# Tributaries to Totten, Eld, and Little Skookum Inlets: Fecal Coliform Bacteria and Temperature Total Maximum Daily Load

## Water Quality Improvement Report

March 2006

Publication No. 06-03-007

This report is available on the Department of Ecology home page on the World Wide Web at www.ecy.wa.gov/biblio/0603007.html

Data for this project are available at Ecology's Environmental Information Management (EIM) website www.ecy.wa.gov/eim/index.htm. Search User Study ID, AAHm001.

Ecology's Project Code for this study is 04-049-02.

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# Tributaries to Totten, Eld, and Little Skookum Inlets: Fecal Coliform Bacteria and Temperature Total Maximum Daily Load

## Water Quality Improvement Report

by

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March 2006

Waterbody Numbers: WA-13-1100, WA-14-1100, WA-14-1190,
WA-14-1195, WA-14-1200, WA-14-1300, WA-14-1400

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# List of Acronyms and Abbreviations

| | |
|---|---|
| 303(d) | Section 303(d) of the federal Clean Water Act |
| 7Q10 | Seven-day, ten-year frequency flow |
| cfs | cubic feet per second |
| cfu | colony-forming units (bacterial concentration count) |
| cms | cubic meters per second |
| DNR | Washington State Department of Natural Resources |
| Ecology | Washington State Department of Ecology |
| EPA | U.S. Environmental Protection Agency |
| FC | Fecal coliform bacteria |
| GDRCo | Green Diamond Resource Company |
| HCP | Habitat Conservation Plan |
| NMP | National Monitoring Program (under Clean Water Act section 319) |
| NOAA | National Oceanic and Atmospheric Administration |
| NPDES | National Pollutant Discharge Elimination System |
| SIT | Squaxin Island Tribe |
| TIR | Thermal infrared |
| TMDL | Total Maximum Daily Load |
| USGS | U.S. Geological Survey |
| WAC | Washington Administrative Code |
| WRIA | Water Resource Inventory Area |

# Glossary

**303(d) list:** Section 303(d) of the federal Clean Water Act requires Washington State periodically to prepare a list of all surface waters in the state for which beneficial uses of the water – such as for drinking, recreation, aquatic habitat, and industrial use – are impaired by pollutants. These are water quality limited estuaries, lakes, and streams that fall short of state surface water quality standards, and are not expected to improve within the next two years.

**$90^{th}$ percentile:** A statistical number obtained from a distribution of a data set, above which 10% of the data exists while 90% of the data are below this number.

**Animal unit:** The weight of an animal (or animals) equivalent to 1000 pounds.

**Best management practices (BMPs):** Physical, structural, and/or operational practices that, when used singularly or in combination, prevent or reduce pollutant discharges.

**Clean Water Act (CWA):** Federal act passed in 1972 that contains provisions to restore and maintain the quality of the nation's waters. Section 303(d) of the CWA establishes the TMDL program.

**Concentration:** The amount of a substance in a given amount of water (e.g., bacteria colonies per 100 milliliter).

**Critical period.** When the highest exceedance of the water quality standards has historically occurred.

**Effective shade:** Shade is the amount of solar energy that is obscured or reflected by vegetation or topography above a stream. Effective shade is defined as the fraction of the total possible solar radiation heat energy that is prevented from reaching the surface of the water.

**Exceedance:** When bacteria levels or stream temperature failed to meet water quality standards.

**Fecal coliform (FC):** That portion of the coliform group of bacteria which is present in intestinal tracts and feces of warm-blooded animals as detected by the product of acid or gas from lactose in a suitable culture medium within 24 hours at 44.5 plus or minus 0.2 °Celsius. FC are "indicator" organisms that suggest the possible presence of disease-causing organisms. Concentrations are measured in colony forming units per 100 milliliters of water (cfu/100 mL).

**Geometric mean:** A mathematical expression of the central tendency (an average) of multiple sample values. A geometric mean, unlike an arithmetic mean, tends to dampen the effect of very high or low values, which might bias the mean if a straight average (arithmetic mean) were calculated. This is helpful when analyzing bacteria concentrations, because levels may vary anywhere from ten to 10,000 fold over a given period. The calculation is performed by either: (1) taking the nth root of a product of n factors, or (2) taking the antilogarithm of the arithmetic mean of the logarithms of the individual values.

**Load**:  Refers to the total amount of a pollutant being carried by a waterbody.  It is calculated by multiplying the concentration of the pollutant times the volume of water.

**Load allocation (LA):**  The portion of a receiving waters' loading capacity attributed to one or more of its existing or future sources of nonpoint pollution or to natural background sources.

**Long-term 90$^{th}$ percentile:**  The 90$^{th}$ percentile of fecal coliform concentrations over the last several years for a particular period.

**Margin of safety (MOS):**  Required component of TMDLs that accounts for uncertainty about the relationship between pollutant loads and quality of the receiving waterbody.

**National Pollutant Discharge Elimination System (NPDES):**  National program for issuing, modifying, revoking and reissuing, terminating, monitoring and enforcing permits, and imposing and enforcing pretreatment requirements under the Clean Water Act.  The NPDES program regulates discharges from wastewater treatment plants, large factories, and other facilities that use, process, and discharge water back into lakes, streams, rivers, bays, and oceans.

**Nonpoint source:**  Pollution that enters any waters of the state from any dispersed land-based or water-based activities, including but not limited to atmospheric deposition, surface water runoff from agricultural lands, urban areas, or forest lands, subsurface or underground sources, or discharges from boats or marine vessels not otherwise regulated under the National Pollutant Discharge Elimination System Program.  Generally, any unconfined and diffuse source of contamination.  Legally, any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act.

**Pathogen:**  Disease-causing microorganisms such as bacteria, protozoa, and viruses.

**Phase I Stormwater Permit:**  The first phase of stormwater regulation required under the federal Clean Water Act.  The permit is issued to medium and large municipal separate storm sewer systems (MS4s) and construction sites of five or more acres.

**Phase II Stormwater Permit:**  The second phase of stormwater regulation required under the federal Clean Water Act.  The permit is issued to smaller municipal separate storm sewer systems (MS4s) and construction sites over one acre.

**Point source:**  Pollution that discharges at a specific location from pipes, outfalls, and conveyance channels to a surface water.  Examples of point source discharges include municipal wastewater treatment plants, municipal stormwater systems, industrial waste treatment facilities, and construction sites that clear more than five acres of land.

**Pollution:**  Such contamination, or other alteration of the physical, chemical, or biological properties, of any waters of the state, including change in temperature, taste, color, turbidity, or odor of the waters, or such discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state as will or is likely to create a nuisance or render such waters harmful, detrimental, or injurious to the public health, safety, or welfare, or to domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or to livestock, wild animals, birds, fish, or other aquatic life.

**Stormwater:** The portion of precipitation that does not naturally percolate into the ground or evaporate but instead runs off roads, pavement, and roofs during rainfall or snowmelt. Stormwater can also come from hard or saturated grass surfaces such as lawns, pastures, playfields, and from gravel roads and parking lots.

**Surface waters of the state**: Lakes, rivers, ponds, streams, inland waters, saltwaters, wetlands and all other surface waters and water courses within the jurisdiction of the state of Washington.

**Synoptic survey**: A single field event where water quality and stream hydraulic parameters are measured for all stations on the same day.

**System potential temperature**: Considered to be an approximation of the temperatures that would occur under natural conditions. System potential is our best understanding of natural conditions that can be supported by available analytical methods. In this report, the simulation of the system potential condition uses best estimates of mature riparian vegetation (*vegetation which can grow and reproduce on a site, given: climate, elevation, soil properties, plant biology and hydrologic processes).*

**Total maximum daily load (TMDL):** The amount of pollution that a waterbody can assimilate before beneficial uses (such as swimming and shellfishing) are affected. A TMDL is equal to the sum of all of the following: (1) individual wasteload allocations for point sources, (2) load allocations for nonpoint sources, (3) the contribution of natural sources, and (4) a margin of safety to allow for uncertainty in the wasteload determination. A reserve for future growth is also generally provided.

**Wasteload allocation (WLA):** The portion of a receiving water's loading capacity allocated to existing or future point sources of pollution.

**Watershed:** A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

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# Abstract

Four tributaries to Totten Inlet (Pierre, Burns, Kennedy, and Schneider creeks), two tributaries to Eld Inlet (McLane and Perry creeks), and one tributary to Little Skookum Inlet (Skookum Creek) have been placed on the federal 303(d) list for not meeting Washington State's water quality standard for fecal coliform bacteria. Kennedy Creek and Skookum Creek are also not meeting the state's standards for temperature.

This report provides a comprehensive evaluation of fecal coliform data collected over ten years (1994-2004) for many of these tributaries, and establishes target reductions to bring bacterial concentrations down to within water quality standards. The target reductions are based on the statistical roll-back method. A monitoring strategy is proposed to evaluate the effectiveness of the total maximum daily load (TMDL) implementation measures.

A temperature TMDL for the listed segment of Kennedy Creek will not be conducted at this time pending implementation of the Green Diamond Resource Company Habitat Conservation Plan. Temperature data gathered during the implementation of the Habitat Conservation Plan will be evaluated to establish the need for a TMDL in the listed segment.

Substantial reductions in water temperatures in Skookum Creek are predicted for conditions with mature riparian vegetation. The temperature TMDL is based on data collected in 2004. Potential reduced temperatures are predicted to be less than the water quality standard of 16°C in all segments of the streams evaluated. Load allocations were developed for effective shade for segments of Skookum Creek using the QUAL2Kw model.

