrier information from that report is likely outdated, but Washington Department of Fish and Wildlife (WDFW) maintains a fish passage database and mapping application (<http://apps.wdfw.wa.gov/fishpassage/>). The WDFW database identifies 129 known or potential fish passage barrier culverts in the Little Bear Creek system in Snohomish County. At least 15 barriers have been corrected, mainly via culvert replacements.

Other key findings from the habitat limiting factors report were as follows (Kerwin, 2001, pp. 412-413):

- *Benthic Index of Biotic Integrity (B-IBI) variability in Little Bear Creek was strongly related to local land cover changes (urban to vegetated condition) observed among sampling sites.*
- *LWD [large woody debris] is generally lacking throughout the watershed.*
- *Only 7 of 12 stream segments contained at least 50 percent forested riparian area, and total riparian forest cover (within 300 feet of stream and wetlands) was estimated to be 45 percent.*

Table 31 includes habitat indicators and diagnosis for Little Bear Creek summarized from the WRIA 8 Limiting Factors Report (Kerwin, 2001). Thresholds of function (e.g., not properly functioning, at risk, etc.) are explained in Kerwin (2001); although biotic integrity and B-IBI were discussed in the report, a level of function was not defined.

**Table 31. Functional Condition for Salmonid Habitat Indicators (Kerwin, 2001)**

Indicator	Level of Function
Temperature	Not Properly Functioning
Sediment/Turbidity	At Risk
Chemical Contamination/Nutrients	Not Properly Functioning
Physical Barriers	At Risk
Substrate Embeddedness	Not Properly Functioning
Large Woody Debris	Not Properly Functioning
Pool Frequency	Not Properly Functioning
Pool Quality	Not Properly Functioning
Off-Channel Habitat	Not Properly Functioning
Refugia	Not Properly Functioning
Channel Width/Depth Ratio	At Risk
Streambank Condition	At Risk
Floodplain Connectivity	Not Properly Functioning
Change in Peak/Base Flows	Not Properly Functioning
Increase in Drainage Network	Not Properly Functioning
Road Density and Location	Not Properly Functioning
Disturbance History	Not Properly Functioning
Riparian Areas	Not Properly Functioning

Large woody debris (LWD) is a critical component of stream habitat because it creates pools, channel structure, and habitat diversity. The density of LWD reported for Little Bear Creek is below published natural ranges (King County, 2001a). The pool frequency in Little Bear Creek failed to meet a salmon habitat suitability target of 56 pools per mile (King County, 2001a). King County (2001a) combined stream riffle, pool, and LWD metrics into a Habitat Quality Index (HQI) score for each stream segment of Little Bear Creek. In Little Bear Creek, five of twelve stream segments evaluated scored in the low quality habitat rating, six segments scored in the medium-low quality habitat rating, one segment scored in the medium-high quality rating, and none scored in the high quality rating.

The floodplain indicator includes the hydrologic linkage between adjacent off-channel area, wetlands, and riparian vegetation. In Little Bear Creek, channel complexity and connectivity with the floodplain and adjacent stream reaches are reduced due to road crossings and culverts (5.6 per mile as reported by Kerwin (2001)), streambank modification (i.e. armoring), channel incision and instability, and historic and on-going clearing and development in riparian areas.

To supplement existing stream habitat information and better align habitat and biological conditions under the scope of this project (same locations and sample years), Snohomish County implemented a modified wadeable stream survey that was co-located with well-established benthic macroinvertebrate sample sites (see Figure 32). The length of stream surveyed varied from 50 to 150 meters depending on the stream channel width—longer surveys for wider channels. In no case was a survey length shorter than 17 times the bankfull channel width (BFW), and reaches ranged up to 45 times the bankfull width. Thus, these surveys can be considered to represent local stream conditions where B-IBI samples were collected. The stream survey collected quantitative data for channel dimensions, streambank conditions, habitat units, woody debris, streambed substrate size, summer flow, and vegetation canopy cover over the stream. Summary values for each parameter were based on survey totals, average, density or percentage. Summary results by stream reach are highlighted below and provided in more detail with definitions in Appendix C.

The tables below include summary values for stream locations surveyed in 2014 or 2015 in Little Bear Creek and its tributaries. Because these sites were selected based on the locations of B-IBI sample sites and prior locations were not resurveyed, there was no direct attempt to compare these results to earlier results from prior to 2000. The upstream land cover among sites ranges from 10 percent to 42 percent impervious area and 36 percent to 75 percent forest (Table 32).

**Table 32. Stream Metric Site Contributing Characteristics**

Site Name	River Mile	Drainage Area (km <sup>2</sup> )	Upstream Landcover (2013)		Upstream Buffer (150m wide) (%Forest minus %TIA)		Avg BFW (m)	BFW/BFD Ratio
			%TIA	%Forest	500 meters up	1000 meters up		
<b>LB2603</b>	8.8	3.16	27.1	38.2	65.7	81.5		
<b>LB169</b>	8.6	3.40	27.1	38.2	72.5	72.8	3.35	8.74
<b>LB2602</b>	8.2	5.06	20.9	54.9	46.5	62.7	3.60	8.35
<b>LB51</b>	7.6	8.72	17.0	50.8	73.5	68.7	4.32	8.81
<b>LB196</b>	6.2	11.89	10.3	67.6			5.18	9.90
<b>LBC19830</b>	6.1	11.89	10.3	67.6	95.5	94.6	3.87	9.46
<b>LBC520</b>	5.5	14.63	9.5	75.3	60.4	76.6	5.47	10.34
<b>LBC224</b>	3.8	28.62	15.9	56.4	25.9	51.0	5.75	8.17
<b>LBLD</b>	3.4	29.27	18.0	55.0	33.2	27.7	5.77	10.57
<b>LB238</b>	3	30.68	26.3	45.7	-7.5	-1.6	5.83	7.58
<b>LB58</b>	2.2	32.69	41.5	35.5	3.7	-16.7	5.55	8.46
<b>Trout</b>	7.9	2.18	15.0	59.5	55.4	77.6	2.16	5.42
<b>WEST</b>	5.8	1.52	15.0	51.3	85.6	52.2	2.89	9.24
<b>DANE</b>	4.5	5.87	19.3	56.6	71.5	59.8	3.08	6.75
<b>CUTT</b>	4	2.92	24.0	50.0	39.9	61.9	2.75	8.51
<b>Cutt78</b>	4	0.65	37.3	48.6	99.3	69.5	1.60	4.05
<b>Rowland</b>	2	1.51	17.9	58.0	87.9	79.1	2.84	7.70

Pool - Pool count; Riffle - Riffle count; CW - Channel width

An important element of the survey was the characterization and quantity of streambed gravel and fine sediment. Fine sediment has been identified as an important factor affecting biological condition. The surface fine sediment content was estimated where benthic macroinvertebrates were directly sampled, as well as total substrate size distribution (including sand and silts) within each B-IBI riffle targeted in the survey. For substrate size, in particular, conditions in 2014 and 2015 were evaluated. The results of these comparisons to B-IBI scores will be provided in a future project report on B-IBI modeling. Substrate size information is included in Table 33. Results vary between sites. For example in 2014, sand in the B-IBI sample surface ranged from 1.0 percent to 36 percent. In 2015, these values ranged from 0.5 percent to 18 percent. Fine sediment less than 12 percent is generally considered to have higher suitability for spawning salmon. Further determination of suitability for spawning was beyond the scope of the stream metrics work.

**Table 33. Fine Sediment and Pebble Count Characteristics**

Site Name	2014				2015			
	% Fines - BIBI Grid	D50 (mm) Riffle	% Fines - Riffle	Grid + Riffle Fines	% Fines - BIBI Grid	D50 (mm) Riffle	% Fine - Riffle	Grid + Riffle Fines
<b>LB2603</b>					2.5	19.1	4.5	7.0
<b>LB169</b>	13.0	12.8	20.0	33	5.0	16.3	8.0	13.0
<b>LB2602</b>					9.5	18.2	15.5	25.0
<b>LB51</b>	25.1	12.24	20.0	45	10.5	14.9	20.5	31.0
<b>LB196</b>					17.0	26.3	6.0	23.0
<b>LBC19830</b>	10.0	21.0	4.5	14.5				
<b>LBC520</b>	3.5	24.2	11.5	15	2.5	34.7	1.5	4.0
<b>LBC224</b>					15.5	26.7	10.0	25.5
<b>LBLD</b>					4.0	21.7	4.5	8.5
<b>LB238</b>	36.0	14.1	8.9	44.9	7.5	17.1	9.5	17.0
<b>LB58</b>	17.0	17.5	20.0	37	3.0	22.3	10.0	13.0
<b>Trout</b>	12.5	23.3	2.5	15	4.6	16.8	10.3	14.9
<b>WEST</b>	1.0	23.4	5.5		6.3	21.0	7.4	
<b>DANE</b>	4.0	26.9	5.0	9	0.5	30.7	3.0	3.5
<b>CUTT</b>	3.5	25.1	11.0	14.5	5.0	20.5	10.0	15.0
<b>Cutt78</b>	27.0	9.9	19.5		7.0	14.3	9.0	16.0
<b>Rowland</b>	16.0	17.9	10.0	26	18.0	24.5	16.0	34.0

Fines are all sand and finer substrate including silt  $\leq 2\text{mm}$ .

A selection of summary habitat metrics are included in Table 34. Additional metrics are summarized in Appendix C. Woody debris density ranged from 20 to 200 pieces per kilometer of stream channel or, summarized another way, zero to 1.2 pieces per channel width. Habitat suitability criteria recommend woody debris abundance in excess of two pieces per channel width. Hence, as previously reported in Kerwin (2001), woody debris remains a limiting factor. Pool spacing ranges from 2.6 to 30 channel widths between pools. Ideally, pools would be separated by no more than the equivalent distance of two channel widths (see Appendix C). Thus, pool numbers appear to be substantially lower than habitat suitability criteria would recommend.

Streambank erosion and modification, taken together, range from zero to 45.5 percent of surveyed bank length. More extensive bank modification was noted near SR-9, as Little Bear Creek parallels (and abuts) the road prism. Relatively greater erosion was observed along tributary stream survey locations, which flow across relatively unconsolidated sediment deposits (alluvial fans described in Section 3.6) and/or are generally alluvial and susceptible to lateral channel movement. As noted in Section 3.6.2, many of the tributaries are characterized by incised erosional gullies upstream from these stream survey locations, which may deliver quantities of sediment that settle in the alluvial areas forcing erosional channel migration.



Lastly, vegetated canopy cover was very poor in survey locations LB238 and LB58. Because Little Bear Creek and its tributaries are relatively narrow, mature trees could form a nearly complete shaded canopy over the stream, and with few exceptions, would be expected to provide 90 percent canopy cover. This condition is met in many locations. Further study through a watershed-wide analysis of stream buffer land cover would be useful for identifying locations for enhancement to target water temperature exceedances.

**Table 34. Physical Habitat Metrics**

Site Name	Pool count	Riffle count	Woody debris per km	Woody debris per CW	% Wood-formed Pools	Pool Spacing/ CW	Erosion %	Mod %	%Center Channel Cover
<b>LB2603</b>									
<b>LB169</b>	1	9	90	0.3	0	29.81	10.5	0.0	76.6
<b>LB2602</b>	8	6	180	0.6	75	3.47	7.3	0.0	94.5
<b>LB51</b>	3	6	180	0.8	100	7.72	1.0	0.0	90.6
<b>LB196</b>	4	5	173	0.9	100	7.24	2.7	0.0	81.3
<b>LBC19830</b>	6	8	120	0.5	66.7	4.31	3.2	1.5	92.9
<b>LBC520</b>	6	6	130	0.7	66.7	3.05	2.9	10.5	82.1
<b>LBC224</b>	8	8	180	1.0	62.5	3.26	6.5	36.0	81.7
<b>LBLD</b>	10	8	200	1.2	50	2.60	8.6	36.9	80.2
<b>LB238</b>	11	6	61	0.4	27.3	2.56	23.1	6.8	36.3
<b>LB58</b>	9	7	110	0.6	66.7	4.00	12.0	0.0	51.3
<b>Trout</b>	6	18	20	0.0	16.7	7.70	17.3	0.0	88.8
<b>WEST</b>	7	9	140	0.4	57.1	2.47	15.7	0.0	98.8
<b>DANE</b>	2	8	20	0.1	100	16.22	21.0	4.3	77.1
<b>CUTT</b>	3	3	120	0.3	100	6.07	31.6	0.0	90.5
<b>Cutt78</b>	2	6	80	0.1	50	15.63	0.0	0.0	96.4
<b>Rowland</b>	4	13	140	0.4	75	8.81	22.3	1.5	97.1

CW – Channel width; Mod- Human-made bank modifications

## 5.4 Known Problems

Known, probable, and possible salmon habitat factors of decline were identified in a 2001 draft report prepared by the Greater Lake Washington Technical Committee and principally authored by Snohomish County staff. Much of the same content was reorganized in the WRIA 8 limiting factors report (Kerwin, 2001). Many of the habitat factors of decline identified in these reports and summarized below were based on data collected prior to 2000 and interpreted using the National Marine Fisheries Matrix of Pathways and Indicators (NMFS, 1996) or other published thresholds of natural function (e.g., Peterson et al., 1992).