# Acknowledgements

The author would like to thank the following for their contribution to the study:

- Stephanie Kenny, Mason County, for providing fecal coliform data on Kennedy, Schneider, and Skookum creeks, and for review and comments on the draft report.
- Sue Davis, Thurston County Environmental Health Division, for providing fecal coliform data for tributaries to Totten and Eld inlets, and for review and comments on the draft report.
- Kathleen Whalen, Thurston Conservation District, for review and comments on the draft report.
- Roy Iwai, City of Olympia, Public Works Department, for review and comments on the draft report.
- Bill Young, a private citizen, for review and comments on the draft report.
- Laurie Mann, U.S. Environmental Protection Agency, for review and comments on the draft report.
- Staff with the Squaxin Island Tribe:
  - John Konovsky for providing fecal coliform data on Skookum Creek, for organizing the field work for the temperature TMDL, and for review and comments on the draft report.
  - Joe Puhn for the temperature TMDL field work, including installation of temperature tidbits, and for streamflow and cross-section measurements.
  - Nadine Romero for hydrogeologic field work for the temperature TMDL, including installation of piezometers, for temperature i-buttons and follow-up monitoring, and for review and comments on the draft report.
- Staff with the Washington State Department of Ecology:
  - David Batts and Keith Seiders for data collection and evaluation under the National Monitoring Program.
  - Lawrence Sullivan for coordinating and conducting field work.
  - Sara Livingston for evaluating orthophotos and creating the database using ArcView for shade calculations, and for help with field work.
  - James Kardouni and Nuri Mathieu for helping with field work.
  - Greg Pelletier for assistance with QUAL2Kw model calibration and confirmation, and for peer review and comments.
  - Nicoleta Cristea for assistance with QUAL2Kw model calibration and confirmation.
  - Kirk Sinclair for assistance with VS2DHI model calibration and interpretation.
  - Christine Hempleman for review and comments on the draft report
  - Karol Erickson for review and comments on the draft report.
  - Joan LeTourneau for formatting and editing the final report.

# Executive Summary

This *Water Quality Improvement Report* addresses four tributaries to Totten Inlet (Pierre, Burns, Kennedy, and Schneider creeks), two tributaries to Eld Inlet (McLane and Perry creeks), and one tributary to Little Skookum Inlet (Skookum Creek). Fecal coliform bacteria concentrations in these creeks are high enough to indicate a potential health risk to recreational users. These creeks also drain to inlets that support commercial, Tribal, and private shellfish harvest. Elevated bacteria concentrations indicate a potential health risk to people who eat shellfish, and can result in restrictions on shellfish harvest. In addition to bacteria problems, Skookum Creek and Kennedy Creek are too warm to be healthy for the organisms that live there, especially salmon. These waterbodies are listed as “impaired” in Washington’s Water Quality Assessment.

The study area for this report, shown in Figure ES-1, includes portions of Thurston and Mason counties, and portions of the Deschutes and Kennedy/Goldsborough watersheds.

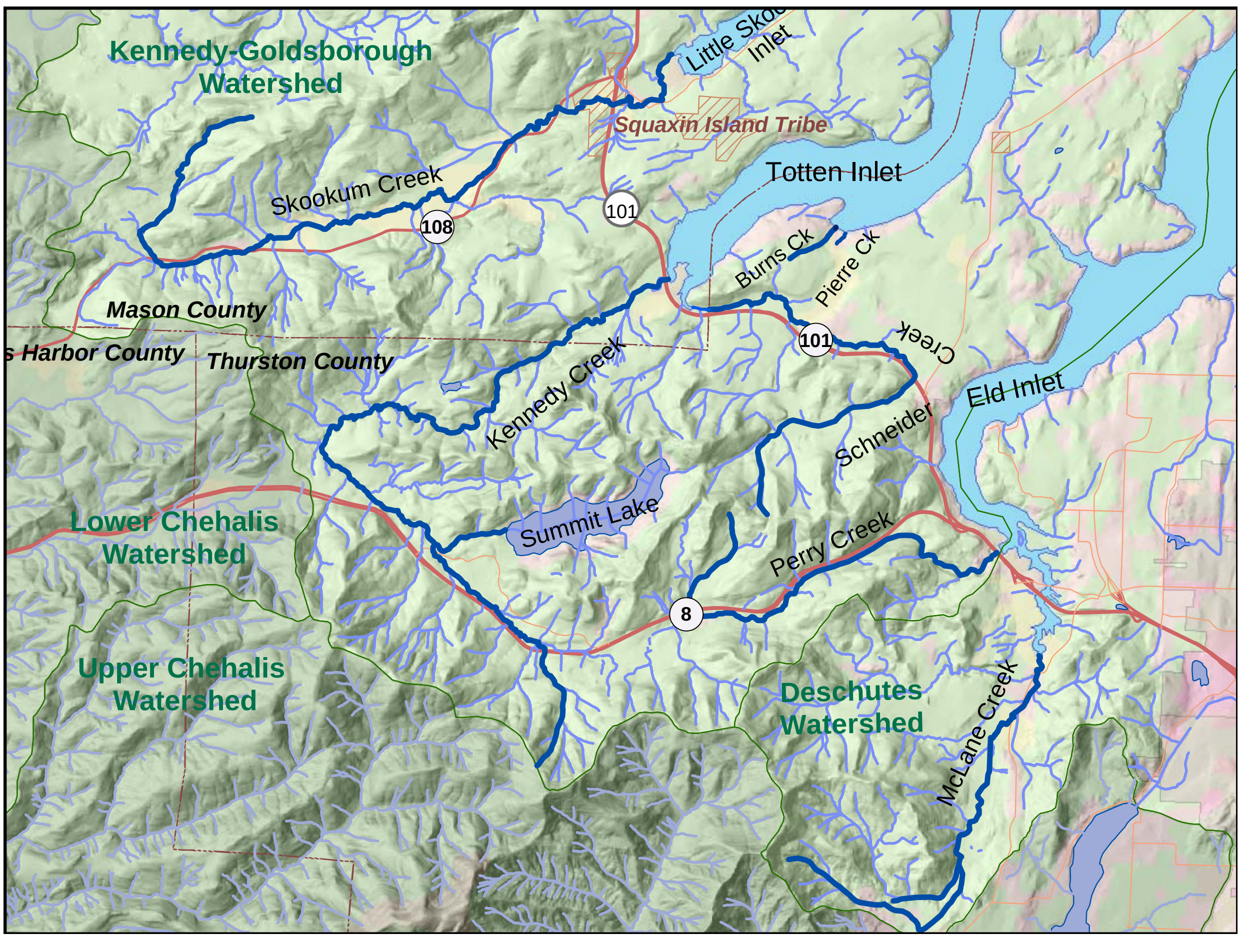


Figure ES-1. Study area.

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The federal Clean Water Act requires that impaired waterbodies be restored to clean water standards through a total maximum daily load, or TMDL, process. This process starts with a study and analysis of pollution levels and sources. Then, based on that analysis, it requires conducting activities necessary to restore healthy water quality.

This report is based on more than ten years of data from the Department of Ecology, the Squaxin Island Tribe, Thurston County, and Mason County. The report:

- Provides a comprehensive evaluation of data.
- Calculates how much bacteria the creeks can tolerate naturally and still be healthy for their beneficial uses (called the total maximum daily load, or TMDL), and how much reduction is needed to reach healthy levels.
- Proposes a monitoring strategy to evaluate the effectiveness of improvement measures.
- Describes the framework for water quality improvement, including participating organizations, primary funding sources, and the general approach to address primary pollution sources.

For tributaries to Eld and Totten inlets, water quality samples were collected at one site near the mouth. For McLane Creek, samples were also collected near the mouth of Swift Creek, a major tributary. In Skookum Creek, water quality samples were collected at several locations. Recommended bacteria reductions are calculated for sampling locations. "Critical period" is also established. This refers to the time of year when bacteria concentrations are highest. Recommended reductions are based on that period of time. The following table shows recommended bacteria reductions for sampling locations.

Table ES-1. Recommended bacteria reductions for sampling locations on tributaries to Totten, Eld, and Little Skookum inlets.

| Location | Critical period | Target reduction |
|---|---|---|
| Kennedy Creek | Aug-Sept | 73% |
| Schneider Creek | July-Sept | 73% |
| Burns Creek | May-June | 99% |
| Pierre Creek | May-June | 96% |
| McLane Creek<br>- Swift Creek | August<br>June-Oct | 95%<br>77% |
| Perry Creek | August | 46% |
| Skookum<br>o Mainstem at Hwy 108 (river mile 6)<br>o Near mouth of Hurley Cr at Eich Rd culvert<br>o Mainstem at Eich Rd bridge, below Hurley Cr<br>o Mainstem at Hwy 108 (river mile 2.2)<br>o Near mouth of Clary Cr at RR crossing | <br>May-Oct<br>May-Oct<br>May-Oct<br>May-Oct<br>May-Oct | <br>35%<br>75%<br>72%<br>51%<br>67% |

The main human-controlled sources of fecal coliform bacteria in this watershed are livestock waste, leaking or poorly maintained on-site septic systems, and pet waste. Restoring good water quality will depend on the actions of the people living in the watershed. For livestock sources, technical assistance is available and, in some cases, cost share incentives may also be available. For septic systems, assistance may be available to help identify problems and, in Thurston County, low interest loans may be available to help with repairs or upgrades. Generally, participating organizations will work with landowners to build awareness and create solutions in a voluntary way. While voluntary compliance is the goal, enforcement options exist at the county and state level, if needed.

Temperature issues in Kennedy Creek are not addressed by this *Water Quality Improvement Report.* The Green Diamond Resource Company is currently putting into action a Habitat Conservation Plan (HCP) that includes Kennedy Creek. During implementation of the HCP, the Green Diamond Resource Company will monitor upper Kennedy Creek, while the lower listed segment will be monitored by the Squaxin Island Tribe. Data gathered will be evaluated to determine if the HCP is effective in lowering the temperature in the listed segment to within the water quality standards. The need for developing a TMDL for the listed segment will be established through this evaluation.

Required temperature improvements for Skookum Creek are expressed in the report in terms of restoring shade (Table ES-2). Modeling shows that higher streamflows would cool the water, but the incremental improvement is much smaller than increasing shade. Restored mature streamside vegetation would cool Skookum Creek enough to meet water quality standards. The technical evaluation determined the amount of shade needed in various segments of the creek.

This plan establishes a goal of achieving bacteria reductions by 2015 (i.e., eight years following completion of the *Water Quality Implementation Plan).* Fifty percent reduction is anticipated by the year 2011.

Achieving temperature reductions is a long-term goal, requiring time for plantings to become mature. Within three years, implementing agencies anticipate restoring vegetation to 85% of degraded riparian areas (replanting as necessary for mortalities). Temperature goals are anticipated to be achieved when tree height reaches 30 meters, estimated as approximately 50 years.

Ecology will submit this *Water Quality Improvement Report* to the U.S. Environmental Protection Agency (EPA) for approval. Following approval, local and state agencies, the Squaxin Tribe, the SW Puget Sound Watershed Council, and local citizens will develop a detailed plan for clean up. That *Water Quality Implementation Plan* is anticipated to be complete by the fall of 2007.

Table ES-2. Load allocations for effective shade for Skookum Creek.

| Stations and Landmarks | Upstream (km) | Downstream (km) | Average Target Effective Shade (%) | |
|---|---|---|---|---|
| | | | Potential | Deficit |
| S9, below confluence of north and south forks | 13.35 | 12.95 | 90% | 20% |
| | 12.95 | 12.55 | 90% | 40% |
| | 12.55 | 12.15 | 90% | 20% |
| | 12.15 | 11.75 | 90% | 40% |
| S8, upstream of upper Hwy 108 bridge | 11.75 | 11.35 | 80% | 30% |
| | 11.35 | 10.95 | 90% | 25% |
| | 10.95 | 10.55 | 90% | 20% |
| | 10.55 | 10.15 | 90% | 50% |
| | 10.15 | 9.75 | 80% | 50% |
| | 9.75 | 9.35 | 90% | 5% |
| | 9.35 | 8.95 | 90% | 30% |
| | 8.95 | 8.55 | 90% | 40% |
| | 8.55 | 8.15 | 85% | 30% |
| | 8.15 | 7.75 | 80% | 50% |
| | 7.75 | 7.35 | 80% | 35% |
| | 7.35 | 6.95 | 80% | 40% |
| | 6.95 | 6.55 | 90% | 30% |
| S5, below Eich Road bridge | 6.55 | 6.15 | 90% | 40% |
| | 6.15 | 5.75 | 90% | 35% |
| | 5.75 | 5.35 | 90% | 40% |
| | 5.35 | 4.95 | 90% | 20% |
| S4, bridge at Stohr driveway | 4.95 | 4.55 | 90% | 40% |
| | 4.55 | 4.15 | 85% | 40% |
| | 4.15 | 3.75 | 90% | 50% |
| | 3.75 | 3.35 | 90% | 40% |
| S3, upstream of lower Hwy 108 bridge | 3.35 | 2.95 | 80% | 30% |
| Squaxin Island Tribal boundary | 2.95 | 2.55 | 70% | 40% |

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# Introduction

Tributaries to the Totten, Eld, and Little Skookum inlets have been placed on Washington State's 2004 303(d) list of waterbodies that do not meet water quality standards for fecal coliform bacteria and temperature (Table 1). Thus, under the federal Clean Water Act of 1972, a cleanup plan must be developed and implemented to address this impairment and bring the waterbody segments into compliance with the standards.

This report is a technical analysis that contains the allowable "total maximum daily loads" (TMDLs) of fecal coliform bacteria and temperature to ensure that the standard is met in all relevant segments of the impaired tributaries to Totten, Eld, and Little Skookum inlets, at all times and locations under a reasonable worst-case scenario.

A TMDL is the maximum pollutant loading a waterbody can tolerate and still meet water quality standards. If the pollutant comes from a point source, the allowable load is called a wasteload allocation. If it comes from a nonpoint source, the allowable load is called a load allocation.

A TMDL must also consider seasonal variations and include a margin of safety that accounts for uncertainties in development of the TMDL. The sum of the load and wasteload allocations and the margin of safety is the pollutant-specific TMDL for a waterbody.

Table 1. Tributaries to Totten, Eld, and Little Skookum inlets on the 2004 303(d) list for fecal coliform bacteria and temperature.

| Inlets | Tributaries | Listing[a] Parameter | Location on the Creek | Township | Range | Section | Listing ID |
|---|---|---|---|---|---|---|---|
| Totten | Pierre Creek | FC | Near mouth | 19N | 3W | 27 | 40958[b] |
| | Burns Creek | FC | Near mouth | 19N | 3W | 27 | 40605[c] |
| | Kennedy Creek | Temp | 125m above Old Olympic Hwy bridge | 19N | 3W | 32 | 23545 |
| | | FC | | | | | 41736 |
| | Schneider Creek | FC | Near mouth, RM 0.3 | 19N | 3W | 33 | 12583 |
| Eld | McLane Creek | FC | RM 0.2 | 18N | 3W | 24 | 12581 |
| | | | | 18N | 2W | 19 | 41707 |
| | Perry Creek | FC | RM 1 | 18N | 3W | 13 | 12582 |
| Little Skookum | Skookum Creek | Temp | RM 1.0 @ Hwy 101 | 19N | 3W | 19 | 23758 |
| | | FC | RM 2.2 @ Hwy 108 | | | | 7601 |

[a] FC = fecal coliform; Temp = temperature
[b] the 2004 303(d) list contains other FC listing IDs which will be consolidated to a single listing ID of 40958
[c] the 2004 303(d) list contains other FC listing IDs which will be consolidated to a single listing ID of 40605

## Scope of the Fecal Coliform TMDL

The coliform bacteria group consists of several genera of bacteria belonging to the family *enterobacteriaceae*. These mostly harmless bacteria are passed through the fecal excrement of humans, livestock, wildlife, and domesticated animals. A specific subgroup of this collection is fecal coliform bacteria, the most common member being *Escherichia coli.*

The presence of fecal coliform bacteria in aquatic environments indicates that the water has been contaminated with the fecal material of humans or other animals. Fecal coliform bacteria can enter rivers through direct discharge of waste from mammals and birds, indirectly from agricultural and storm runoff, and from untreated human sewage. Individual on-site sewage systems can become overloaded during the rainy season and allow untreated human wastes to flow into drainage ditches and nearby waters. Improperly maintained on-site sewage systems can fail and leak sewage all year round. Agricultural practices such as allowing animal wastes to wash into nearby streams during the rainy season, spreading manure and fertilizer on fields during rainy periods, and allowing livestock watering in streams can all contribute to fecal coliform contamination.

While fecal coliform bacteria do not directly cause disease, high quantities of fecal coliform bacteria suggest the presence of disease-causing agents. Some waterborne pathogenic diseases include ear infections, dysentery, typhoid fever, viral and bacterial gastroenteritis, and hepatitis A.

Although fecal coliform bacterial die-off rates are not used in this report, nor is modeling done to show how bacteria migrate downstream, a short discussion on survival of microbes in the environment is presented here to portray the fact that microbes are not persistent pollutants but rather die in the environment. Factors that impact the survival of pathogens in streams include temperature, pH, the presence of ammonia and nutrients, ultra-violet (UV) radiation, and predation. Temperature is important in the destruction of viruses (Scheuerman et al., 1983), bacteria (Farrah and Bitton, 1983), and parasites (Kiff and Jones, 1984). Ward and Ashley (1977) showed that ammonia can be destructive to viruses. Watson (1980) noted that most enteric bacteria survive pH values between 5 and 8 and that outside this range they die rapidly. Under limiting substrate conditions, microbes compete for the nutrient that is limiting, and microbial growth rates decrease (Ahmed, 1990). UV radiation from sunlight is effective in the destruction of microorganisms that are near the surface of the water (Al-Azawi, 1986). Protozoa are thought to be predators of coliform bacteria (Tate, 1978). Hay et al. (1990) noted that fecal coliform bacteria were more resistant to thermal inactivation than most enteric bacterial pathogens, and the absence of this group generally indicated the destruction of most enteric bacterial pathogens.

There is some evidence of fecal coliform regrowth in streams, particularly from chlorinated discharges after the chlorine has dissipated in the stream or if the discharge is dechlorinated prior to discharge (Rifai and Jensen, 2002). However, the regrowth was not as significant as bacteria addition from resuspension of sediments (Rifai and Jensen, 2002). It is known that bacteria settle to bottom sediments during low-flow conditions and resuspend during high-flow conditions (EPA, 1985; Chapra, 1997; Rifai and Jensen, 2002). The bottom sediments act as a reservoir of previously deposited bacteria (Stephenson and Rychert, 1982; Weiskel et al., 1996) providing physical protection from predation and light (Faust et al., 1975), thereby extending the life of the bacteria. Survival rates in sediment can be as much as 30 days compared with several days in the water column (Sherer et al., 1992). However, if the supply of bacteria to the sediments from the settling of animal-derived bacteria is reduced, then the concentration of bacteria in the sediments will eventually be lower due to natural die-off.

Target reductions may be either in terms of concentration, or load, or both. For the tributaries to Totten, Eld, and Little Skookum inlets, the TMDL for fecal coliform is expressed in terms of fecal coliform concentration as allowed under Federal Regulations [40 CFR 130.2(I)] as "other appropriate measures". The density measure is appropriate since the water quality standard can be directly compared to measured concentrations in the receiving water under all flow scenarios. The "target reductions" show what is necessary to achieve the water quality standard. Therefore the use of a flow rate to calculate the "daily loads" is deemed unnecessary. However, loads at the mouth of tributaries have been established to provide a relative comparison of contributions of fecal coliform. Where applicable, target reductions have been set for a critical period when most historical exceedances of the fecal coliform standards have occurred (i.e., when bacteria levels were highest). Segments of the tributaries where "best management practices" (BMPs) need to be implemented and monitoring conducted are identified.

Over ten years of bi-weekly fecal coliform data (www.ecy.wa.gov/eim/) were obtained from the National Monitoring Program (Batts and Seiders, 2003) for tributaries to Totten and Eld inlets. In addition, data on these and other smaller tributaries were available from the Thurston County database (www.geodata.org/swater/swdata.html) and through personal communication (Davis, 2005). Extensive fecal coliform data have been gathered by the Squaxin Island Tribe for Skookum Creek and were made available to Ecology (Konovsky, 2004). Data on some tributaries were also obtained from Mason County (Kenny, 2004).

The TMDL will be based on the roll-back method of Ott (1995). This method is discussed in detail in the *Allowable Loads for Fecal Coliform Bacteria* section of this report.

## Scope of the Temperature TMDL

A temperature TMDL calculates the allowable heat content of a waterbody above which the temperature will exceed the water quality standards. General processes that elevate water temperatures include increased solar radiation due to reduced riparian vegetation and widening of channels caused by disruption of geomorphic processes. Temperatures also increase when groundwater exchange decreases and when baseflows are low. Point sources also contribute heat to the waterbody. However, there are no known point sources in listed segments of Kennedy and Skookum creeks. This study uses riparian shade as a surrogate measure of solar heat flux to waterbodies. Increases in riparian shade reduce the solar heat flux to the stream. Effective shade is defined as the fraction of the potential solar shortwave radiation that is blocked by vegetation and topography before it reaches the stream surface. Since topography is more or less permanent, the load allocations will be expressed as percent riparian shade needed to reduce temperature.