#### 5.4.1 Known Factors of Decline

- *Fish Access and Passage Barriers* – The WDFW database lists approximately 130 potential fish passage barriers (culverts, dams, fishways) on Little Bear Creek, 30 of which are publicly owned. The barrier conditions include water surface drop, slope depth and velocity. Both the County and WSDOT have replaced 15 barrier culverts between 1997 and 2013. The County has recently replaced additional culverts and has other planned projects, and remaining WSDOT barrier culverts—including Great Dane Creek at Maltby Road (SR-524)—will be replaced over the next several years.

#### 5.4.2 Probable Factors of Decline

- *Loss of Channel Complexity/Connectivity* - In Little Bear Creek, channel complexity and connectivity with the floodplain and adjacent stream reaches are reduced due to road crossings/culverts, streambank modification, abrupt rural-to-urban land-use changes, channel incision and instability, and historical and on-going clearing and development in riparian areas. Changes in land-use practices (forest harvest, rural development, and suburbanization) over time have limited in-stream large wood recruitment that contributes to channel complexity. Additionally, with less wood, scour is exacerbated and channel beds are less stable and become riffle-dominated. These factors may impact spawning success. In-stream habitat complexity, as characterized by low LWD abundance, simplified channel form and low pool area, is significantly degraded (King County 2001).
- *Degradation of Riparian Conditions* - Clearing and development in the riparian corridors has reduced the extent of riparian forests and changed land cover from predominantly coniferous and mixed forests to deciduous forest, and, in places, from forest to impervious surfaces. These changes in riparian conditions, along with stream wood removal (May et al. 1997) have led to a reduced amount of new woody debris from riparian buffers that could function as fish habitat (King County, 2001). Morley (2000) found that B-IBI variability was a function of local riparian land cover changes (urban to vegetated condition) observed among sampling sites.
- *Altered Hydrology/Flow* - Changes in hydrology within Little Bear Creek that are attributable to land use changes over time is lacking. However, land cover characteristics of the study area and past stream surveys indicate negative effects of hydrologic change on instream habitat conditions throughout Little Bear Creek. Additionally, the undocumented loss of wetlands, loss of floodplain area, water withdrawal and increasing levels of impervious surfaces contribute to altered hydrologic regimes. Additionally, many stream segments (primarily in tributaries) dry up in summer.
- *Increased Sedimentation/Altered Sediment Transport Processes* - The delivery and routing of sediments to stream channels in urbanizing drainages is characterized by pulses of sediment originating from basin-wide soil disturbing activities and also from streambank erosion (Trimble, 1997). More sediment can be routed to streams by way of the increased drainage network of

roads, ditches, outfalls, and surface flow. Where stream discharge increases, streambank erosion is expected. Further, where hydromodifications restrict channel adjustment and LWD is scarce, streambed incision and suspension of bedload to depths critical to incubating salmonids is more frequent.

Total suspended solids in storm flows are significantly greater in basins with higher impervious area (May et al., 1997). The direct and indirect effects of excess fine sediment include higher streambed embeddedness, where sand and finer silts fill porous spaces in stream gravel, intrusion of sand and silts into salmon spawning redds, filling of pools, and higher turbidity. Fine sediment load (or alternatively the coarsening of the streambed) can also affect the benthic macroinvertebrate community (Wydzga, 1997), and indirectly, the food supply for fish (Sloane-Richey et al., 1981).

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## **Appendix A:      GIS Data Inventory**

Category	Data	Source	Date	Description	Shapefile(s)
Assessor	Cadastral Parcels	Snohomish County		The Parcels data set is a thematic layer depicting current real property parcel boundaries within Snohomish County, Washington based on the legal descriptions contained in the assessment roll.	cadastral_parcels_assessor
Drainage	Drainage Facilities	Snohomish County		Drainage facility points including pollution control, detention, infiltration, flow control, conveyance	drainage_facilities_pnts
Drainage	Drainage Inventory	Snohomish County		Drainage points, pipe/ditch network, catch basins	utilities_drainage_catchbas; utilities_drainage_drainpnt; utilities_drainage_network; utilities_drainage_xs
Drainage	Drainage Inventory	City of Bothell		Catch basins, swales, ponds, pipes, streams/ditches, culverts, vaults	Bothell_Berms_PondSwale; Bothell_BioSwales; Bothell_catchbas; Bothell_culverts; Bothell_dams; Bothell_DetentionPonds; Bothell_Ditches; Bothell_OpenChannels; Bothell_Pipes; Bothell_Pipes_Detention; Bothell_Vaults; Bothell_Wetlands
Drainage	Drainage Inventory	City of Woodinville		Detention facilities, streams/ditches, pipes, inlets/outlets	Woodinville_Commercial_detention; Woodinville_facility; Woodinville_residential_detention; Woodinville_structure_VaultLid; sw_facility; sw_inlet_outlet; sw_open_channel; sw_pipe; sw_structure



Category	Data	Source	Date	Description	Shapefile(s)
Environmental	303d_list	WA Ecology	2016	Subset of waters whose beneficial uses are impaired by pollutants are placed in the polluted water category on the water quality assessment. These water bodies fall short of state surface water quality standards, <b>do not have a clean-up plan developed</b> , and are not expected to improve within the next two years. The <i>303(d) list</i> , so called because the process is described in Section 303(d) of the Clean Water Act.	303d_list
Environmental	305b_list	WA Ecology	2016	Complete list of overall conditions of waters whose beneficial uses have been assessed and are placed into categories ranging from non-impaired to impaired and having or not having a clean-up plan. The 305(b) list is so called because it refers to a report that EPA delivers to Congress under Section 305(b) of the Clean Water Act.	305b_list
Hydro	Aquifers Recharge Areas	Snohomish County	1997	Recharge areas with low, medium and high aquifer sensitivity	CAR_AQUIFER_usgs_sensitivity
Hydro	Streamline	Snohomish County	2015	Updated Little Bear Creek stream mapping	LBC_streamlines_rev_20151102
Hydro	Subbasins	NHC	2016	Major drainage basins within Little Bear Creek	LB_Subbasins_20160914
Hydro	Wetlands	Snohomish County		Designated wetland areas	LBC_wetlands_CAR2007; LBC_Wetlands_NWI; LBC_Wetlands_PDS
Land Cover	Land Cover	NHC	2016	Land cover categories derived from image analysis of NAIP 2013 aerial imagery and impervious area analysis	landcover_NAIP2013_v4

Category	Data	Source	Date	Description	Shapefile(s)
Land Use	Land Use	Snohomish County	2016	Hydrologic modeling land use categories broken up at the parcel level. Categories include: commercial, forest, grass, multi-family residential, pasture, rural, single family residential-low, single family residential-medium, single family residential-high and transportation.	lbu_nhc_v9
Land Use	Non-Designated Agriculture	Snohomish County	2006-2007	Land not zoned for agriculture but being used as agriculture	Ag_nondesignated_LBC
Land Use	Parks	Snohomish County		Countywide park layer	SnoCo_Parks
Land Use	Septic Parcels	Snohomish County		This dataset is an estimation of which parcels have septic systems. It was created using information from both the Snohomish County Assessor parcel data and the Snohomish Health District septic data.	septic_repairs_2001_2012; septic_residential_parcel_pts; sewerlines_2012
Monitoring	B-IBI Sample Sites	Snohomish County	2015	B-IBI monitoring location point file	BIBI_Locations_20151102
Monitoring	Hydro Gages	King County	1994 - current	This dataset shows the locations of King County hydrologic gages from 1994 to the present (except for Water Temperature gages which are listed from 1988 to present).	KC_HydroGages; OtherGages
Monitoring	Rain/Stream Gages	Snohomish County	2014	Point file showing Snohomish County rain and flow gage locations	operating_stream_rain_gages_20141205
Monitoring	Temperature Monitoring	Snohomish County		Point file showing locations of temperature gage sites	Temperature_Monitoring_Locations
Monitoring	Water Quality Monitoring	Snohomish County		Point file showing locations of water quality gage sites	Water_Monitoring_points_12-17-13
Other	Animals	Snohomish County	2010	Commercial and Private Kennel centroids; livestock survey data	CommercialKennelsCentroids12062010; PrivateKennelsCentroids12062010; SnohomishCountyLivestockSurveyData

Category	Data	Source	Date	Description	Shapefile(s)
Soils	Soils	Snohomish County		Polygon layer showing NRCS SSURGO soil types	SSURGO_BasinSoils
Topography	HSPF Slopes	Snohomish County		Land surface slopes grouped into categories used for HSPF analysis	hspf_slopes
Topography	Topography	Puget Sound LiDAR Consortium	2010	2010 composite LiDAR surface	

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## **Appendix B: Streamwalk Summary Data**



Table B1a. Geomorphic and basic descriptive attributes by interval

Interval	Geomorphic and basic descriptive attributes								
	river station at down-stream boundary (miles)	approx. contrib-uting drainage area (mi <sup>2</sup> )	field measured main channel length (ft)	field measured main channel low flow area (ft)	Dominant channel morphology	slope (% LiDAR derived)	bankfull width (W <sub>bf</sub> ft)	bankfull depth (ft)	W <sub>bf</sub> / depth ratio
LBC_A1	2.17	12.3	465	10,346	Plane bed	0.18	23	3.3	7.0
LBC_A2	2.27	12.3	273	4,483	Pool riffle	0.67	29	2.6	11.2
LBC_B1	2.73	11.7	207	2,103	Pool riffle	0.19	16	3.8	4.2
LBC_B2	2.78	11.5	264	3,188	Pool riffle	0.19	19	4.0	4.8
LBC_C1	3.10	11.4	259	4,470	Pool riffle	0.33	22	3.2	6.9
LBC_C2	3.16	11.4	183	2,030	Pool riffle	0.33	27	3.2	8.4
LBC_C3	3.19	10.9	209	4,021	Pool riffle	0.33	30	3.2	9.4
LBC_C4	3.22	10.9	195	1,518	Pool riffle	0.33	38	2.8	13.6
LBC_C5	3.26	10.9	250	2,483	Pool riffle	0.33	26	2.4	10.8
LBC_D1	3.38	10.8	166	2,087	Pool riffle	0.83	32	2.4	13.3
LBC_D2	3.44	10.6	357	4,608	Plane bed	0.47	19	3.4	5.6
LBC_E1	3.61	10.6	236	4,548	Pool riffle	0.36	24	3.4	7.1
LBC_E2	3.66	10.5	388	5,299	Pool riffle	0.53	27	3.3	8.2
LBC_F1	3.93	10.4	200	5,861	Step pool (wood forced)	0.60	15	3.6	4.2
LBC_F2	3.98	10.3	281	2,256	Plane bed	1.52	15	3.6	4.2
LBC_F3	4.02	10.3	357	6,753	Pool riffle	0.56	17	3.5	4.7
LBC_G1	4.20	10.1	205	3,585	Pool riffle	0.27	56	2.0	28.0
LBC_G2	4.25	10.0	210	3,159	Pool riffle	1.28	24	1.9	12.6
LBC_G3	4.28	10.0	153	1,648	Pool riffle	0.91	45	1.5	30.0
LBC_H1	4.74	8.9	130	2,664	Pool riffle	1.58	24	2.4	9.8
LBC_H2	4.75	8.9	103	1,562	Plane bed	0.30	38	2.4	15.8
LBC_H3	4.77	8.9	187	2,277	Step pool (wood forced)	1.35	44	3.0	14.7
LBC_H4	4.72	6.5	1,000	11,869	Step pool (wood forced)	0.02	20	3.2	6.3
LBC_I1	5.33	5.8	230	2,280	Pool riffle	0.71	19	2.8	6.7
LBC_I2	5.37	5.8	239	2,195	Pool riffle	0.11	15	2.0	7.5
LBC_I3	5.41	5.8	215	2,927	Pool riffle	1.07	15	1.5	10.0
LBC_I4	5.46	5.8	250	3,550	Pool riffle	0.68	14	1.6	8.8
LBC_J1	5.61	5.5	215	3,201	Pool riffle	0.76	18	2.3	7.8
LBC_J2	5.65	5.5	207	2,570	Pool riffle	0.88	18	1.8	10.0
LBC_J3	5.70	5.5	203	2,922	Pool riffle	1.70	28	2.5	11.2
LBC_J4	5.74	5.5	264	18,796	Pool riffle	0.93	20	1.5	13.3
LBC_K1	6.68	4.3	230	3,245	Pool riffle	1.82	30	1.2	25.0
LBC_K2	6.72	4.3	261	3,308	Pool riffle	0.13	27	1.1	24.7
LBC_K3	6.77	4.3	161	5,215	Pool riffle	0.55	23	1.0	24.2
LBC_L1	7.59	3.4	206	2,165	Pool riffle	0.67	17	2.3	7.4
LBC_L2	7.62	3.4	205	3,248	Dune ripple	0.21	15	2.0	7.5
LBC_L3	7.66	3.4	205	3,507	Dune ripple	0.91	16	2.0	8.2
LBC_M1	9.67	0.90	212	1,917	Plane bed	0.19	21	1.2	18.3
LBC_M1	9.71	0.90	60	1,917	Plane bed	0.10	21	1.2	18.3
LBC_N1	9.84	0.74	214	788	Plane bed	0.29	10	1.4	7.1
LBC_N2	9.87	0.73	188	639	Pool riffle	1.05	16	0.6	28.1
LBC_N3	9.91	0.72	217	663	Pool riffle	1.60	5.0	1.3	3.8
LBC_N4	9.94	0.71	188	513	Step pool (wood forced)	3.46	5.0	1.0	5.0
Row_A1	2.21	0.58	203	730	Plane bed	4.70	9.0	1.1	8.2
Row_A2	2.26	0.58	201	928	Pool riffle	3.38	8.7	0.8	11.6
Row_A3	2.30	0.58	248	907	Plane bed	2.90	8.6	0.6	13.7
Row_B1	2.56	0.55	200	761	Plane bed	3.79	14	0.6	24.1