The effects of increased flow on stream temperature will not be specifically incorporated in the load allocation based upon a Memorandum of Agreement between EPA and Ecology regarding the implementation of section 303(d) of the Clean Water Act (October 29, 1997, page 18 Section XVIII Property Rights, www.ecy.wa.gov/programs/wq/tmdl/303moa12.pdf) and as prohibited under state law RCW 90.48.422 (www.leg.wa.gov/RCW/index.cfm?section=90.48.422&fuseaction=section). However, the relative effect of increased flows on stream temperature will be modeled and presented in this report. It is the task of Ecology's Water Resource Program to consider water quality issues when establishing minimum instream flows as mandated in RCW 90.22.010: "*In addition, the Department of Ecology shall … establish such minimum flows or levels as are required to protect the resource or preserve the water quality described in the request or determination*".

Most of Kennedy Creek is in Green Diamond Resource Company (GDRCo) timberland and is covered under a temperature TMDL which is based on a habitat conservation plan (HCP) (Cleland et al., 2000). The HCP uses shade as a surrogate for temperature. The assumptions behind the model are explained in detail in the Technical Assessment Report attached to the HCP (Cleland et al., 2000). Implementation of the Olympic HCP began in 2000. The riparian areas along Kennedy Creek receive protection that exceeds standard forest practices (Beach, 2005). To further empirically explore the relationship between stream shading and water temperature, GDRCo has installed three long-term temperature monitoring stations along Kennedy Creek, as well as two to four transient stations adjacent to planned harvest units. The transient units are installed upstream and downstream of harvest units and are used to monitor pre- and post-treatment stream temperature to elucidate any effect of harvest on stream temperature. These data are currently being analyzed, and the results will be transmitted to the HCP scientific advisory team upon completion of the analysis.

The segment of Kennedy Creek included in the 2004 303(d) list is an approximately one-mile segment at the mouth of the creek which is not covered by the HCP. Temperature monitoring for this segment will be continued by the Squaxin Island Tribe (Konovsky, 2005). As the HCP is implemented and monitoring data becomes available from both the areas covered by the HCP and the listed area, data will be evaluated to determine if the listed area temperatures are improving. Whether a TMDL is necessary in the listed area will be determined with the evaluation of the monitoring data.

Extensive field data for Skookum Creek were collected in summer 2004 by the Squaxin Island Tribe and the Department of Ecology (Ahmed, 2004c). The temperature TMDL in this report was based on modeling the heat sources and sinks along the channel, as per the method developed by Chapra (1997) with calibration and confirmation using the data collected in 2004.

# Study Area

The Totten Inlet watershed, located in Water Resources Inventory Area (WRIA) 14, falls within Mason and Thurston counties (Figure 1). The Eld Inlet watershed, in WRIAs 13 and 14, is in Thurston County. The Little Skookum Inlet watershed, in WRIA 14, is in Mason County.

The boundary between WRIA 13 (Deschutes watershed to the south) and WRIA 14 (Kennedy-Goldsborough watershed to the north) cuts through the middle of the Eld Inlet (Figure 1).

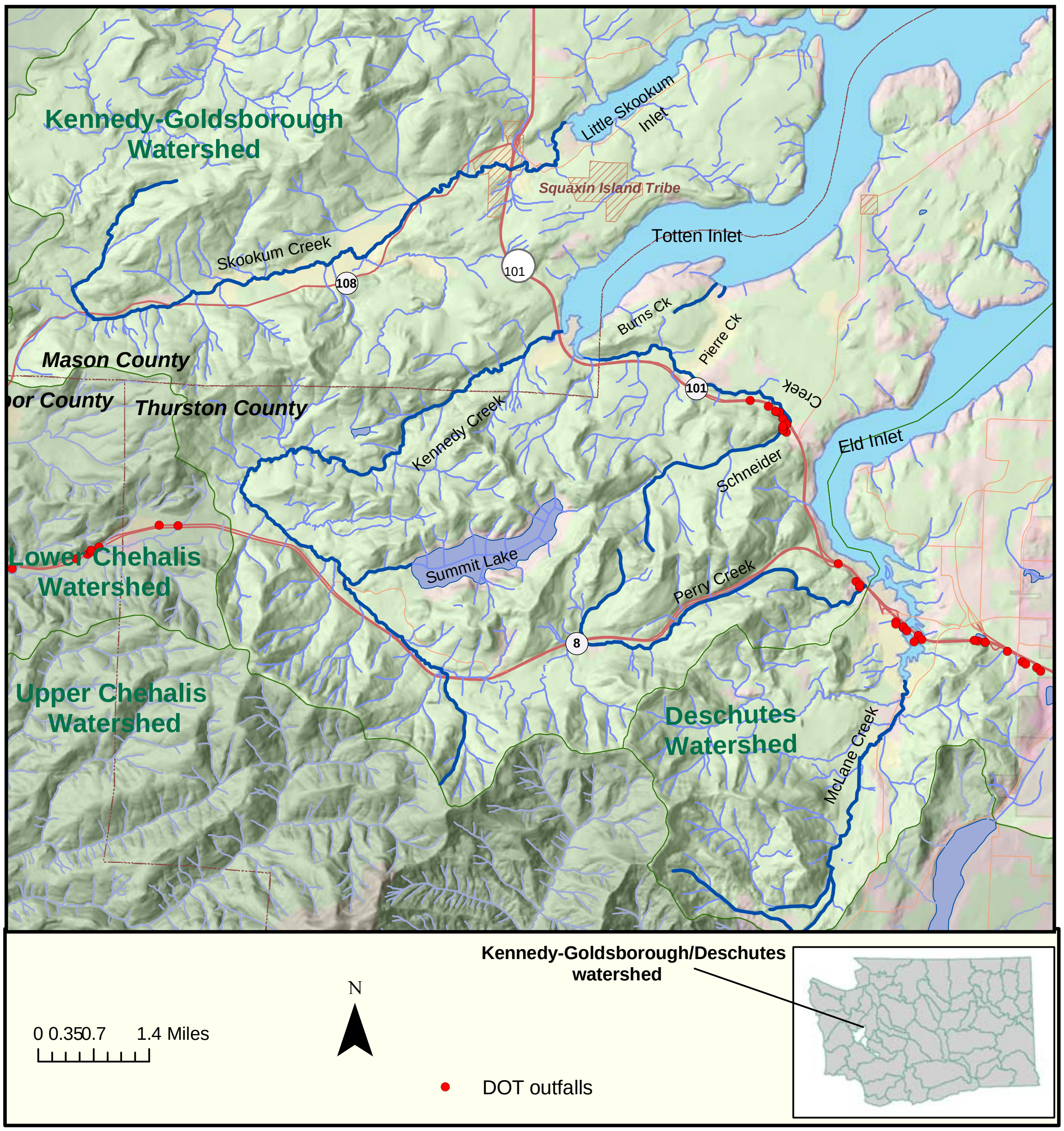


Figure 1. Tributaries to Totten, Eld, and Little Skookum inlets.

## Tributaries to Totten Inlet

Totten Inlet is located on the boundary of Mason and Thurston counties. The mouths of Kennedy and Schneider creeks are located in Mason County, while the rest of Kennedy and Schneider creeks and all of Burns and Pierre creeks are located in Thurston County (Figure 1). The total Totten Inlet watershed area is approximately 69.2 square miles.

Although the mouth of Kennedy Creek and a small portion thereof is in Mason County, most of the Kennedy Creek watershed is in Thurston County. Kennedy Creek is one of the highest chum producing streams in Washington State (Washington Department of Fish and Wildlife 2000), but has lower instream summer flows, relative to other streams in the Kennedy-Goldsborough watershed (see Figure 1), due to the basalt rock formations in the Black Hills area (EnviroVision, 2003). The Kennedy Creek subbasin contains the Black Hills portion of Water Resources Inventory Area (WRIA) 14. The average annual precipitation in the watershed is approximately 75 inches. The Kennedy Creek subbasin has 3 farms and 21 on-site sewage systems (Seiders, 1999).

Based on the October 2005 Thurston County parcel database, Kennedy Creek basin has a drainage area of 15.43 square miles with 3% roads, 0% agricultural, 49% forestry, 4% residential, 0.1% commercial, 41% undeveloped residential, and 3% other land uses (Calahan, 2005). Kennedy Creek is approximately 9.6 miles long and is by far the largest tributary to Totten Inlet (Williams et al., 1975). The creek originates in the Black Hills and descends gradually to lowlands. With the exception of a series of falls, cascades, and log jams at river mile 2.5, the rest of the creek is rather gentle in slope (Thurston County, 2004). It discharges to the head of Totten Inlet. The Green Diamond timberland on Kennedy Creek extends from the public fish viewing area (about a mile upstream of the mouth of Kennedy Creek) to below the mouth of the tributary that drains Summit Lake into Kennedy Creek. The Green Diamond timberland is covered by a habitat conservation plan (HCP) (Cleland et al., 2000) which addresses water quality standards within Green Diamond timberlands.

Schneider Creek is located in Thurston County except for the mouth which is in Mason County. Schneider Creek is approximately 5.3 miles long and the next largest tributary to Totten Inlet. It originates in Schneider Prairie and flows north-northeast and then follows Highway 101 to the head of Totten Inlet. The terrain is flat with pastures and forest land, and the stream gradient is gentle throughout its length (Thurston County, 2004). Based on the October 2005 Thurston County parcel database, Schneider Creek basin has a drainage area of 8.2 square miles with 3% roads, 5% agriculture, 28% forestry, 17% residential, 0.2% commercial, 46% undeveloped residential, and 0.4% other land uses (Calahan, 2005). In 1999, the subbasin had 21 farms and 118 on-site sewage systems (Seiders, 1999).

Both Burns and Pierre creeks are located within Thurston County. The drainage areas for Burns and Pierre creeks are 0.26 and 0.16 square miles, respectively. Based on the October 2005 Thurston County parcel database, Burns Creek basin includes 5% roads, 10% agriculture, 0% forestry, 69% residential, 0% commercial, 15% undeveloped residential, and 0.1% other land uses (Calahan, 2005). Pierre Creek basin includes 5% roads, 31% agriculture, 0% forestry, 45% residential, 0% commercial, 17% undeveloped residential, and 3% other land uses

(Calahan, 2005). In 1999, there were an estimated 3 farms and 13 on-site sewage systems in Burns subbasin, and 2 farms and 9 on-site sewage systems in Pierre subbasin (Seiders, 1999).

## Tributaries to Eld Inlet

The two major tributaries to Eld Inlet are McLane Creek and Perry Creek, both draining into Mud Bay, at the upper end of Eld Inlet. The total Eld Inlet watershed area is approximately 35.8 square miles.

McLane Creek is located within Thurston County (see Figure 1). McLane Creek is the largest tributary and is 14.5 miles long and is located in WRIA 13 (Deschutes watershed). McLane Creek originates in the Alpine Hills area and flows through fairly level terrain, including wooded areas and open pastures (Thurston County, 2004). Based on the October 2005 Thurston County parcel database, McLane Creek basin has a drainage area of 11.41 square miles which includes 1% roads, 2% agriculture, 2% forestry, 20% residential, 0% commercial, 62% undeveloped residential, and 1% other land uses (Calahan, 2005). As of 2002, the subbasin had 43 farms with 142 wet-season animal units, and 295 on-site sewage systems. The number of farms, animal units, and on-site sewage systems are the highest of all subbasins in the Totten-Eld watershed (Batts and Seiders, 2003).

Perry Creek is within Thurston County, and discharges into the headwaters of Eld Inlet near Highway 101 (see Figure 1). Perry Creek is 4.5 miles long and is located in WRIA 14 (Kennedy-Goldsborough watershed) along the border with WRIA 13. Perry Creek originates in wetlands and flows through a forested area. It winds through a gentle, rolling rural/residential area before dropping through wooded ravines (Thurston County, 2004). Based on the October 2005 Thurston County parcel database, Perry Creek basin has a drainage area of 6.33 square miles which includes 4% roads, 1% agriculture, 7% forestry, 16% residential, 0% commercial, 68% undeveloped residential, and 3% other land uses (Calahan 2005). As of 2002, the subbasin had 8 farms with 44.3 wet-season animal units, and 57 on-site sewage systems (Batts and Seiders, 2003).

## Tributaries to Little Skookum Inlet

The Little Skookum Inlet watershed encompasses a small finger of bay branching from the northwest side of Totten Inlet in southeastern Mason County (Figure 1). Total watershed area is approximately 30.78 square miles (Taylor, 1999) and includes several major tributaries of which Skookum Creek, with nine miles of mainstem, is the largest and represents the most significant freshwater input to the Inlet. Although the drainage area for the Skookum Creek basin is 23.6 square miles, the gaged part of the basin (gage located near Highway 101 bridge) represents 16.32 square miles. The Little Creek component of the basin which feeds into Skookum Creek (downstream of the gage) is 1.88 square miles, and the Clary Creek subbasin comprises 0.75 square miles. The total basin area for these components is therefore a total of 18.95 square miles.

Skookum Creek originates from perennial springs near Stimson Station on the Northern Pacific Railroad close to the Mason County line and from wetlands on the ridgetop of the north side of the valley. Although the headwaters and tributaries drain the steep ridges of the Black Hills, most of mainstem Skookum Creek meanders in a northeasterly direction through a wide, alluvial valley. In several places, the channel appears to be incised within the sediments of the valley floor. A well-developed estuary has formed at the mouth of the creek, and is dominated by estuarine emergent wetlands with deep pools that offer good transitional habitat for juvenile salmon (Schuett-Hames and Flores, 1993). Approximately 76 acres of this estuary have been incorporated into a Natural Area Preserve managed by the state Department of Natural Resources (Freidman, 1988). The mean annual discharge based on data from USGS gage (three miles upstream of mouth) between 1951 and 1958 is 54 cfs (Taylor, 1999), and the maximum elevation is 1575 feet (Schuett-Hames et al., 1996). This is the latest land-use data available for this watershed (Kenny, 2006).

Land use in the Little Skookum Inlet watershed is dominated by commercial forestry, with less substantial portions dedicated to marine aquaculture and small agricultural operations. Lands owned by the Squaxin Island Tribe lie both in Kamilche Valley and in the uplands above the inlet. A tribal casino and trading post, and a small commercial strip along Highway 101, constitute the most concentrated commercial areas in the watershed. In 1999, land uses in the Little Skookum Inlet watershed included approximately 75.4% forest, 20% residential, 4% agriculture, 0.2% industrial, and 0.5% commercial (Taylor et al., 1999). This is the latest land-use data available for this watershed (Kenny, 2006).

Intensive ground surveys in 1984-85 identified four farms, including one on Skookum Creek at RM 1.2, one on lower Hurley Creek (now sold for development), and one on Clary Creek. A pigpen located over a small, unnamed tributary to Skookum Inlet was also implicated. Although priority farms have been designated by the Mason County Conservation District and farm plans developed with local landowners, grant funding for these projects has ended, and so, consequently, has the BMP implementation work.

Failing on-site sewage systems have also been consistently implicated for contributing to high fecal coliform concentrations in the Inlet. Intensive surveys in 1984-1985 identified 13 failing on-site sewage systems, or 5.9% of the 237 inspected. All were later repaired. Most of the failed on-site sewage systems were more than ten years old and appeared to be different systems than those found failing in a 1979 sanitary survey, suggesting that system repairs had occurred within the previous six years. The 1992-95 survey located a few homes with failing on-site sewage systems, all of which were repaired as of 1995.

The Washington Administrative Code (WAC), Chapter 173-514-030, establishes a minimum instream flow of 3.0 cubic feet per second (cfs) for Skookum Creek between July 15 and October 1, although this standard is seldom met. As a result, Ecology has closed Skookum Creek watershed for further surface water appropriation from May 1 through October 31 as specified in WAC 173-514-030(2).

# Sources of Fecal Coliform Bacteria

## Nonpoint Sources

The sources of fecal coliform bacteria in the Totten-Eld watershed are generally nonpoint in nature. Examples of nonpoint sources are failing on-site sewage systems, livestock operations, hobby farms, urban areas, wildlife, and recreational uses. Documented anthropogenic (human-related) sources of bacterial pollution in the Totten-Eld watershed include failing on-site sewage systems and small-farm livestock keeping practices (Hofstad, 1993). Potential human-related sources of fecal coliform bacteria in Skookum Creek include livestock and on-site sewage systems (Taylor, 1999) with animal waste being by far the largest contributor to high fecal coliform concentrations (McNichols, 1986).

Totten and Eld inlets have an estimated 513 on-site sewage systems (Seiders, 1999). Little Skookum Inlet has in excess of 237 on-site sewage systems with the largest on-site sewage system associated with the Squaxin Tribe's Little Creek Casino built in 1995 (Taylor, 1999). When on-site sewage systems are constructed over soils that are not well drained (e.g., very sticky clay soils), sewage can overflow onto the soil around drain fields and reach nearby streams during storm events. Saturated soils also cause poor drainage resulting in overflow of drainfields. Poor maintenance can also result in septic system failures. Understanding and caring for on-site sewage systems (www.co.thurston.wa.us/health/ehoss/maintenance.html) are important in preventing system failures. Figure 2 shows the location of on-site sewage systems along a 500-ft buffer on both sides of tributaries to Totten and Eld inlets (Calahan, 2005).

Runoff from livestock operations and hobby farms can also contribute fecal coliform bacteria to streams. Tributaries to Totten and Eld inlets have an estimated 85 farm sites with 293 animal units (1 animal unit = 1000 lbs) (Seiders, 1999). Hobby farms are also located on Skookum Creek and its tributaries (Clary and Hurley Waldrup creeks) (Taylor, 1999). Table 2 gives a break out of farms and animal units as obtained from Seiders (1999) for stream subbasins studied in the National Monitoring Program.

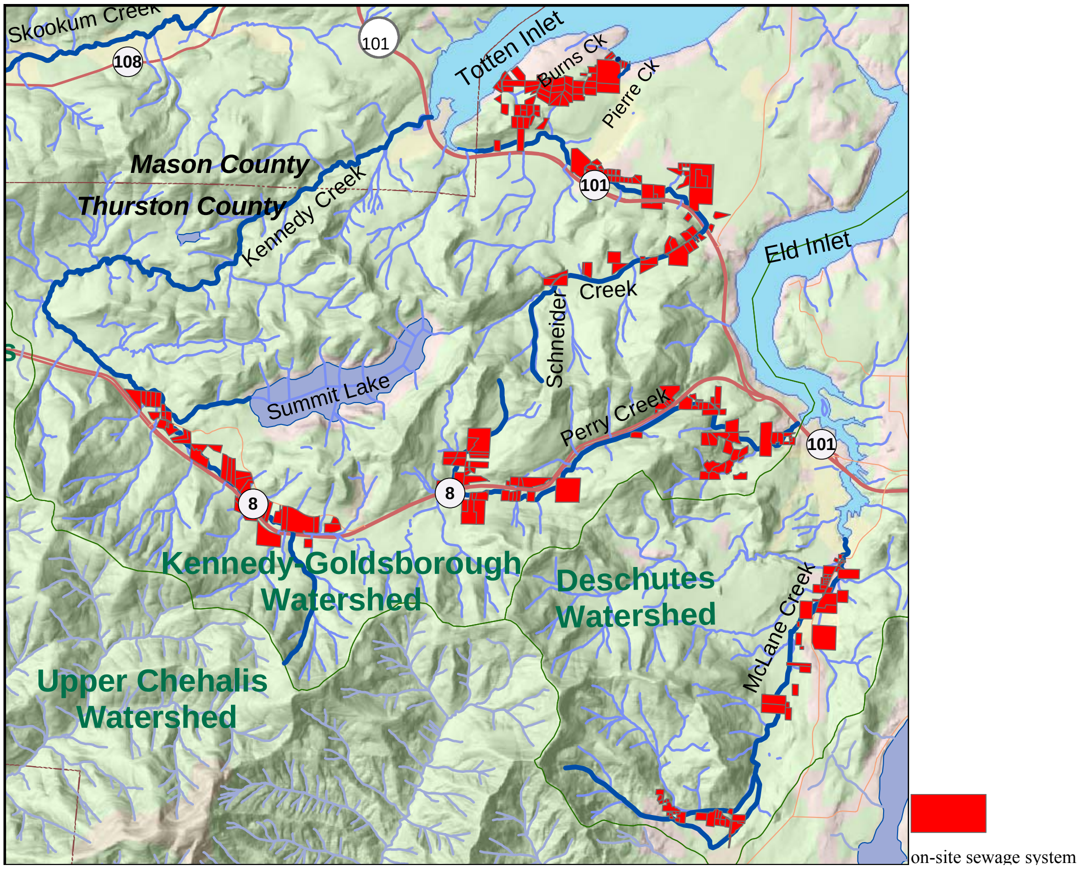


Figure 2. Parcels with on-site sewage systems within 500 feet of tributaries to Totten and Eld inlets.