Table B1a. Geomorphic and basic descriptive attributes by interval

Interval	Geomorphic and basic descriptive attributes								
	river station at downstream boundary (miles)	approx. contributing drainage area (mi <sup>2</sup> )	field measured main channel length (ft)	field measured main channel low flow area (ft)	Dominant channel morphology	slope (% LiDAR derived)	bankfull width (W <sub>bf</sub> , ft)	bankfull depth (ft)	W <sub>bf</sub> / depth ratio
Row_C1	2.68	0.50	298	394	Plane bed	4.75	15	0.5	29.3
Row_C2	2.76	0.48	111	25	Plane bed	3.38	15	0.4	36.6
Row_D1	2.99	0.34	76	dry	Plane bed	7.51	5.5	0.8	7.3
Row_D2	3.04	0.33	200	0	Plane bed	10.83	7.0	0.6	11.5
Row_E1	3.35	0.20	191	dry	Plane bed	3.36	4.0	0.8	4.8
TRo2_A1	3.23	0.04	199	dry	Colluvial	4.07	6.8	0.8	9.0
TRo3_A1	3.30	0.02	182	dry	Colluvial	4.93	1.0	0.1	10.0
Howell1	3.21	0.48	200	678	Plane bed	2.13	5.8	0.5	11.6
Howell2	3.25	0.47	217	614	Pool riffle	1.03	4.0	1.0	4.0
Howell3	3.29	0.47	110	479	Plane bed	0.59	4.0	1.0	4.0
TB_A1	4.02	0.08	210	332	Step pool	3.01	3.0	0.5	6.0
TD_A1	4.16	0.02	245	dry	Step pool	5.18	3.0	0.5	6.0
TD_A2	4.22	0.01	275	dry	Step pool	4.27	3.0	0.5	6.0
TD_A3	4.28	0.01	224	dry	Step pool	4.45	3.0	1.3	2.3
TD_A4	4.32	0.01	151	dry	Pool riffle	2.73	4.0	1.3	3.1
TD_A5	4.34	0.01	243	dry	Plane bed	2.91	4.0	1.3	3.1
TD_A6	4.39	0.00	257	dry	Plane bed	3.09	4.0	1.5	2.7
CC_A1	5.32	0.31	175	900	Pool riffle	3.20	10	0.8	12.5
CC_B1	5.50	0.27	110	366	Plane bed	2.95	6.0	1.0	6.0
CC_B2	5.52	0.27	175	675	Pool riffle	3.65	6.0	1.4	4.3
CC_B3	5.55	0.22	157	556	Plane bed	2.66	6.0	1.0	6.0
CC_B4	5.58	0.14	257	414	Plane bed	1.70	4.0	1.0	4.0
TCu1_A1	5.56	0.13	119	dry	Step pool (wood forced)	5.56	1.5	0.5	3.0
TCu2_A1	5.31	0.11	241	dry	Pool riffle	4.42	8.0	1.0	8.0
TCu2_A2	5.36	0.11	202	dry	Plane bed	5.75	8.0	2.9	2.8
TCu2_A3	5.41	0.11	204	dry	Plane bed	4.03	8.3	0.3	27.7
TE_uns1	4.86	0.06	264	dry	Plane bed	1.72	1.5	1.0	1.5
GD_A1	4.84	2.3	180	597	Pool riffle	1.21	8.4	1.6	5.3
GD_B1	5.11	2.2	89	530	Pool riffle	0.45	11	1.9	5.8
GD_C1	5.21	2.2	204	1,468	Pool riffle	2.31	8.8	1.3	6.8
GD_C2	5.26	2.2	217	2,106	Pool riffle	2.55	10	2.2	4.5
GD_C3	5.29	2.2	191	1,222	Pool riffle	1.38	11	0.7	15.7
GD_C4	5.32	2.2	247	1,913	Plane bed	0.73	12	2.5	4.8
GD_C5	5.38	0.04	197	734	Step pool (wood forced)	2.77	15	2.0	7.5
GD_D1	5.58	2.1	208	771	Pool riffle	1.21	24	1.0	23.1
GD_E1	6.04	1.9	220	0	Pool riffle	0.06	11	1.5	7.4
GD_F1	6.19	1.6	259	dry	Plane bed	1.40	12	2.1	5.6
GD_F2	6.25	1.6	163	0	Plane bed	3.19	12	2.1	5.6
GD_F3	6.28	1.6	184	0	Step pool (wood forced)	1.49	9.4	1.2	8.0
GD_F4	6.31	1.5	234	0	Step pool	0.25	10	1.3	7.7
GD_G1	6.61	1.3	240	dry	Step pool (wood forced)	2.50	26	1.2	21.3
GD_G2	6.67	0.90	161	dry	Step pool (wood forced)	3.51	19	1.0	19.0
GD_G3	6.69	0.90	191	dry	Plane bed	3.52	21	0.8	26.3
GD_G5	6.79	0.89	255	dry	Pool riffle	1.56	12	2.2	5.5
GD_G6	6.85	0.7	282	dry	Plane bed	3.47	12	3.0	4.0
GD_H1	8.33	0.1	156	dry	Colluvial	1.84	2.0	0.2	10.0
TGD3_A1	6.36	0.2	270	dry	Plane bed	5.00	2.0	1.0	2.0

Table B1a. Geomorphic and basic descriptive attributes by interval

Interval	Geomorphic and basic descriptive attributes								
	river station at downstream boundary (miles)	approx. contributing drainage area (mi <sup>2</sup> )	field measured main channel length (ft)	field measured main channel low flow area (ft)	Dominant channel morphology	slope (% LiDAR derived)	bankfull width (W <sub>bf</sub> , ft)	bankfull depth (ft)	W <sub>bf</sub> / depth ratio
TGD3_A2	6.42	0.1	329	dry	Plane bed	4.27	2.0	1.0	2.0
TGD3_A3	6.49	0.1	218	dry	Plane bed	4.41	1.0	0.5	2.0
TGD3_A4	6.53	0.1	135	dry	Plane bed	4.71	1.0	0.5	2.0
TGD4_A1	6.57	0.1	114	dry	Plane bed	2.06	1.5	1.0	1.5
TGD4_A1	6.58	0.1	205	dry	Plane bed	3.52	1.5	1.0	1.5
TGD5_A1	6.68	0.9	158	dry	Colluvial	2.88	3.0	0.2	15.0
TGD5_B1	7.44	0.2	212	dry	Plane bed	2.12	5.0	1.0	5.0
TGD5_B2	7.49	0.2	267	dry	Plane bed	1.75	5.0	1.0	5.0
TG_A1	5.63	0.2	185	569	Plane bed	2.82	4.0	1.0	4.0
TG_B1	5.73	0.1	285	10,639	Plane bed	2.70	11	0.8	14.9
TG_B2	5.77	0.1	172	513	Plane bed	4.33	4.0	1.0	4.0
TJ_A1	6.67	0.5	300	945	Step pool (wood forced)	1.62	3.0	1.0	3.0
TL_A1	7.46	0.5	207	949	Plane bed	3.81	5.0	1.6	3.1
TL_A2	7.50	0.5	206	867	Pool riffle	3.40	5.0	1.1	4.5
TL_A3	7.53	0.5	244	841	Plane bed	1.87	5.0	1.0	5.0
TL_A4	7.59	0.3	79	102	Step pool (wood forced)	4.83	2.0	1.3	1.5
TL1_A0	7.59	0.1	223	712	Plane bed	3.99	2.0	1.0	2.0
TL1_A2	7.62	0.1	237	973	Plane bed	5.56	2.0	1.0	2.0
TL1_A3	7.68	0.1	67	30	Plane bed	0.57	2.0	1.0	2.0
TrC_A1	8.50	0.9	201	939	Dune ripple	0.02	5.4	0.9	6.1
TrC_A2	8.55	0.9	111	198	Pool riffle	0.41	5.4	0.9	6.1
TrC_B1	8.88	0.8	279	1,230	Pool riffle	0.53	4.0	1.0	4.0
TrC_B2	8.93	0.8	71	236	Pool riffle	2.36	4.0	1.0	4.0
TrC_C1	9.27	0.7	212	dry	Plane bed	2.41	7.9	2.0	4.0
TrC_C2	9.32	0.7	203	dry	Plane bed	4.66	7.9	1.0	7.9
TrC_C3	9.35	0.7	82	dry	Plane bed	3.18	8.0	0.5	16.0
TrC_D1	9.71	0.6	227	dry	Plane bed	3.44	5.0	1.0	5.0
TO_A1	9.76	0.2	211	dry	Plane bed	3.44	5.6	0.5	10.6
TO_A2	9.76	0.2	408	dry	Plane bed	0.17	5.6	0.5	10.6
TO_A3	9.86	0.1	176	dry	Plane bed	1.26	3.0	0.2	15.0
TO2_A2	9.78	0.0	220	dry	Plane bed	9.49	3.9	0.4	9.1

Table B1b. Geomorphic and basic descriptive attributes by interval (continued)