Table 2. Number of on-site sewage systems, farms, BMPs, and animal units in each subbasin within Totten and Eld inlets (Seiders, 1999).

| Basin Characteristics | Kennedy | Schneider | McLane | Perry | Burns | Pierre |
|---|---|---|---|---|---|---|
| Number of on-site sewage systems | 21 | 118 | 295 | 57 | 13 | 9 |
| Number of farms in the basin | 3 | 26 | 43 | 8 | 3 | 2 |
| Number of BMPs implemented | 0 | 39 | 80 | 22 | 26 | 13 |
| Animal units | 1 | 93 | 142 | 44.3 | 7.6 | 5 |

Runoff from residential areas is known to have fecal coliform bacteria (EPA, 1983), primarily due to poorly managed pet waste and natural sources such as birds and other animals.

Where a majority of the watershed is forested, wildlife can be a source of fecal coliform bacteria. Using DNA typing method, Thurston County found that in rural creeks, fecal coliforms from birds, deer, canines (e.g., coyotes, dogs, foxes) and rodents were the source of fecal coliforms, while dogs and humans were found to be the likely source in an urban creek (www.co.thurston.wa.us/shellfish/pdf/dna_qa2.pdf ).

In certain cases, elevated coliform bacteria counts have been associated with recreational use of waterbodies. Sobsey (2003) found elevated levels of coliform bacteria at a marina, compared to a non-boating site over the Labor Day weekend. It is therefore likely that recreational uses (e.g., fishing, boating, swimming) may contribute coliform bacteria to the streams.

Nonpoint source fecal coliform reductions are achieved primarily by implementing a number of practices – such as restricting farm animals from waterbodies, proper manure storage practices, regular septic system maintenance, and pasture rotation – collectively called "best management practices" or BMPs.

BMPs have been implemented in the Totten and Eld watershed, including structural BMPs such as fencing and provision for water troughs, and managerial BMPs such as livestock exclusion and nutrient management (Seiders, 1999; Batts and Seiders, 2003). However, no known BMPs were implemented for the three farms in the Kennedy Creek basin (Seiders 1999). BMP implementation in Schneider Creek basin showed consistent reduction in fecal coliforms in the post-BMP period, while the reductions were not as significant or consistent in other basins (Batts and Seiders, 2003). However, the BMPs in the watersheds were not effective in reducing bacteria concentrations to water quality standards, likely due to project incompletion and non-participation in some instances, and improper or inadequate BMP operations and maintenance in other instances (Batts and Seiders, 2003).

Data included in the technical analysis in this report were generally limited to post-BMP periods only. However, data older than ten years were used only when (1) there was no significant difference in fecal coliform concentrations between pre-and post-BMP periods (as obtained from Batts and Seiders, 2003) *and* (2) additional data were needed to meet the minimum ten data set requirement for technical analysis.

## Point Sources

The watershed is traversed by three major highways. Highway 101 crosses north-south over Perry, Schneider, Kennedy, and Skookum creeks. Highway 8 runs east-west crossing Kennedy and Perry watersheds and connecting with Highway 101 near the mouth of Perry Creek. Highway 108 runs northeast-southwest along Skookum Creek connecting with Highway 101 near the mouth of Skookum Creek. There are several roadside storm drains along Highway 101 (see Figure 1) that belong to Washington State Department of Transportation (WSDOT) that discharge to Schneider and Perry creeks. An inventory of stormwater outfalls along highways in Washington is available at
http://www.wsdot.wa.gov/mapsdata/geodatacatalog/Maps/24k/DOT_EAO/outfall.htm.

The national stormwater quality database (Pitt et al., 2004) shows that runoff from freeways across the nation had a median fecal coliform concentration of 1700 cfu/100 mL. In Washington, WSDOT collected samples between December 2004 and April 2005 to measure fecal coliform in stormwater flowing onto highway right-of-ways from adjacent properties, untreated highway runoff, and treated runoff (White, 2005).

Figure 3 shows a re-evaluation of data from this study. The number in parenthesis in each category represents the respective data points. Data points from the same day were averaged.

Washington State water quality standards for fecal coliform bacteria shown in Figure 3 corresponds to a geometric mean of 50 cfu/100 mL and no more than 10% of the samples exceeding 100 cfu/100 mL. Both untreated highway run-off and untreated highway run-on had high fecal coliform bacteria. While not specifically designed to remove fecal coliform bacteria, limited data from existing stormwater BMPs showed that the treated WSDOT runoff generally met the first part of the two-tiered water quality standard for fecal coliform bacteria (White, 2005). However, the second part of the water quality standard (i.e., no more than 10% of the samples shall exceed 100 cfu/100 mL) was not met in any of the stormwater types tested except for the pond outlet on SR-525. The degree of reductions provided by the BMPs is not conclusive given the limited data set.

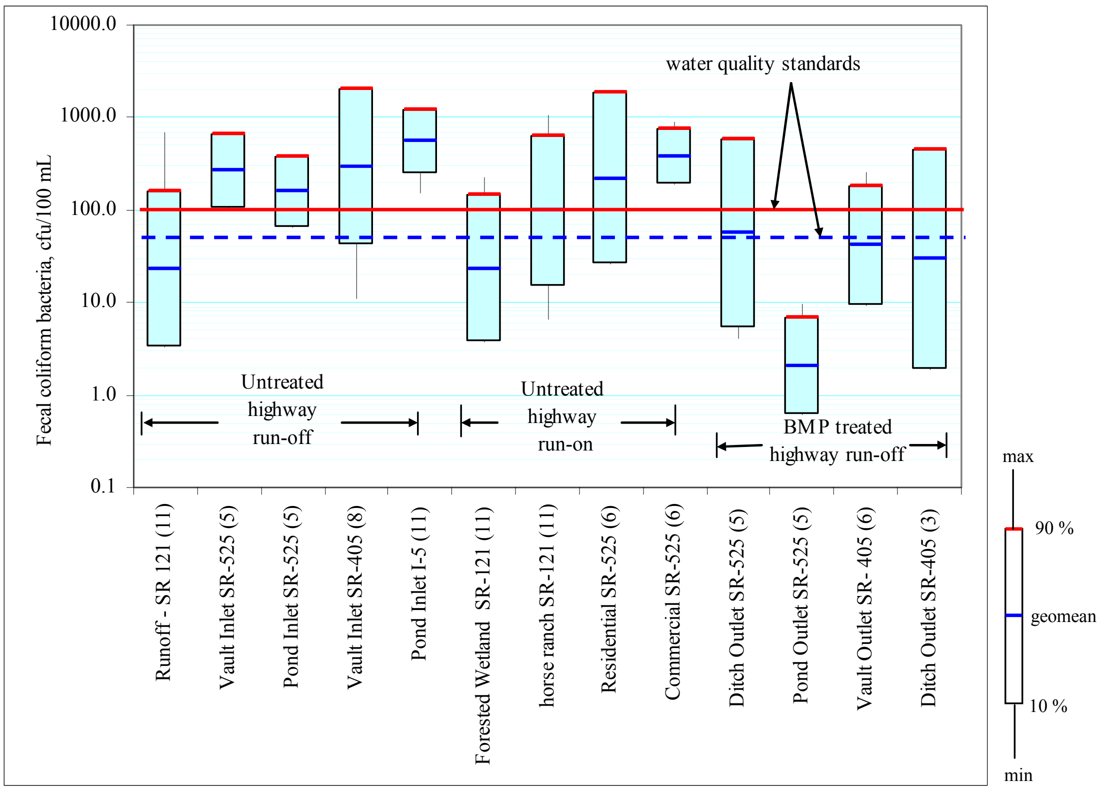


Figure 3. Fecal coliform concentrations in runoff entering WSDOT right-of-ways, coming off WSDOT pavement, and after treatment (data adapted from White, 2005).

WSDOT is required by state and federal regulations to have a stormwater permit in areas covered by Phase I and Phase II of the municipal stormwater permit program. The permit will cover stormwater runoff from state highways, rest areas, scenic viewpoints, park-and-ride lots, ferry terminals, and maintenance facilities. This permit will replace WSDOT's coverage under the current Phase I general permit.

The actual geographic scope of the permit is under discussion, and may be statewide (Szvetecz, 2006). If WSDOT discharges are not within a permitted area, sources will be considered nonpoint, and required actions will be addressed on a project-specific basis.

The target date for issuance of the new permit and approval of the WSDOT Stormwater Management Program is late fall 2006.

# Causes of Elevated Stream Temperature

Agriculture and forestry are perhaps the biggest influences on riparian vegetation along mainstem Skookum Creek where extensive removal of vegetation has occurred for agricultural purposes (Taylor et al., 1999). Local riparian vegetation removal reduces the amount of shortwave radiation absorbed by leaves in the canopy, which increases the incident shortwave radiation to the stream. These disturbances result in elevated temperatures that propagate downstream.

As the amount of water in the stream decreases, the volume of water capable of absorbing the heat decreases and temperature increases. Thus, stream temperatures are higher in shallow water than in deeper water. Shallow waters may be caused either by disruption of stream hydrology (resulting in low flows) or disruption of geomorphic processes (resulting in widening of the stream channel). In stream segments where riparian vegetation density approaches pre-settlement levels, segment width, depth, and length become important in establishing the extent of shading in the stream.

The capacity for temperature reduction in a stream also decreases if either the volume of groundwater inflow to the stream or the volume of mixed surface/groundwater that recirculates through the gravel bed is reduced.

Sedimentation of streams may also contribute to elevated water temperatures. Sediment can fill pools and cause the width-to-depth ratio of a stream to increase, which can facilitate heat exchange (Poole and Berman, 2000). Hagans et al. (1986) reported that sedimentation caused stream temperatures to increase, as dark-colored fine sediment replaced lighter-colored course gravels. The darker sediment stored more solar radiation.

Fine sediment may block exchange between surface waters and intragravel flows, also contributing to warming. In a 1993 survey of a short segment of upper Skookum Creek, substrate composition rated 'fair' on the Timber-Fish-Wildlife scale for the percent of sediment fines less than 0.85 mm (Schuett-Hames et al., 1996). A major source of fine sediment may be the extensive natural and human-induced bank erosion observed along Skookum Creek (Flores et al., 1991). As the creek has downcut through the fine silty soils that comprise the valley floor, it has created over-steepened banks, a situation further exacerbated by unrestricted livestock access to the creek, and removal of riparian vegetation and the subsequent root mass that once stabilized the soil. Flores and his colleagues documented over six miles of eroding banks in Skookum Creek, including the area sampled in the 1993 assessment (Schuett-Hames et al., 1996). Eroding banks threaten existing riparian vegetation and limit proliferation of new vegetation.

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# Applicable Criteria

## Fecal Coliform Bacteria

The water quality standards for Washington State (WAC 173-201A-140) designate Totten and Little Skookum inlets and its tributaries (i.e., west of longitude 122˚ 56′ 32″) as Class AA. This classification is for waters of "extraordinary" quality; the fecal coliform standard for freshwater calls for a geometric mean not to exceed 50 colony forming units (cfu) /100 mL with no more than 10% of samples greater than 100 cfu/100 mL. The characteristic beneficial uses designated for protection under this classification are: water supply; stock watering; fish migration; fish and shellfish rearing, spawning and harvesting; wildlife habitat; primary contact recreation; and commerce and navigation.

The water quality standards designate Eld Inlet and its tributaries (i.e., west of longitude 122˚ 56′ 32″) as Class A. This classification is for 'excellent' waters; the fecal coliform standard calls for a geometric mean not to exceed 100 cfu /100 mL with no more than 10% of samples greater than 200 cfu/100 mL. The characteristic beneficial uses designated for protection under this classification are: water supply; stock watering; fish migration; fish and shellfish rearing, spawning and harvesting; wildlife habitat; primary contact recreation; and commerce and navigation.

The new water quality standards rule (WAC 173-201A), as adopted on July 1, 2003 (not yet approved by EPA), designates Totten and Little Skookum inlets (i.e., to the west of longitude 122 56'W) as having an extraordinary quality with primary contact recreational use and shellfish harvesting. As per Table 600 of the new rule, all tributaries to these waterbodies have an extraordinary primary contact recreational use, with the fecal coliform standard of a geometric mean not to exceed 50 cfu /100 mL with no more than 10% of samples greater than 100 cfu/ 100 mL. Eld Inlet lies to the west of longitude 122˚ 52′ 30″ and has been designated as having excellent quality with primary recreation and shellfish harvesting. All tributaries to Eld Inlet have a primary contact recreational use, with the fecal coliform standard of a geometric mean of not to exceed 100 cfu /100 mL with no more than 10% of samples greater than 200 cfu/100 mL. Therefore, the new rule, in essence, does not change the water quality criteria for fecal coliform bacteria for these waterbodies. Table 3 summarizes the water quality standards for the tributaries considered in this report.

Table 3. Classification of tributaries to Totten-Eld-Little Skookum inlets.

| Inlets | Tributary | Classification | Fecal Coliform Standard, cfu/100 mL | |
|---|---|---|---|---|
| | | | ≤ geometric mean | ≤ 10% samples exceeding |
| Totten Inlet | Kennedy Creek | Class AA | 50 | 100 |
| | Schneider Creek | Class AA | 50 | 100 |
| | Burns Creek | Class AA | 50 | 100 |
| | Pierre Creek | Class AA | 50 | 100 |
| Little Skookum Inlet | Skookum Creek | Class AA | 50 | 100 |
| Eld Inlet | McLane Creek | Class A | 100 | 200 |
| | Perry Creek | Class A | 100 | 200 |

## Temperature

Skookum Creek is a Class AA waterbody. The temperature standard for Class AA freshwater is a daily maximum of 16°C, with a 0.3°C degradation allowed if natural conditions are in excess of 16°C. When stream temperatures are below the criterion, incremental temperature increases resulting from nonpoint source activities shall not exceed 2.8°C nor cause the stream temperature to exceed the criterion (WAC 173-201A-030 (1)).

Washington State has adopted a new rule on water quality standards (WAC 173-201A) as of July 2003. Based on relevant designated uses in WAC-173-201A-600 (i.e., salmon and trout spawning, core rearing, and migration; and extraordinary primary contact recreation) and the aquatic life temperature criterion in Table 200(1)(c) (WAC-173-201A-200), the temperature standard for Skookum Creek is a 16°C as a 7-day average of daily maximum temperatures (7-DADMax), with a 0.3°C degradation allowed if natural conditions are in excess of 16°C. When stream temperatures are below the criterion, incremental temperature increases resulting from nonpoint source activities shall not exceed 2.8°C nor cause the stream temperature to exceed the criterion. These revised standards are still being reviewed by EPA.

To help understand the potential of the watershed to provide cool water, natural conditions in this TMDL have been estimated under a scenario where the system is modeled with full potential riparian vegetation and at critically low river flows and critical warm weather conditions. This modeling condition is referred to as the "system potential temperature".

# Allowable Loads for Fecal Coliform Bacteria

Establishment of allowable loads for fecal coliforms for the tributaries is based on an analysis of historical and recent field data obtained from Ecology's Environmental Information Management database (www.ecy.wa.gov/eim/), the Squaxin Island Tribe (Konovsky, 2004), the Thurston County Environmental Health Division database (www.geodata.org/swater/swdata.html; Davis, 2004; Davis, 2005), and Mason County (Kenny, 2004).

## Methods for Computing Load Reductions

Excel® spreadsheets were used to evaluate the data, including statistical analyses and plots.

The statistical roll-back method (Ott, 1995) was employed to establish fecal coliform bacteria reduction targets for the mainstem segments and the tributaries and sub-tributaries. This method has been previously employed by Sargeant et al. (2005), Ahmed (2004a, 2004b), Roberts (2003), Joy (2000), and Pelletier and Seiders (2000).

The roll-back method assumes that the distribution of fecal coliform bacteria concentrations measured at a station over time follows a log-normal distribution. Thus, log-normal distribution properties can be used to estimate the geometric mean and 90th percentile bacterial concentrations. When these estimates are higher than the standards, the target reductions are simply estimated by rolling back the estimated geometric mean or 90th percentile concentrations (whichever is most restrictive) to the respective water quality standards. Here is how the process works:

a) The data are first plotted on a log-scale against a linear cumulative probability function; a straight line signifies a log-normal distribution of the data.

b) The geometric mean of the data has a cumulative probability of 0.5. Alternately, the geometric mean can be estimated by the following formula:

$$\text{geometric mean} = 10^{(\mu_{\log})}$$

where: $\mu_{\log}$ = mean of the log transformed data

c) The 90th percentile of the data has a cumulative probability of 0.9. This is equivalent to the "no more than 10% samples exceeding …." criterion in the fecal coliform standard (WAC 173-201A). Alternately, the 90th percentile can also be estimated by using the following statistical equation:

$$90^{\text{th}} \text{ percentile} = 10^{(\mu_{\log} + 1.281552\sigma_{\log})}$$

where: $\sigma_{\log}$ = standard deviation of the log transformed data

d) The target percent reduction required is the higher of the following two comparisons.

$$\left[\frac{\text{observed } 90^{\text{th}} \text{ percentile} - 90^{\text{th}} \text{ percentile standard}}{\text{observed } 90^{\text{th}} \text{ percentile}}\right] x100$$

or: $$\left[\frac{\text{observed geometric mean} - \text{geometric mean standard}}{\text{observed geometric mean}}\right] x100$$

e) As "best management practices" for nonpoint sources and treatment technologies for point sources are implemented and the target reductions are achieved, a new but similar distribution (same coefficient of variation) of the data is assumed to be realized with the previous mean and standard deviation reduced by the target percent reductions.

f) If the $90^{th}$ percentile is limiting, then the goal would be to meet the $90^{th}$ percentile fecal coliform standard (either 100 cfu/100 mL or 200 cfu/100 mL), and no goals would be set for the geometric mean since, with the implementation of the target reductions, the already low geometric mean (<50 cfu/100 mL or <100 cfu/100 mL)) would only get better. Similarly, if the geometric mean is limiting, the goal would be to achieve the geometric mean standard with no goal for the already low $90^{th}$ percentile concentration.

For presentation of the technical analysis, the study area has been divided into three inlets which will be discussed in the order listed below:

1. Tributaries to Totten Inlet
2. Tributaries to Eld Inlet
3. Tributaries to Little Skookum Inlet

# 1. Tributaries to Totten Inlet

## Kennedy Creek

Under the National Monitoring Program (Batts and Seiders, 2003), Kennedy Creek was monitored over ten years (1992-2002) by Ecology and Thurston County at a location 125 meters upstream of the Old Olympic Highway bridge. The location of this station is shown in Figure 4. Thurston County collected additional data prior to 1992 and following 2002 (www.geodata.org/swater/summaryaa.asp?site=TOTKE0000). Additional data were also collected at this station by Mason County in 2003 and 2004 (Appendix A).

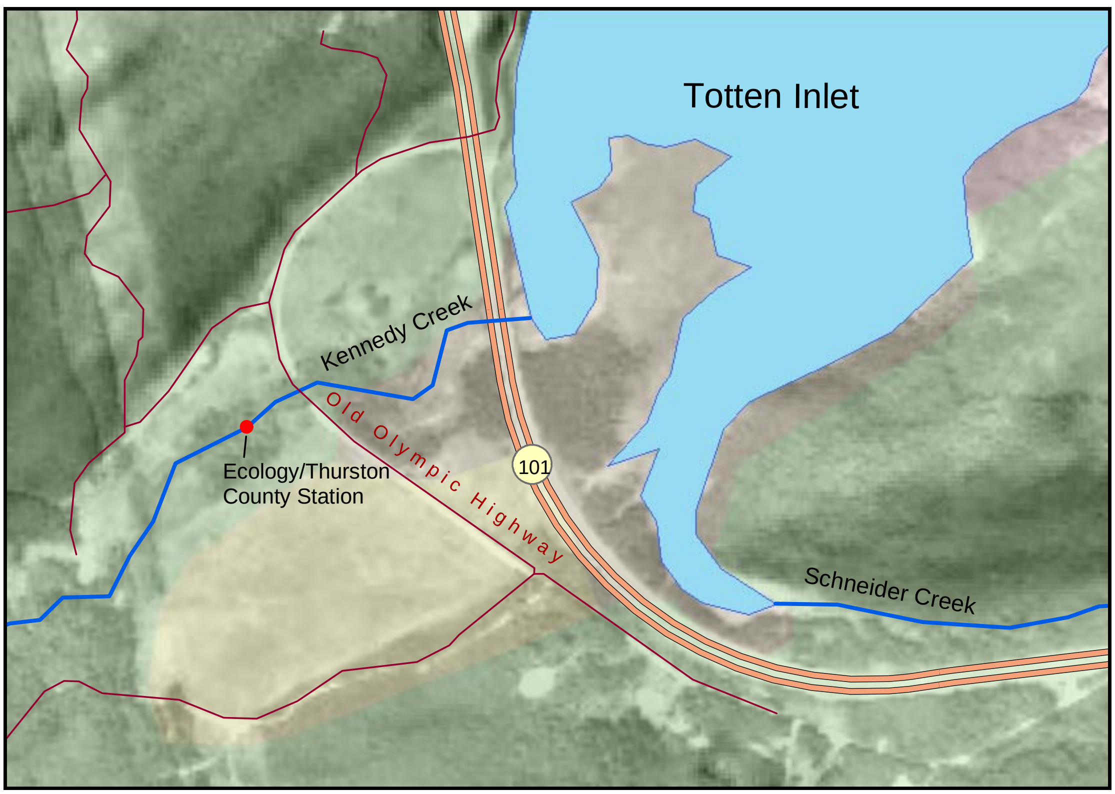


Figure 4. Ecology and Thurston County sampling station.