Interval	Geomorphic and basic descriptive attributes ctd.		Geomorphic unit attributes (proportion of low flow wetted area)						
	field measured percent canopy cover (at upstream transect)	Dominant Bank Vegetation	Other/ Control	Cascade	Step- Pool	Forced Step-Pool	Riffle	Glide	Pool
LBC_A1	63	Deciduous trees	0.10	0.00	0.00	0.00	0.39	0.05	0.45
LBC_A2	58	Blackberry	0.00	0.00	0.00	0.00	0.17	0.00	0.83
LBC_B1	8	Shrubs	0.00	0.00	0.00	0.00	0.25	0.32	0.42
LBC_B2	0	Grass	0.03	0.00	0.00	0.00	0.02	0.28	0.66
LBC_C1	75	Grass	0.00	0.00	0.00	0.00	0.00	0.66	0.34
LBC_C2	4	Grass	0.01	0.00	0.00	0.00	0.05	0.55	0.39
LBC_C3	50	Deciduous trees	0.00	0.00	0.00	0.00	0.33	0.13	0.54
LBC_C4	33	Grass	0.00	0.00	0.00	0.00	0.25	0.00	0.75
LBC_C5	0	Blackberry	0.00	0.00	0.00	0.00	0.36	0.16	0.48
LBC_D1	50	Deciduous trees	0.00	0.00	0.00	0.00	0.29	0.18	0.53
LBC_D2	21	Blackberry	0.00	0.00	0.00	0.00	0.02	0.61	0.37
LBC_E1	58	Grass	0.00	0.00	0.00	0.00	0.32	0.42	0.26
LBC_E2	83	Deciduous trees	0.00	0.00	0.00	0.00	0.36	0.19	0.45
LBC_F1	0	Shrubs	0.00	0.01	0.00	0.00	0.00	0.19	0.80
LBC_F2	96	Deciduous trees	0.00	0.00	0.29	0.00	0.48	0.23	0.00
LBC_F3	63	Shrubs	0.06	0.01	0.00	0.00	0.25	0.07	0.61
LBC_G1	88	Coniferous Trees	0.00	0.00	0.00	0.00	0.71	0.00	0.29
LBC_G2	50	Grass	0.00	0.00	0.00	0.00	0.29	0.11	0.61
LBC_G3	92	Coniferous Trees	0.00	0.00	0.00	0.00	0.64	0.36	0.00
LBC_H1	63	Grass	0.00	0.00	0.00	0.00	0.61	0.26	0.13
LBC_H2	88	Shrubs	0.00	0.00	0.00	0.00	0.40	0.00	0.60
LBC_H3	46	Shrubs	dry	dry	dry	dry	dry	dry	dry
LBC_H4	0	Grass	0.01	0.00	0.00	0.00	0.01	0.11	0.88
LBC_I1	79	Shrubs	0.00	0.00	0.00	0.00	0.21	0.06	0.73
LBC_I2	17	Grass	0.00	0.00	0.00	0.00	0.18	0.00	0.82
LBC_I3	79	Shrubs	0.00	0.00	0.00	0.00	0.44	0.00	0.56
LBC_I4	83	Shrubs	0.00	0.00	0.00	0.00	0.45	0.08	0.48
LBC_J1	75	Shrubs	0.00	0.00	0.00	0.00	0.46	0.12	0.42
LBC_J2	50	Shrubs	0.00	0.00	0.00	0.05	0.49	0.13	0.33
LBC_J3	75	Deciduous trees	0.00	0.10	0.00	0.00	0.21	0.17	0.53
LBC_J4	42	Grass	0.00	0.00	0.00	0.00	0.93	0.01	0.06
LBC_K1	88	Shrubs	0.00	0.00	0.00	0.00	0.67	0.33	0.00
LBC_K2	88	Shrubs	0.00	0.00	0.00	0.00	0.40	0.12	0.47
LBC_K3	83	Deciduous trees	0.00	0.00	0.00	0.00	0.99	0.00	0.01
LBC_L1	4	Deciduous trees	0.00	0.00	0.00	0.00	0.08	0.80	0.12
LBC_L2	79	Deciduous trees	0.00	0.00	0.00	0.00	0.00	1.00	0.00
LBC_L3	63	Shrubs	0.00	0.00	0.00	0.00	0.01	0.99	0.00
LBC_M1	88	Coniferous Trees	0.00	0.00	0.00	0.00	0.00	0.61	0.39
LBC_M1	63	Shrubs	0.00	0.00	0.00	0.00	0.00	0.61	0.39
LBC_N1	79	Deciduous trees	0.08	0.00	0.00	0.00	0.00	0.80	0.12
LBC_N2	75	Deciduous trees	0.00	0.00	0.00	0.00	0.17	0.62	0.21
LBC_N3	79	Deciduous trees	0.00	0.00	0.00	0.00	0.28	0.59	0.13
LBC_N4	88	Deciduous trees	0.04	0.00	0.00	0.16	0.30	0.50	0.00
Row_A1	88	Deciduous trees	0.02	0.00	0.00	0.00	0.62	0.05	0.31
Row_A2	88	Coniferous Trees	0.00	0.00	0.00	0.00	0.81	0.00	0.19
Row_A3	92	Coniferous Trees	0.00	0.00	0.00	0.00	0.86	0.00	0.14
Row_B1	92	Shrubs	0.00	0.00	0.00	0.00	0.86	0.00	0.14

Table B1b. Geomorphic and basic descriptive attributes by interval (continued)

Interval	Geomorphic and basic descriptive attributes ctd.		Geomorphic unit attributes (proportion of low flow wetted area)						
	field measured percent canopy cover (at upstream transect)	Dominant Bank Vegetation	Other/ Control	Cascade	Step- Pool	Forced Step-Pool	Riffle	Glide	Pool
Row_C1	58	Blackberry	0.03	0.02	0.00	0.00	0.69	0.00	0.26
Row_C2	96	Deciduous trees	0.00	0.00	0.00	0.00	1.00	0.00	0.00
Row_D1	96	Coniferous Trees	dry	dry	dry	dry	dry	dry	dry
Row_D2	92	Shrubs	dry	dry	dry	dry	dry	dry	dry
Row_E1	100	Deciduous trees	dry	dry	dry	dry	dry	dry	dry
TRo2_A1	13	Shrubs	dry	dry	dry	dry	dry	dry	dry
TRo3_A1	96	Coniferous Trees	dry	dry	dry	dry	dry	dry	dry
Howell1	100	Deciduous trees	0.28	0.00	0.00	0.00	0.63	0.09	0.00
Howell2	100	Deciduous trees	0.00	0.00	0.00	0.16	0.17	0.00	0.67
Howell3	96	Deciduous trees	0.18	0.00	0.00	0.00	0.44	0.22	0.17
TB_A1	88	Deciduous trees	0.09	0.00	0.00	0.31	0.24	0.36	0.00
TD_A1	100	Deciduous trees	dry	dry	dry	dry	dry	dry	dry
TD_A2	75	Shrubs	dry	dry	dry	dry	dry	dry	dry
TD_A3	46	Shrubs	dry	dry	dry	dry	dry	dry	dry
TD_A4	100	Coniferous Trees	dry	dry	dry	dry	dry	dry	dry
TD_A5	96	Shrubs	dry	dry	dry	dry	dry	dry	dry
TD_A6	100	Shrubs	dry	dry	dry	dry	dry	dry	dry
CC_A1	100	Shrubs	0.00	0.00	0.00	0.00	0.37	0.00	0.63
CC_B1	88	Shrubs	0.00	0.00	0.00	0.00	0.00	1.00	0.00
CC_B2	92	Shrubs	0.00	0.00	0.00	0.00	0.08	0.40	0.52
CC_B3	71	Shrubs	0.00	0.00	0.00	0.00	0.46	0.40	0.14
CC_B4	96	Shrubs	0.00	0.00	0.00	0.00	0.08	0.92	0.00
TCu1_A1	92	Deciduous trees	dry	dry	dry	dry	dry	dry	dry
TCu2_A1	96	Coniferous Trees	dry	dry	dry	dry	dry	dry	dry
TCu2_A2	96	Shrubs	dry	dry	dry	dry	dry	dry	dry
TCu2_A3	75	Shrubs	dry	dry	dry	dry	dry	dry	dry
TE_uns1	0	Grass	dry	dry	dry	dry	dry	dry	dry
GD_A1	0	Shrubs	0.00	0.00	0.00	0.00	0.19	0.81	0.00
GD_B1	83	Deciduous trees	0.00	0.00	0.00	0.00	0.54	0.19	0.26
GD_C1	13	Deciduous trees	0.00	0.00	0.00	0.00	0.25	0.22	0.53
GD_C2	92	Deciduous trees	0.00	0.00	0.00	0.24	0.20	0.29	0.27
GD_C3	71	Deciduous trees	0.00	0.00	0.00	0.22	0.32	0.23	0.23
GD_C4	79	Shrubs	0.00	0.00	0.00	0.00	0.14	0.43	0.44
GD_C5	96	Coniferous Trees	0.07	0.00	0.00	0.00	0.36	0.33	0.25
GD_D1	38	Shrubs	0.00	0.00	0.00	0.00	0.22	0.19	0.58
GD_E1	92	Shrubs	dry	dry	dry	dry	dry	dry	dry
GD_F1	71	Deciduous trees	dry	dry	dry	dry	dry	dry	dry
GD_F2	75	Shrubs	dry	dry	dry	dry	dry	dry	dry
GD_F3	83	Coniferous Trees	dry	dry	dry	dry	dry	dry	dry
GD_F4	0	Shrubs	dry	dry	dry	dry	dry	dry	dry
GD_G1	88	Coniferous Trees	dry	dry	dry	dry	dry	dry	dry
GD_G2	92	Coniferous Trees	dry	dry	dry	dry	dry	dry	dry
GD_G3	96	Deciduous trees	dry	dry	dry	dry	dry	dry	dry
GD_G5	75	Shrubs	dry	dry	dry	dry	dry	dry	dry
GD_G6	96	Shrubs	dry	dry	dry	dry	dry	dry	dry
GD_H1	96	Shrubs	dry	dry	dry	dry	dry	dry	dry
TGD3_A1	8	Shrubs	dry	dry	dry	dry	dry	dry	dry



Table B1b. Geomorphic and basic descriptive attributes by interval (continued)

Interval	Geomorphic and basic descriptive attributes ctd.		Geomorphic unit attributes (proportion of low flow wetted area)						
	field measured percent canopy cover (at upstream transect)	Dominant Bank Vegetation	Other/ Control	Cascade	Step- Pool	Forced Step-Pool	Riffle	Glide	Pool
TGD3_A2	88	Shrubs	dry	dry	dry	dry	dry	dry	dry
TGD3_A3	83	Shrubs	dry	dry	dry	dry	dry	dry	dry
TGD3_A4	83	Other	dry	dry	dry	dry	dry	dry	dry
TGD4_A1	96	Grass	dry	dry	dry	dry	dry	dry	dry
TGD4_A1	92	Shrubs	dry	dry	dry	dry	dry	dry	dry
TGD5_A1	92	Deciduous trees	dry	dry	dry	dry	dry	dry	dry
TGD5_B1	21	Grass	dry	dry	dry	dry	dry	dry	dry
TGD5_B2	83	Grass	dry	dry	dry	dry	dry	dry	dry
TG_A1	67	Deciduous trees	0.00	0.00	0.00	0.00	0.81	0.09	0.10
TG_B1	88	Coniferous Trees	0.00	0.00	0.00	0.00	0.04	0.00	0.96
TG_B2	96	Shrubs	0.00	0.00	0.00	0.00	0.95	0.00	0.05
TJ_A1	92	Coniferous Trees	0.03	0.00	0.00	0.29	0.00	0.11	0.58
TL_A1	100	Coniferous Trees	0.02	0.00	0.00	0.00	0.81	0.00	0.17
TL_A2	92	Coniferous Trees	0.00	0.00	0.00	0.00	0.57	0.32	0.12
TL_A3	96	Shrubs	0.00	0.00	0.00	0.00	0.40	0.33	0.27
TL_A4	100	Shrubs	dry	dry	dry	dry	dry	dry	dry
TL1_A0	92	Shrubs	0.08	0.00	0.00	0.07	0.82	0.03	0.00
TL1_A2	71	Shrubs	0.00	0.00	0.00	0.00	0.97	0.03	0.00
TL1_A3	88	Shrubs	0.00	0.00	0.00	0.00	0.33	0.67	0.00
TrC_A1	0	Shrubs	0.00	0.00	0.00	0.00	0.00	1.00	0.00
TrC_A2	25	Shrubs	0.00	0.00	0.00	0.00	0.26	0.52	0.22
TrC_B1	63	Grass	0.00	0.00	0.00	0.00	0.18	0.38	0.44
TrC_B2	96	Grass	0.00	0.00	0.00	0.00	0.28	0.23	0.49
TrC_C1	96	Coniferous Trees	dry	dry	dry	dry	dry	dry	dry
TrC_C2	92	Coniferous Trees	dry	dry	dry	dry	dry	dry	dry
TrC_C3	96	Coniferous Trees	dry	dry	dry	dry	dry	dry	dry
TrC_D1	79	Coniferous Trees	dry	dry	dry	dry	dry	dry	dry
TO_A1	83	Deciduous trees	dry	dry	dry	dry	dry	dry	dry
TO_A2	75	Deciduous trees	dry	dry	dry	dry	dry	dry	dry
TO_A3	92	Coniferous Trees	dry	dry	dry	dry	dry	dry	dry
TO2_A2	92	Shrubs	dry	dry	dry	dry	dry	dry	dry

Table B2. Pool attributes by interval

Interval	Pool Attributes						
						Pool Forming Features	
	No. Pools	Average Pool Max Depth (ft)	Average Pool Residual depth (ft)	pools / mi	$W_{bf}$ / pool	Dominant	Subdominant
LBC_A1	3	2.7	2.3	34	7	Wood	NA
LBC_A2	2	2.9	2.3	39	5	Free form	NA
LBC_B1	2	2.8	2.1	51	6	Wood	Other
LBC_B2	5	3.0	2.2	100	3	Wood	Other
LBC_C1	3	3.5	1.6	61	4	Free form	NA
LBC_C2	2	2.1	1.3	58	3	Free form	NA
LBC_C3	2	2.5	1.5	51	3	Free form	NA
LBC_C4	3	2.2	1.6	81	2	Free form	Wood
LBC_C5	2	2.3	1.7	42	5	Rip rap or mod	Wood
LBC_D1	3	1.8	1.2	95	2	Free form	Rip rap or mod
LBC_D2	2	3.2	2.4	30	9	Free form	Wood
LBC_E1	4	1.4	1.0	89	2	Free form	Wood
LBC_E2	3	2.4	2.0	41	5	Wood	Rip rap or mod
LBC_F1	2	3.0	2.4	53	7	Beaver	Free form
LBC_F2	0	0.0	0.0	0	$\infty$	NA	NA
LBC_F3	7	1.9	1.5	235	1	Beaver	Wood
LBC_G1	3	1.1	0.8	77	1	Wood	NA
LBC_G2	4	1.6	1.2	101	2	Wood	Free form
LBC_G3	0	0.0	0.0	0	$\infty$	NA	NA
LBC_H1	1	1.3	1.0	41	5	Wood	NA
LBC_H2	1	1.6	1.2	51	3	Rip rap or mod	NA
LBC_H3	4	1.9	1.2	113	1	Wood	Rip rap or mod
LBC_H4	2	3.3	3.3	11	25	Beaver	NA
LBC_I1	5	1.8	1.4	115	2	Rip rap or mod	Free form
LBC_I2	7	1.7	1.2	155	2	Free form	Rip rap or mod
LBC_I3	4	1.7	1.4	98	4	Wood	Free form
LBC_I4	4	1.8	1.4	84	4	Free form	Beaver
LBC_J1	4	1.1	0.8	98	3	Wood	Free form
LBC_J2	3	1.7	1.4	77	4	Wood	NA
LBC_J3	3	1.4	1.2	78	2	Wood	NA
LBC_J4	2	1.3	1.1	40	7	Free form	Rip rap or mod
LBC_K1	0	0.0	0.0	0	$\infty$	NA	NA
LBC_K2	3	1.5	0.9	61	3	Wood	NA
LBC_K3	1	0.9	0.8	33	7	Wood	NA
LBC_L1	1	1.8	1.4	26	12	Free form	NA
LBC_L2	0	0.0	0.0	0	$\infty$	NA	NA
LBC_L3	0	0.0	0.0	0	$\infty$	NA	NA
LBC_M1	1	1.5	1.4	25	10	Free form	NA
LBC_M1	1	1.5	1.4	88	3	Free form	NA
LBC_N1	2	0.8	0.7	49	11	Wood	NA
LBC_N2	2	0.5	0.3	56	6	Free form	Wood
LBC_N3	2	0.5	0.4	49	22	Wood	NA
LBC_N4	0	0.0	0.0	0	$\infty$	NA	NA
Row_A1	8	0.8	0.7	208	3	Rip rap or mod	Wood
Row_A2	5	0.6	0.5	131	5	Wood	Free form
Row_A3	3	0.6	0.5	64	10	Wood	NA
Row_B1	2	0.7	0.6	53	7	Free form	Wood

Table B2. Pool attributes by interval

Interval	Pool Attributes						
						Pool Forming Features	
	No. Pools	Average Pool Max Depth (ft)	Average Pool Residual depth (ft)	pools / mi	W <sub>bf</sub> / pool	Dominant	Subdominant
Row_C1	5	0.4	0.4	89	4	Rip rap or mod	Wood
Row_C2	0	0.0	0.0	0	∞	NA	NA
Row_D1	dry	dry	dry	dry	dry	NA	NA
Row_D2	0	0.0	0.0	0	∞	NA	NA
Row_E1	dry	dry	dry	dry	dry	NA	NA
TRo2_A1	dry	dry	dry	dry	dry	NA	NA
TRo3_A1	dry	dry	dry	dry	dry	NA	NA
Howell1	0	0.0	0.0	0	∞	NA	NA
Howell2	5	0.7	0.6	122	11	Wood	Free form
Howell3	2	0.8	0.7	96	14	Beaver	Wood
TB_A1	0	0.0	0.0	0	∞	NA	NA
TD_A1	dry	dry	dry	dry	dry	NA	NA
TD_A2	dry	dry	dry	dry	dry	NA	NA
TD_A3	dry	dry	dry	dry	dry	NA	NA
TD_A4	dry	dry	dry	dry	dry	NA	NA
TD_A5	dry	dry	dry	dry	dry	NA	NA
TD_A6	dry	dry	dry	dry	dry	NA	NA
CC_A1	4	0.6	0.5	121	4	Wood	Other
CC_B1	0	0.0	0.0	0	∞	NA	NA
CC_B2	3	0.5	0.5	91	10	Bedrock or till	Boulder
CC_B3	1	0.5	0.4	34	26	Wood	NA
CC_B4	0	0.0	0.0	0	∞	NA	NA
TCu1_A1	dry	dry	dry	dry	dry	NA	NA
TCu2_A1	dry	dry	dry	dry	dry	NA	NA
TCu2_A2	dry	dry	dry	dry	dry	NA	NA
TCu2_A3	dry	dry	dry	dry	dry	NA	NA
TE_uns1	dry	dry	dry	dry	dry	NA	NA
GD_A1	0	0.0	0.0	0	∞	NA	NA
GD_B1	1	0.9	0.7	59	8	Wood	NA
GD_C1	3	1.5	1.3	78	8	Wood	NA
GD_C2	3	1.5	1.4	73	7	Wood	Free form
GD_C3	1	1.2	1.1	28	17	Free form	NA
GD_C4	4	1.3	1.2	86	5	Wood	Free form
GD_C5	2	1.0	0.8	54	7	Wood	NA
GD_D1	4	0.9	0.8	102	2	Wood	NA
GD_E1	4	0.8	0.8	96	5	Wood	NA
GD_F1	dry	dry	dry	dry	dry	NA	NA
GD_F2	1	0.3	0.3	32	14	Bedrock or till	NA
GD_F3	5	1.2	1.2	143	4	Rip rap or mod	Wood
GD_F4	2	3.3	3.3	45	12	Rip rap or mod	NA
GD_G1	dry	dry	dry	dry	dry	NA	NA
GD_G2	dry	dry	dry	dry	dry	NA	NA
GD_G3	dry	dry	dry	dry	dry	NA	NA
GD_G5	dry	dry	dry	dry	dry	NA	NA
GD_G6	dry	dry	dry	dry	dry	NA	NA
GD_H1	dry	dry	dry	dry	dry	NA	NA
TGD3_A1	dry	dry	dry	dry	dry	NA	NA

Table B2. Pool attributes by interval

Interval	Pool Attributes						
						Pool Forming Features	
	No. Pools	Average Pool Max Depth (ft)	Average Pool Residual depth (ft)	pools / mi	$W_{bf}$ / pool	Dominant	Subdominant
TGD3_A2	dry	dry	dry	dry	dry	NA	NA
TGD3_A3	dry	dry	dry	dry	dry	NA	NA
TGD3_A4	dry	dry	dry	dry	dry	NA	NA
TGD4_A1	dry	dry	dry	dry	dry	NA	NA
TGD4_A1	dry	dry	dry	dry	dry	NA	NA
TGD5_A1	dry	dry	dry	dry	dry	NA	NA
TGD5_B1	dry	dry	dry	dry	dry	NA	NA
TGD5_B2	dry	dry	dry	dry	dry	NA	NA
TG_A1	1	0.6	0.5	29	46	Free form	NA
TG_B1	4	1.6	1.5	74	6	Rip rap or mod	Free form
TG_B2	1	0.9	0.8	31	43	Wood	NA
TJ_A1	8	0.6	0.6	141	13	Wood	NA
TL_A1	5	0.5	0.4	128	8	Wood	Free form
TL_A2	4	0.4	0.4	103	10	Free form	Wood
TL_A3	6	0.5	0.4	130	8	Wood	Free form
TL_A4	1	0.6	0.6	67	40	Wood	NA
TL1_A0	0	0.0	0.0	0	$\infty$	NA	NA
TL1_A2	0	0.0	0.0	0	$\infty$	NA	NA
TL1_A3	0	0.0	0.0	0	$\infty$	NA	NA
TrC_A1	0	0.0	0.0	0	$\infty$	NA	NA
TrC_A2	1	1.0	0.8	48	21	Wood	NA
TrC_B1	7	0.9	0.8	132	10	Free form	Rip rap or mod
TrC_B2	2	0.9	0.8	149	9	Wood	NA
TrC_C1	dry	dry	dry	dry	dry	NA	NA
TrC_C2	dry	dry	dry	dry	dry	NA	NA
TrC_C3	dry	dry	dry	dry	dry	NA	NA
TrC_D1	dry	dry	dry	dry	dry	NA	NA
TO_A1	dry	dry	dry	dry	dry	NA	NA
TO_A2	dry	dry	dry	dry	dry	NA	NA
TO_A3	dry	dry	dry	dry	dry	NA	NA
TO2_A2	dry	dry	dry	dry	dry	NA	NA

Table B3. Substrate attributes by interval

Interval	Substrate Attributes								
	dominant substrate (proportion of low flow wetted area)								% Sand Cover (area weighted average of field observations)
	Non alluvial (till, outwash, pre-Fraser interglacial)	Boulder	Cobble	Gravel (>16mm)	Gravel (<16mm)	Sand	Fines	Organic	
LBC_A1	0.00	0.00	0.00	0.00	0.53	0.00	0.10	0.37	42
LBC_A2	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.83	77
LBC_B1	0.00	0.00	0.00	0.00	0.30	0.28	0.00	0.42	45
LBC_B2	0.00	0.00	0.00	0.00	0.02	0.00	0.03	0.95	77
LBC_C1	0.00	0.00	0.00	0.00	0.26	0.74	0.00	0.00	29
LBC_C2	0.00	0.00	0.00	0.00	0.55	0.44	0.01	0.00	20
LBC_C3	0.00	0.00	0.00	0.00	0.34	0.46	0.00	0.19	40
LBC_C4	0.00	0.00	0.00	0.00	0.25	0.75	0.00	0.00	20
LBC_C5	0.00	0.00	0.00	0.00	0.36	0.64	0.00	0.00	21
LBC_D1	0.00	0.00	0.00	0.00	0.86	0.14	0.00	0.00	10
LBC_D2	0.00	0.00	0.00	0.00	0.41	0.32	0.00	0.27	30
LBC_E1	0.00	0.00	0.00	0.00	0.96	0.04	0.00	0.00	10
LBC_E2	0.00	0.00	0.00	0.21	0.79	0.00	0.00	0.00	19
LBC_F1	0.00	0.00	0.00	0.70	0.19	0.10	0.01	0.00	45
LBC_F2	0.00	0.29	0.59	0.00	0.12	0.00	0.00	0.00	20
LBC_F3	0.00	0.00	0.00	0.01	0.37	0.23	0.18	0.21	34
LBC_G1	0.00	0.00	0.38	0.00	0.62	0.00	0.00	0.00	21
LBC_G2	0.00	0.00	0.06	0.00	0.69	0.16	0.00	0.08	18
LBC_G3	0.00	0.00	0.64	0.00	0.36	0.00	0.00	0.00	2
LBC_H1	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	8
LBC_H2	0.00	0.00	0.60	0.00	0.40	0.00	0.00	0.00	3
LBC_H3	0.00	0.00	0.00	0.00	0.71	0.29	0.00	0.00	18
LBC_H4	0.00	0.00	0.00	0.00	0.00	0.02	0.89	0.09	90
LBC_I1	0.00	0.00	0.00	0.00	0.11	0.27	0.00	0.62	55
LBC_I2	0.00	0.00	0.00	0.00	0.28	0.00	0.04	0.69	57
LBC_I3	0.00	0.00	0.00	0.00	0.75	0.00	0.00	0.25	32
LBC_I4	0.00	0.00	0.17	0.00	0.51	0.23	0.00	0.09	32
LBC_J1	0.00	0.00	0.12	0.00	0.00	0.68	0.00	0.19	28
LBC_J2	0.00	0.00	0.14	0.00	0.58	0.13	0.00	0.16	22
LBC_J3	0.00	0.00	0.17	0.00	0.45	0.06	0.10	0.23	18
LBC_J4	0.00	0.00	0.04	0.00	0.96	0.00	0.00	0.00	2
LBC_K1	0.00	0.00	0.03	0.00	0.76	0.22	0.00	0.00	20
LBC_K2	0.00	0.00	0.07	0.00	0.55	0.22	0.00	0.16	43
LBC_K3	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.97	69
LBC_L1	0.00	0.00	0.00	0.00	0.08	0.31	0.00	0.60	79
LBC_L2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	100
LBC_L3	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.99	82
LBC_M1	0.00	0.00	0.00	0.72	0.00	0.10	0.18	0.00	90
LBC_M1	0.00	0.00	0.00	0.72	0.00	0.10	0.18	0.00	90
LBC_N1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	94
LBC_N2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	72
LBC_N3	0.00	0.00	0.00	0.26	0.14	0.07	0.19	0.34	77
LBC_N4	0.00	0.00	0.03	0.00	0.34	0.30	0.01	0.32	35
Row_A1	0.00	0.01	0.46	0.00	0.26	0.00	0.01	0.26	33
Row_A2	0.00	0.00	0.38	0.00	0.47	0.03	0.00	0.12	33
Row_A3	0.00	0.00	0.42	0.00	0.49	0.00	0.00	0.09	34
Row_B1	0.00	0.00	0.00	0.00	0.09	0.76	0.00	0.14	24



**Table B3. Substrate attributes by interval**

[illegible]

**Table B3. Substrate attributes by interval**

[illegible]

Table B4. Large wood summary attributes by interval

Interval	Wood summary attributes							
	Wood Loading					Wood Jams		
	total number pieces of brush wood (<7.6m long)	number individual pieces 7.6-15 m	number individual pieces > 15 m	number pieces > 7.6m in jams	total number pieces > 7.6 m/mi	No. Jams	Average % W <sub>bf</sub> blockage by Jams	Average Jam Volume (m <sup>3</sup> )
LBC_A1	13	3	1	6	114	2	97	25
LBC_A2	7	0	0	0	0	0		
LBC_B1	23	0	0	0	0	0		
LBC_B2	28	0	0	0	0	0		
LBC_C1	11	0	0	0	0	0		
LBC_C2	11	0	0	0	0	0		
LBC_C3	3	0	0	0	0	0		
LBC_C4	1	0	0	0	0	0		
LBC_C5	9	1	0	0	21	0		
LBC_D1	6	2	0	0	64	0		
LBC_D2	1	0	0	0	0	0		
LBC_E1	52	0	0	2	45	2	75	6
LBC_E2	9	1	0	0	14	0		
LBC_F1	2	1	0	0	26	0		
LBC_F2	13	0	0	0	0	0		
LBC_F3	17	1	0	0	15	0		
LBC_G1	37	2	1	0	77	0		
LBC_G2	28	0	0	9	226	3	73	35
LBC_G3	9	0	0	0	0	0		
LBC_H1	3	1	0	0	41	0		
LBC_H2	0	0	0	0	0	0		
LBC_H3	6	1	1	0	56	1	100	25
LBC_H4	26	0	0	0	0	0		
LBC_I1	38	1	0	0	23	0		
LBC_I2	10	1	0	0	22	0		
LBC_I3	17	1	0	0	25	0		
LBC_I4	11	2	0	0	42	0		
LBC_J1	30	2	0	0	49	0		
LBC_J2	30	0	0	0	0	0		
LBC_J3	35	1	0	0	26	0		
LBC_J4	12	0	0	0	0	0		
LBC_K1	17	6	0	0	138	0		
LBC_K2	59	3	0	3	121	1	90	7
LBC_K3	26	5	0	0	164	0		
LBC_L1	12	1	0	0	26	0		
LBC_L2	16	6	0	3	232	1	50	7
LBC_L3	6	4	1	0	129	0		
LBC_M1	6	4	2	0	149	0		
LBC_M1	4	4	2	0	528	0		
LBC_N1	8	2	2	0	99	0		
LBC_N2	3	2	0	0	56	0		
LBC_N3	9	0	0	0	0	0		
LBC_N4	6	1	1	0	56	0		
Row_A1	5	0	0	0	0	0		
Row_A2	12	0	0	0	0	0		
Row_A3	11	0	1	0	21	0		
Row_B1	8	2	0	0	53	0		

Table B4. Large wood summary attributes by interval

Interval	Wood summary attributes							
	Wood Loading					Wood Jams		
	total number pieces of brush wood (<7.6m long)	number individual pieces 7.6-15 m	number individual pieces > 15 m	number pieces > 7.6m in jams	total number pieces > 7.6 m/mi	No. Jams	Average % W <sub>bf</sub> blockage by Jams	Average Jam Volume (m <sup>3</sup> )
Row_C1	6	0	0	0	0	0		
Row_C2	2	0	0	0	0	0		
Row_D1	0	0	1	0	69	0		
Row_D2	5	0	0	0	0	0		
Row_E1	0	0	0	0	0	0		
TRo2_A1	0	0	0	0	0	0		
TRo3_A1	5	1	0	0	29	0		
Howell1	5	0	0	0	0	0		
Howell2	0	0	0	0	0	0		
Howell3	6	1	0	0	48	0		
TB_A1	8	0	0	0	0	0		
TD_A1	1	9	1	0	216	0		
TD_A2	0	7	0	0	134	0		
TD_A3	2	4	0	0	94	0		
TD_A4	1	1	0	0	35	0		
TD_A5	7	3	0	0	65	0		
TD_A6	9	1	0	0	21	0		
CC_A1	12	0	0	0	0	0		
CC_B1	17	1	0	0	48	0		
CC_B2	22	0	1	0	30	0		
CC_B3	11	0	0	0	0	0		
CC_B4	22	2	1	4	144	1	50	20
TCu1_A1	14	0	0	0	0	0		
TCu2_A1	16	0	0	0	0	0		
TCu2_A2	16	0	0	0	0	0		
TCu2_A3	14	2	0	0	52	0		
TE_uns1	4	0	0	0	0	0		
GD_A1	24	1	0	0	29	0		
GD_B1	3	0	0	0	0	0		
GD_C1	7	4	0	0	104	0		
GD_C2	18	4	0	0	97	0		
GD_C3	19	1	1	3	138	1	100	5
GD_C4	4	1	0	0	21	0		
GD_C5	16	4	0	0	107	0		
GD_D1	4	1	0	0	25	0		
GD_E1	9	5	0	0	120	0		
GD_F1	20	0	1	0	20	0		
GD_F2	2	0	0	0	0	0		
GD_F3	6	0	0	0	0	0		
GD_F4	2	1	0	0	23	0		
GD_G1	6	0	0	0	0	0		
GD_G2	11	1	0	0	33	0		
GD_G3	8	1	2	0	83	0		
GD_G5	16	1	0	0	21	0		
GD_G6	14	1	0	0	19	0		
GD_H1	2	0	0	0	0	0		
TGD3_A1	23	1	0	0	20	0		

Table B4. Large wood summary attributes by interval

Interval	Wood summary attributes							
	Wood Loading					Wood Jams		
	total number pieces of brush wood (<7.6m long)	number individual pieces 7.6-15 m	number individual pieces > 15 m	number pieces > 7.6m in jams	total number pieces > 7.6 m/mi	No. Jams	Average % W <sub>bf</sub> blockage by Jams	Average Jam Volume (m <sup>3</sup> )
TGD3_A2	31	0	0	0	0	0		
TGD3_A3	26	0	0	3	73	1	50	9
TGD3_A4	0	0	0	0	0	0		
TGD4_A1	0	0	0	0	0	0		
TGD4_A1	0	0	0	0	0	0		
TGD5_A1	12	1	0	0	33	0		
TGD5_B1	0	0	0	0	0	0		
TGD5_B2	0	0	0	0	0	0		
TG_A1	24	1	0	0	29	0		
TG_B1	19	0	0	0	0	0		
TG_B2	6	1	0	0	31	0		
TJ_A1	56	5	2	0	123	0		
TL_A1	23	3	2	0	128	0		
TL_A2	14	1	0	0	26	0		
TL_A3	6	3	1	0	87	0		
TL_A4	11	1	0	0	67	0		
TL1_A0	7	1	0	0	24	0		
TL1_A2	4	1	0	0	22	0		
TL1_A3	1	0	0	0	0	0		
TrC_A1	11	1	0	0	26	0		
TrC_A2	6	0	0	0	0	0		
TrC_B1	0	0	0	0	0	0		
TrC_B2	4	0	0	0	0	0		
TrC_C1	13	0	0	0	0	1	100	3
TrC_C2	7	1	0	0	26	1	50	1
TrC_C3	7	0	0	0	0	0		
TrC_D1	9	2	0	0	47	0		
TO_A1	8	2	0	0	50	0		
TO_A2	5	0	0	0	0	0		
TO_A3	14	0	0	0	0	0		
TO2_A2	0	0	0	0	0	0		



Table B5a. Bank condition attributes by interval

Interval	Bank Condition						
	Sum of length natural, active (ft)	Sum of length natural, part stabilized (ft)	Sum of length revetted (ft)	% unstable	% revetted	revetment type	Volume of landslides with influence outside of bankfull channel (ft <sup>3</sup> )
LBC_A1	80	0	0	9	0		
LBC_A2	80	0	0	15	0		
LBC_B1	0	40	0	0	0		
LBC_B2	0	25	40	0	8	LWD	
LBC_C1	0	0	0	0	0		
LBC_C2	0	0	0	0	0		
LBC_C3	110	0	0	26	0		
LBC_C4	0	0	50	0	13	Riprap	
LBC_C5	0	0	35	0	7	Riprap	
LBC_D1	0	0	40	0	12	Riprap	
LBC_D2	0	0	75	0	11	Riprap	
LBC_E1	40	0	85	8	18	Riprap	
LBC_E2	0	0	20	0	3	wall	
LBC_F1	0	0	0	0	0		
LBC_F2	0	0	245	0	44	Riprap	
LBC_F3	30	0	131	4	18	Riprap	
LBC_G1	0	0	0	0	0		
LBC_G2	0	0	15	0	4	gabion	
LBC_G3	0	0	0	0	0		
LBC_H1	0	0	93	0	36	Riprap	
LBC_H2	0	0	0	0	0		
LBC_H3	0	0	0	0	0		
LBC_H4	0	0	0	0	0		
LBC_I1	5	0	10	1	2	wall	
LBC_I2	170	0	10	36	2	Riprap	
LBC_I3	0	0	0	0	0		
LBC_I4	0	80	15	0	3	Riprap	
LBC_J1	0	0	0	0	0		
LBC_J2	10	0	0	2	0		
LBC_J3	0	0	0	0	0		
LBC_J4	60	0	100	11	19	Riprap	
LBC_K1	0	0	0	0	0		
LBC_K2	0	15	0	0	0		
LBC_K3	0	0	0	0	0		
LBC_L1	0	0	0	0	0		
LBC_L2	0	0	0	0	0		
LBC_L3	0	0	0	0	0		
LBC_M1	0	0	0	0	0		
LBC_M1	0	0	0	0	0		
LBC_N1	0	0	0	0	0		
LBC_N2	0	0	0	0	0		
LBC_N3	0	0	0	0	0		
LBC_N4	0	0	0	0	0		
Row_A1	120	73	0	30	0		
Row_A2	30	25	0	7	0		
Row_A3	55	25	0	11	0		
Row_B1	106	23	0	27	0		360

Table B5a. Bank condition attributes by interval

Interval	Bank Condition						
	Sum of length natural, active (ft)	Sum of length natural, part stabilized (ft)	Sum of length revetted (ft)	% unstable	% revetted	revetment type	Volume of landslides with influence outside of bankfull channel (ft <sup>3</sup> )
Row_C1	0	0	0	0	0		4,625
Row_C2	190	0	0	86	0		
Row_D1	0	50	0	0	0		
Row_D2	215	0	0	54	0		
Row_E1	200	0	0	52	0		
TRo2_A1	0	0	0	0	0		
TRo3_A1	0	0	0	0	0		
Howell1	0	0	0	0	0		
Howell2	0	0	0	0	0		
Howell3	0	0	0	0	0		
TB_A1	0	0	0	0	0		
TD_A1	0	0	0	0	0		
TD_A2	0	0	0	0	0		
TD_A3	0	0	0	0	0		
TD_A4	0	0	0	0	0		
TD_A5	120	0	0	25	0		
TD_A6	120	0	0	23	0		120
CC_A1	0	47	0	0	0		
CC_B1	0	0	0	0	0		
CC_B2	0	0	0	0	0		
CC_B3	0	0	0	0	0		
CC_B4	0	0	0	0	0		
TCu1_A1	0	0	0	0	0		
TCu2_A1	0	0	0	0	0		
TCu2_A2	260	0	0	64	0		
TCu2_A3	0	0	0	0	0		
TE_uns1	0	0	0	0	0		
GD_A1	0	0	0	0	0		
GD_B1	10	0	0	6	0		
GD_C1	45	0	0	11	0		
GD_C2	40	0	0	9	0		
GD_C3	0	0	0	0	0		
GD_C4	0	0	0	0	0		3,000
GD_C5	50	0	0	13	0		
GD_D1	87	40	0	21	0		
GD_E1	60	10	0	14	0		
GD_F1	0	34	0	0	0		
GD_F2	0	0	0	0	0		
GD_F3	0	28	0	0	0		
GD_F4	0	0	0	0	0		
GD_G1	0	115	35	0	7	Riprap	
GD_G2	0	75	0	0	0		
GD_G3	0	25	0	0	0		
GD_G5	0	80	0	0	0		
GD_G6	0	0	0	0	0		
GD_H1	0	0	0	0	0		
TGD3_A1	0	0	0	0	0		

Table B5a. Bank condition attributes by interval

Interval	Bank Condition						
	Sum of length natural, active (ft)	Sum of length natural, part stabilized (ft)	Sum of length revetted (ft)	% unstable	% revetted	revetment type	Volume of landslides with influence outside of bankfull channel (ft <sup>3</sup> )
TGD3_A2	0	0	0	0	0		
TGD3_A3	0	0	0	0	0		
TGD3_A4	0	0	0	0	0		
TGD4_A1	0	0	0	0	0		
TGD4_A1	0	0	0	0	0		
TGD5_A1	0	0	0	0	0		
TGD5_B1	0	0	0	0	0		
TGD5_B2	0	0	0	0	0		
TG_A1	0	0	0	0	0		
TG_B1	65	0	0	11	0		
TG_B2	20	30	0	6	0		
TJ_A1	20	10	0	3	0		
TL_A1	0	0	0	0	0		
TL_A2	30	0	0	7	0		
TL_A3	25	0	0	5	0		
TL_A4	0	0	0	0	0		
TL1_A0	0	20	0	0	0		
TL1_A2	0	0	0	0	0		
TL1_A3	0	0	0	0	0		
TrC_A1	0	0	0	0	0		
TrC_A2	0	0	0	0	0		
TrC_B1	45	58	8	8	1	Riprap	
TrC_B2	43	10	0	30	0		
TrC_C1	160	0	0	38	0		
TrC_C2	175	0	0	43	0		
TrC_C3	0	0	0	0	0		
TrC_D1	0	0	0	0	0		
TO_A1	5	0	0	1	0		
TO_A2	0	0	0	0	0		
TO_A3	0	0	0	0	0		
TO2_A2	0	0	0	0	0		

Table B5b. Bank condition attributes by interval (ctd.)

Interval	Bank Condition (ctd.)															
	Actively Eroding Bank Area, by soil classification (ft <sup>2</sup> )															
	GW	GW-GM	GP	GP-GC	GM	SW	SW-SM	SP	SP-SM	SP-SC	SM	ML	CL	MH	CH	PT
LBC_A1	0	0	0	90	0	0	0	0	125	0	0	0	300	0	0	0
LBC_A2	161	0	158	0	0	206	0	0	0	0	0	0	0	0	0	0
LBC_B1	0	0	0	0	0	0	0	0	0	0	0	0	240	0	0	0
LBC_B2	0	0	0	0	0	0	0	0	0	0	0	0	138	0	0	0
LBC_C1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LBC_C2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LBC_C3	22	0	0	0	0	0	0	0	473	0	0	0	0	0	0	0
LBC_C4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LBC_C5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LBC_D1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LBC_D2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LBC_E1	0	0	60	0	0	0	0	0	60	0	0	0	0	0	0	0
LBC_E2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LBC_F1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LBC_F2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LBC_F3	0	0	15	0	0	0	0	0	0	30	0	0	0	0	0	0
LBC_G1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LBC_G2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LBC_G3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LBC_H1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LBC_H2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LBC_H3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LBC_H4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LBC_I1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LBC_I2	0	0	78	0	0	0	0	0	0	0	0	0	0	155	0	0
LBC_I3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LBC_I4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	280	0
LBC_J1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LBC_J2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LBC_J3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LBC_J4	0	0	144	0	0	0	0	0	0	0	0	0	0	0	0	0
LBC_K1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LBC_K2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LBC_K3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LBC_L1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LBC_L2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LBC_L3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LBC_M1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LBC_M1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LBC_N1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LBC_N2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LBC_N3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LBC_N4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Row_A1	58	0	82	0	0	0	0	228	0	0	0	0	0	0	0	0
Row_A2	0	0	29	0	0	0	0	16	0	0	25	0	0	0	0	0
Row_A3	0	0	143	0	0	0	0	25	0	0	30	0	0	0	0	0
Row_B1	0	0	0	130	0	0	24	39	86	25	0	0	0	0	0	0



**Table B5b. Bank condition attributes by interval (ctd.)**

[illegible]



**Appendix C:      Habitat Survey Stream Metrics**

Table C1. Stream Channel Metrics. Contributing Characteristics.

Site Name	River Mile	Channel Category	Year measured	Drainage Area (km <sup>2</sup> )	Channel cross-sectional area (m <sup>2</sup> )	Upstream Landcover (2013)		Upstream Buffer (150m wide) (%Forest minus %TIA)*		Base flow Q (cfs)	Base flow Q/km <sup>2</sup>
						%TIA	%Forest	500 meters up	1000 meters up		
LB2603	8.8	Main	None	3.16		27.1	38.2	65.7	81.5	0.88	0.28
LB169	8.6	Main	2014	3.40	1.29	27.1	38.2	72.5	72.8	0.44	0.13
LB2602	8.2	Main	2015	5.06	1.55	20.9	54.9	46.5	62.7	1.21	0.24
LB51	7.6	Main	2014	8.72	2.12	17.0	50.8	73.5	68.7	1.77	0.20
LB196	6.2	Main	2015	11.89	2.71	10.3	67.6			3.31	0.28
LBC19830	6.1	Main	2014	11.89	1.58	10.3	67.6	95.5	94.6		
LBC520	5.5	Main	2014	14.63	2.89	9.5	75.3	60.4	76.6	3.61	0.25
LBC224	3.8	Main	2015	28.62	4.04	15.9	56.4	25.9	51.0	4.96	0.17
LBLD	3.4	Main	2015	29.27	3.15	18.0	55.0	33.2	27.7	6.04	0.21
LB238	3	Main	2014	30.68	4.48	26.3	45.7	-7.5	-1.6	7.54	0.25
LB58	2.2	Main	2014	32.69	3.64	41.5	35.5	3.7	-16.7	6.24	0.19
Trout	7.9	Trib	2014	2.18	0.86	15.0	59.5	55.4	77.6	0.137	0.06
WEST	5.8	Trib	2014	1.52	0.90	15.0	51.3	85.6	52.2	0.04	0.03
DANE	4.5	Trib	2014	5.87	1.41	19.3	56.6	71.5	59.8	0.53	0.09
CUTT	4	Trib	2014	2.92	0.89	24.0	50.0	39.9	61.9	0.3	0.10
Cutt78	4	Trib	2014	0.65	0.63	37.3	48.6	99.3	69.5	0.02	0.03
Rowland	2	Trib	2014	1.51	1.04	17.9	58.0	87.9	79.1	0.5	0.33

Main – Mainstem of Little Bear Creek; Trib – Tributary to Little Bear Creek; TIA – Total Impervious Area; Q – Stream discharge in cubic feet per second (cfs).

\*%Forest minus %TIA represents continuous distribution of Land cover condition. This summary parameter is used in regression analysis as independent continuously variable stream-adjacent metric. Locations with a negative value have more impervious area than forest in buffer.

Table C2. Stream Channel Metrics. Channel Measurements.

Site Name	Avg. Wet Width (meter)	Avg. BFW (meter)	Avg. Wetted Depth (meter)	Avg. BFD (meter)	BFW/BFD Ratio	Channel Cross-Sectional Area (m <sup>2</sup> )	Channel Gradient %	Side Channel Count
<b>LB2603</b>								
<b>LB169</b>	2.43	3.35	0.16	0.38	8.74	1.29	0.40	0
<b>LB2602</b>	2.84	3.60	0.18	0.43	8.35	1.50	1.00	0
<b>LB51</b>	3.62	4.32	0.22	0.49	8.81	2.06	1.33	0
<b>LB196</b>	3.86	5.18	0.27	0.52	9.90	3.28	0.90	2
<b>LBC19830</b>	3.56	3.87	0.25	0.41	9.46	1.56	1.33	0
<b>LBC520</b>	4.10	5.47	0.24	0.53	10.34	2.87	1.25	2
<b>LBC224</b>	4.70	5.75	0.38	0.70	8.17	3.99	0.87	2
<b>LBLD</b>	4.87	5.77	0.29	0.55	10.57	3.12	0.38	0
<b>LB238</b>	4.34	5.83	0.45	0.77	7.58	4.48	1.33	1
<b>LB58</b>	4.80	5.55	0.40	0.66	8.46	3.70	0.55	0
<b>Trout</b>	1.02	2.16	0.08	0.40	5.42	0.86	1.47	1
<b>WEST</b>	1.08	2.89	0.06	0.31	9.24	0.94	2.84	0
<b>DANE</b>	2.10	3.08	0.15	0.46	6.75	1.41	1.34	0
<b>CUTT</b>	1.83	2.75	0.10	0.32	8.51	0.89	0.73	0
<b>Cutt78</b>	0.87	1.60	0.11	0.40	4.05	0.65	1.20	1
<b>Rowland</b>	1.36	2.84	0.07	0.37	7.70	1.05	2.20	0

BFW – Bankfull Channel Width; BFD – Bankfull Channel Depth.

Table C3. Stream Channel Metrics. BIBI Grid Fine Sediment and 2014 BIBI Riffle Pebble Count Statistics.

Site Name	BIBI Grid Surface Substrate (%)			2014 BIBI Riffle Pebble Count (200 pebbles)							
	2014% Fines Grid	2015% Fines Grid	Year- Year Change	D10 (mm)	D15 (mm)	D35 (mm)	D50 (mm)	D84 (mm)	% Sand (≈2mm)	% Silt	% Embedded
<b>LB2603</b>		2.5									
<b>LB169</b>	13.0	5.0	-8.0	1.4	1.7	8.6	12.8	27.7	20.0	0.0	39.5
<b>LB2602</b>		9.5									
<b>LB51</b>	25.1	10.5	-14.6	1.41	1.68	6.97	12.24	26.86	20.0	1.0	33.7
<b>LB196</b>		17.0									
<b>LBC19830</b>	10.0			6.8	8.4	15.8	21.0	40.8	4.5	2.5	9.5
<b>LBC520</b>	3.5	2.5	-1.0	1.8	6.0	15.0	24.2	48.0	11.5	0.0	17.0
<b>LBC224</b>		15.5									
<b>LBLD</b>		4.0									
<b>LB238</b>	36.0	7.5	-28.5	2.3	4.0	10.8	14.1	26.1	8.9	0.0	9.3
<b>LB58</b>	17.0	3.0	-14.0	1.4	1.7	12.6	17.5	42.4	20.0	1.0	33.7
<b>Trout</b>	12.5	4.6	-7.9	8.0	9.5	15.5	23.3	37.3	2.5	0.0	17.0
<b>WEST</b>	1.0	6.3		7.3	10.7	16.2	23.4	47.5	5.5	0.0	37.7
<b>DANE</b>	4.0	0.5	-3.5	8.3	11.6	19.8	26.9	49.2	5.0	0.0	31.0
<b>CUTT</b>	3.5	5.0	1.5	1.9	8.3	17.2	25.1	53.2	11.0	0.0	35.5
<b>Cutt78</b>	27.0	7.0	-20.0	1.4	1.7	7.0	9.9	21.4	19.5	13.0	16.6
<b>Rowland</b>	16.0	18.0	2.0	2.0	6.0	13.1	17.9	43.4	10.0	0.5	26.0

Fines - ≤ 2mm sand and silt; D10, D15, D35, D50, 84 – Diameter (mm) of gravel size at 10<sup>th</sup>, 15<sup>th</sup>, 35<sup>th</sup>, 50<sup>th</sup>, and 84<sup>th</sup> percentile distribution of pebble count measured sample. Silt – Not measured. Determined by feel. *Silt has a moderate specific area with a typically non-sticky, plastic feel. Silt usually has a floury feel when dry, and a slippery feel when wet – from Wikipedia.*

Table C4. Stream Channel Metrics. 2014 BIBI Riffle Pebble Count Statistics and Grid + Riffle Fine Sediment.

2015 BIBI Riffle Pebble Count (200 pebbles)										
Site Name	D10 (mm)	D15 (mm)	D35 (mm)	D50 (mm)	D84 (mm)	% Fines (Sand & Silt)	% Embedded	2014 Grid + Riffle Fines	2015 Grid + Riffle Fines	Year-Year Change (%)
LB2603	6.6	8.6	14.4	19.1	36.5	4.5	14.7		7.0	
LB169	5.4	7.1	13.1	16.3	31.7	8.0	18.9	33	13.0	-20.0
LB2602	1.6	2.0	13.0	18.2	34.4	15.5	26.0		25.0	
LB51	1.4	1.7	11.5	14.9	29.8	20.5	30.0	45	31.0	-14.0
LB196	6.9	12.2	19.0	26.3	46.7	6.0	39.0		23.0	
LBC19830								14.5		
LBC520	12.8	15.2	27.2	34.7	60.1	1.5	16.0	15	4.0	-11.0
LBC224	2.0	8.8	20.0	26.7	49.3	10.0	18.5		25.5	
LBLD	7.0	8.5	14.8	21.7	33.1	4.5	23.0		8.5	
LB238	2.4	6.3	12.7	17.1	29.7	9.5	21.0	44.9	17.0	-27.9
LB58	2.0	3.8	14.8	22.3	44.8	10.0	43.0	37	13.0	-24.0
Trout	2.0	6.7	13.4	16.8	30.0	10.3	21.7	15	14.9	-0.1
WEST	3.4	7.0	14.6	21.0	43.2	7.4	32.6			
DANE	12.4	13.9	25.2	30.7	59.6	3.0	25.0	9	3.5	-5.5
CUTT	2.0	6.1	14.1	20.5	51.6	10.0	27.5	14.5	15.0	0.5
Cutt78	2.2	4.0	9.2	14.3	40.5	9.0	32.0		16.0	
Rowland	1.5	1.9	13.2	24.5	46.1	16.0	32.0	26	34.0	8.0

Table C5. Stream Channel Metrics. Survey-Wide Substrate Size Statistics from Pebble Counts. Relative Bed Stability (from Kaufmann et al. 1999).

Site Name	Survey Transects Substrate (105 Pebbles)								Relative Bed Stability (RBS) - EPA EMAP		
	D10 (mm)	D15 (mm)	D35 (mm)	D50 (mm)	D84 (mm)	Sand % (≈2 mm)	Silt %	% Embedded	RBS survey- wide	RBS Riffle- only 2014	RBS Riffle- only 2015
<b>LB2603</b>											1.281
<b>LB169</b>	1.2	1.3	1.9	6.3	19.8	36	22.9	43.9	0.360	0.670	0.774
<b>LB2602</b>	1.1	1.2	1.5	1.8	23.3	57	1.7	68.4	-0.749		0.246
<b>LB51</b>	1.2	1.3	1.7	4.7	24.3	46	0.0	52.6	-0.496	-0.076	0.010
<b>LB196</b>	1.3	1.5	9.6	15.1	41.1	26	0.4	47.0	0.161		0.402
<b>LBC19830</b>	1.5	1.9	22.1	31.7	63.1	16	1.8	38.6	0.247	0.069	
<b>LBC520</b>	1.3	1.5	7.7	14.6	48.0	25	5.6	30.7	-0.025	0.195	0.352
<b>LBC224</b>	1.2	1.4	2.8	25.3	107.8	34	10.8	53.7	0.309		0.332
<b>LBLD</b>	1.4	1.7	13.4	19.5	43.2	20	0	37.7	0.548		0.594
<b>LB238</b>	1.2	1.3	1.9	7.1	21.2	36	3.2	44.4	-0.610	-0.313	-0.228
<b>LB58</b>	1.2	1.4	3.3	8.9	27.1	31	10.4	43.3	-0.114	0.178	0.283
<b>Trout</b>	1.4	1.6	11.2	20.0	42.7	22	3.9	35.2	0.378	0.445	0.302
<b>WEST</b>	1.4	1.7	11.3	16.9	43.3	19	3.5	50.2	0.066	0.208	0.161
<b>DANE</b>	1.5	1.8	14.2	23.8	59.6	18	8.7	31.6	0.399	0.452	0.510
<b>CUTT</b>	2.4	6.3	16.0	24.1	53.0	9	1.7	40.4	0.581	0.599	0.511
<b>Cutt78</b>	1.5	1.7	8.4	12.8	23.7	19	5.2	22.5	0.375	0.263	0.424
<b>Rowland</b>	1.4	1.6	11.7	17.3	47.2	21	4.8	53.0	0.146	0.161	0.298



Table C6. Stream Channel Metrics. Habitat Units.

Site Name	Glide/ Run Count	Pool Count	Riffle Count	Total Habitat Unit #	Channel Widths in Survey	Non-pool Spacing by BFW CW	% Wood- formed Pools	Habitat Units per BFW CW	Pool Spacing/ # CW	Riffle Spacing/ # CW	Avg. Residual Depth (m)
<b>LB2603</b>											
<b>LB169</b>	9	1	9	19	29.8	1.7	0	0.64	29.81	3.31	0.10
<b>LB2602</b>	5	8	6	19	27.8	2.5	75	0.68	3.47	4.63	0.15
<b>LB51</b>	7	3	6	16	23.2	1.8	100	0.69	7.72	3.86	0.16
<b>LB196</b>	7	4	5	16	28.9	2.4	100	0.55	7.24	5.79	0.17
<b>LBC19830</b>	4	6	8	18	25.8	2.2	66.7	0.70	4.31	3.23	0.20
<b>LBC520</b>	3	6	6	15	18.3	2.0	66.7	0.82	3.05	3.05	0.18
<b>LBC224</b>	3	8	8	19	26.1	2.4	62.5	0.73	3.26	3.26	0.21
<b>LBLD</b>	2	10	8	20	26.0	2.6	50	0.77	2.60	3.25	0.21
<b>LB238</b>	2	11	6	19	28.1	3.5	27.3	0.68	2.56	4.69	0.32
<b>LB58</b>	1	9	7	17	36.0	4.5	66.7	0.47	4.00	5.15	0.31
<b>Trout</b>	9	6	18	33	46.2	1.7	16.7	0.71	7.70	2.57	0.08
<b>WEST</b>	6	7	9	22	17.3	1.2	57.1	1.27	2.47	1.92	0.07
<b>DANE</b>	10	2	8	20	32.4	1.8	100	0.62	16.22	4.06	0.10
<b>CUTT</b>	1	3	3	7	18.2	4.6	100	0.38	6.07	6.07	0.13
<b>Cutt78</b>	3	2	6	11	31.3	3.5	50	0.35	15.63	5.21	0.07
<b>Rowland</b>	10	4	13	27	35.3	1.5	75	0.77	8.81	2.71	0.08

CW – Channel Width is survey length divided by Bankfull Width; Pool/ Riffle Spacing – Number of Channel Widths between riffles or pools.

Table C7. Stream Channel Metrics. Woody Debris, Bank Erosion and Armored Channel Modifications.

Site Name	Woody debris (WD - $\geq 2\text{m}/\geq 10\text{cm}$ )					Bank Erosion and Modifications (Mod)				
	Total Wood (WD)	Survey Length (m)	WD/km	WD spacing/ CW #	Erosion Length (m)	Erosion %	Mod Length (m)	Mod %	Erosion + Mod (m)	Erosion + Mod%
<b>LB2603</b>										
<b>LB169</b>	9	100	90.0	3.3	20.9	10.5	0.0	0.0	20.9	10.5
<b>LB2602</b>	18	100	180.0	1.5	14.6	7.3	0.0	0.0	14.6	7.3
<b>LB51</b>	18	100	180.0	1.3	2.0	1.0	0.0	0.0	2.0	1.0
<b>LB196</b>	26	150	173.3	1.1	8.0	2.7	0.0	0.0	8.0	2.7
<b>LBC19830</b>	12	100	120.0	2.2	6.3	3.2	3.0	1.5	9.3	4.7
<b>LBC520</b>	13	100	130.0	1.4	5.7	2.9	20.9	10.5	26.6	13.3
<b>LBC224</b>	27	150	180.0	1.0	19.6	6.5	108.0	36.0	127.6	42.5
<b>LBLD</b>	30	150	200.0	0.9	25.8	8.6	110.6	36.9	136.4	45.5
<b>LB238</b>	10	164	61.0	2.8	75.8	23.1	22.2	6.8	98.0	29.9
<b>LB58</b>	22	200	110.0	1.6	47.8	12.0	0.0	0.0	47.8	12.0
<b>Trout</b>	2	100	20.0	23.1	34.6	17.3	0.0	0.0	34.6	17.3
<b>WEST</b>	7	50	140.0	2.5	15.7	15.7	0.0	0.0	15.7	15.7
<b>DANE</b>	2	100	20.0	16.2	42.0	21.0	8.6	4.3	50.6	25.3
<b>CUTT</b>	6	50	120.0	3.0	31.6	31.6	0.0	0.0	31.6	31.6
<b>Cutt78</b>	4	50	80.0	7.8	0.0	0.0	0.0	0.0	0.0	0.0
<b>Rowland</b>	14	100	140.0	2.5	44.5	22.3	2.9	1.5	47.4	23.7

Table C8. Stream Channel Metrics. Canopy Cover and Temperature.

Site Name	Channel Canopy Cover (%)			Temperature_2014			Temperature_2015		
	% Right Bank Cover	% Left Bank Cover	% Center Channel Cover	7-DADMAX Celsius	Summer Maximum Celsius	% time >16 Celsius	Summer Maximum Celsius	7-DADMAX Celsius	% time >16 Celsius
<b>LB2603</b>									
<b>LB169</b>	92.0	95.7	76.6	13.7	14.6	0	14.3	14.1	0
<b>LB2602</b>	96.3	98.9	94.5						
<b>LB51</b>	96.8	98.4	90.6	20	20.4	58.1	22.3	21.9	37.8
<b>LB196</b>	96.8	84.0	81.3						
<b>LBC19830</b>	92.9	95.3	92.9						
<b>LBC520</b>	100.0	81.8	82.1	16.8	17.2	7.0	17.9	17.5	9.1
<b>LBC224</b>	93.6	94.1	81.7						
<b>LBLD</b>	87.2	82.4	80.2	18.3	18.8	50.0	20.0	19.5	26.9
<b>LB238</b>	87.6	87.6	36.3						
<b>LB58</b>	96.8	99.5	51.3				20.8	20.4	30.8
<b>Trout</b>	94.7	97.3	88.8	16.7	17.3	53.5	18.2	17.7	21.3
<b>WEST</b>	100.0	99.5	98.8	15.8	16.7	0	18.9	18.0	17.77
<b>DANE</b>	94.7	62.0	77.1	14.8	15.1	0	16.0	15.7	0
<b>CUTT</b>	98.9	98.4	90.5	16.7	17.1	25.6	17.8	17.5	11.5
<b>Cutt78</b>	91.4	97.3	96.4						
<b>Rowland</b>	97.9	100.0	97.1						

Canopy cover is determined with a spherical densiometer per EMAP protocols (Peck et al. 2005). 7-DADMAX is maximum seven-day average of daily maximum temperatures.

Table C9. Several habitat performance criteria from regional sources that describe suitability, degradation or unsuitability of fish habitat.

Indicator	Habitat suitability (rating criteria)			Source
	Suitable/Good	Degraded/Fair	Unsuitable/ Poor	
<b>Streambank instability or shoreline armoring (combined)</b>	Shoreline hardening and unstable banks affect <10% of shorelines	Shoreline hardening and unstable banks affect 10-20% of shorelines	Shoreline hardening and unstable banks affect >20% of shorelines	Stillaguamish TAG< adapted from NOAA (1996)
<b>Pool habitat area</b>	Pool habitat is >50% of the low flow surface area	Pool habitat is 35-50% of the low flow surface area	Pool habitat is <35% of the low flow surface area	WFPB (1997); aka Watershed Analysis Manual
<b>Pool spacing (CW/pool)</b>	<2 CW/ pool	2-4 CW/ pool	>4 CW/ pool	WFPB (1997)
<b>Sediment</b>	<12% fines (< 0.85 mm) in gravel	12-17% fines	>17% fines	NOAA (1996)
<b>Surface fine sediment</b>	<10% surface fines (<6.35mm) in spawning areas	10-17% fines in spawning areas	>17% fines in spawning areas	Bjornn and Reiser (1991)
<b>Substrate size</b>	dominant substrate is gravel or cobble (interstitial spaces clear), or embeddedness <20%3	gravel and cobble is subdominant, or if dominant, embeddedness 20-30%	bedrock, sand, silt or small gravel dominant, or if gravel and cobble dominant, embeddedness >30%2	NOAA (1996)
<b>Canopy cover; bank cover</b>	≥90% for bank cover	>90 %	>90 %	WFPB (1997); Ecology (2007)
<b>Canopy cover; center channel cover</b>	suitable center-channel cover for shading varies as a function of BFW; 90-50% depending on CW			Ecology (2007)

Woody Debris – WD (>2.0m length, >10cm diameter)

Indicator	Channel width (CW)	Suitable/ Good	Degraded/ Fair	Unsuitable/ Poor	Source
<b>WD spacing per channel width</b>	<20m	> 2 pieces	1 – 2 pieces	<1 piece	Bilby and Ward (1989)
<b>WD spacing per CW, channel width classes</b>	0-3m	>0.9	0.5	<0.3	Fox (2001)
	3-12m	>4.8	3.6	<1.5	
	12-20m	>8.3	5.4	<2.7	
<b>WD Volume (m3/km), based on length/width size class categories</b>	0-30m	>990	280-990	<280	Fox (2001)
<b>WD frequency / km, CW classes</b>	0-6m	>380	260-380	<260	Fox (2001)
	>6-30m	>630	290-630	<290	
	>30-100m	>2080	570-2080	<570	
<b>LWD – Key pieces, &gt;15m, &gt;60cm</b>					
<b>Key piece frequency/ km &gt;15m, &gt;60cm</b>	0-40 m	25	7.1	2.5	Fox (2001), pieces size criteria are consistent within 2% of NOAA (1996)
	> 40 m				Quantity is consistent with NOAA (1996)
<b>Key pieces/ CW, based on volume, CW classes</b>	0-10m	>0.6	0.33	0.15	Fox (2001); our comparison is based on WD >15m, >60cm
	10-20 m	>0.33	0.18	0.1	
<b>Key piece frequency/ km, based on piece volume criteria</b>	0-10m	>110	40 - 110	<40	Fox (2001)
	>10-100m	>40	10 - 40	<10	

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