Fecal coliform data for Kennedy Creek showed no significant year-to-year trend during the ten-year (1992-2002) fecal coliform monitoring period under the National Monitoring Program, even when Thurston County data for the prior years (1986-1991) were added (Batts and Seiders, 2003).

Figure 5 shows the monthly pattern of flows and fecal coliform concentrations based on data collected between 1995 and 2005. Flows measured during this period were averaged for the respective months. Most of the fecal coliform bacteria exceedances occurred in the late summer/early fall months when flow was the lowest.

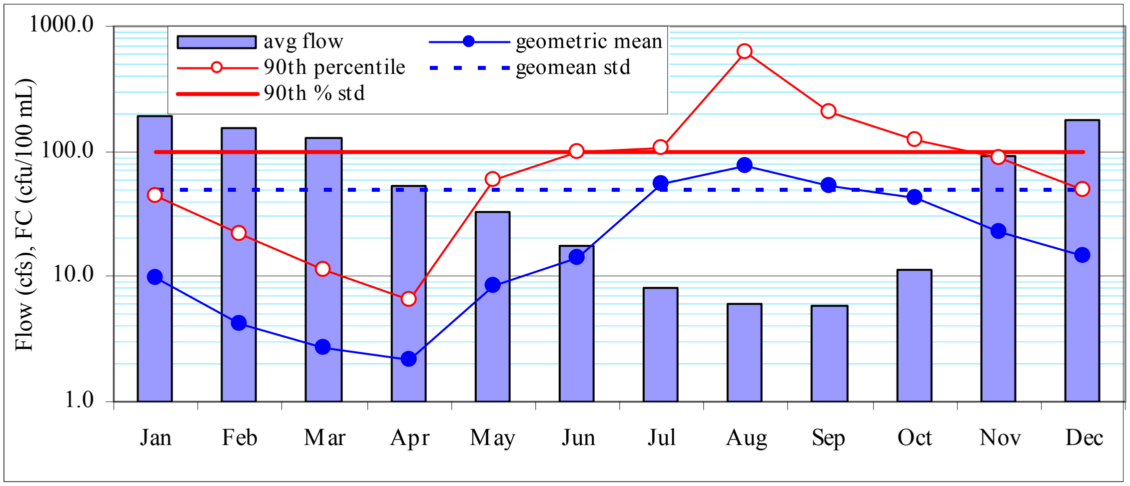


Figure 5. Flows and fecal coliform concentrations in Kennedy Creek (1995-2005).

Figure 6 shows the pattern of fecal coliform concentrations for all months between January 1995 and July 2005. The numbers in parentheses are the number of data points for each month. The least number of data were collected in July (n = 10), and the most data were collected in January (n = 40). Most of the exceedances of water quality standards occurred in August, September, and October, with August being the highest.

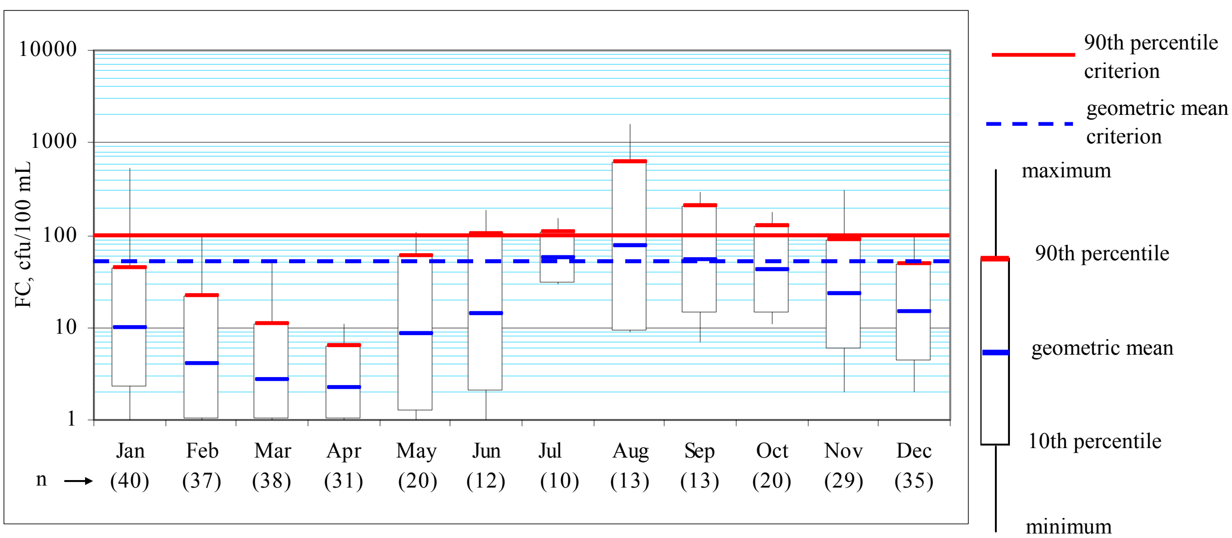


Figure 6. Monthly fecal coliform bacteria patterns in Kennedy Creek (1995-2005).

In order to estimate a target reduction in fecal coliform concentrations, the data from August and September were combined due to similarity in average flows. The long-term 90$^{th}$ percentile and geometric mean for the combined months of August and September (only 1995-2004, no data available for 2005) were 365 cfu/100 mL and 63 cfu/100 mL, respectively. The limiting percent reduction is therefore 73% based on the 90$^{th}$ percentile concentrations (Table 4). With an average flow of 6 cfs in August and September, the allowable loading in this period, based on meeting the 90th percentile standard at the designated location (125 meters upstream of the Old Olympic Highway bridge), is 1.47 x $10^{10}$ cfu/day.

Table 4. Target fecal coliform reductions in Kennedy Creek (1995-2005).

| Location | Period | Number of samples | Geometric mean (cfu/100 mL) | 90th percentile (cfu/100 mL) | Limiting basis for reduction | Target reduction (%) |
|---|---|---|---|---|---|---|
| 125 meters above Old Olympic Highway bridge | Aug-Sept | 26 | 63 | 365 | 90th percentile | 73 |

## Schneider Creek

Under the National Monitoring Program, Schneider Creek was monitored over ten years (1992 -2002) by Ecology (Batts and Seiders, 2003) and since 1988 by Thurston County (www.geodata.org/swater/summaryaa.asp?site=TOTSC0000) off of Highway 101 (Figure 7). A pre- (1988-1993) and post- (1995-1997) evaluation of the effect of watershed-wide BMPs on fecal coliform concentrations showed a decrease in median concentrations, but the difference was not statistically significant (Seiders, 1999). Beyond 1997, the concentrations seem to decrease and then increase, but stayed below the pre-BMP levels. The effects of BMP implementation were somewhat overshadowed by change in ownership of land and changing number of animals. To keep data analyses in the post-BMP period, only the data beyond 1995 were used to set future target reductions (Appendix A).

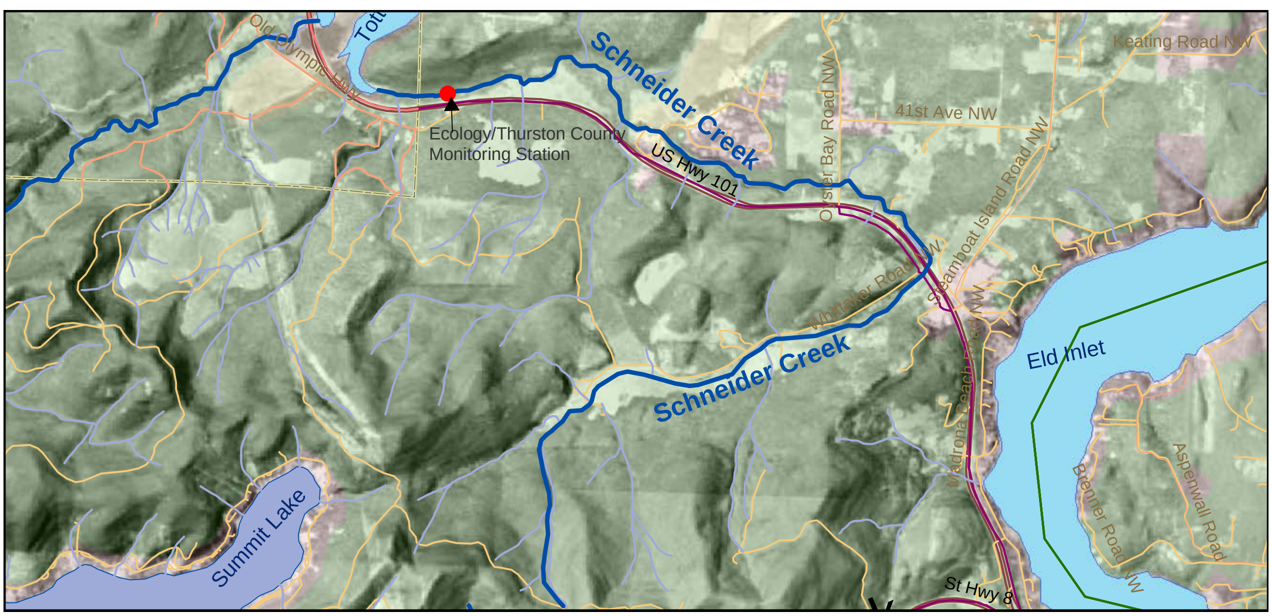


Figure 7. Ecology and Thurston County sampling station in Schneider Creek.

Figure 8 shows the seasonal pattern of flows and fecal coliform concentrations during 1995-2005 based on data collected by Ecology and Thurston County. Flows measured during this period were averaged for the respective months. On a month-to-month basis, the highest bacteria concentrations were observed between May and November. Lowest monthly average flows were observed between July and September.

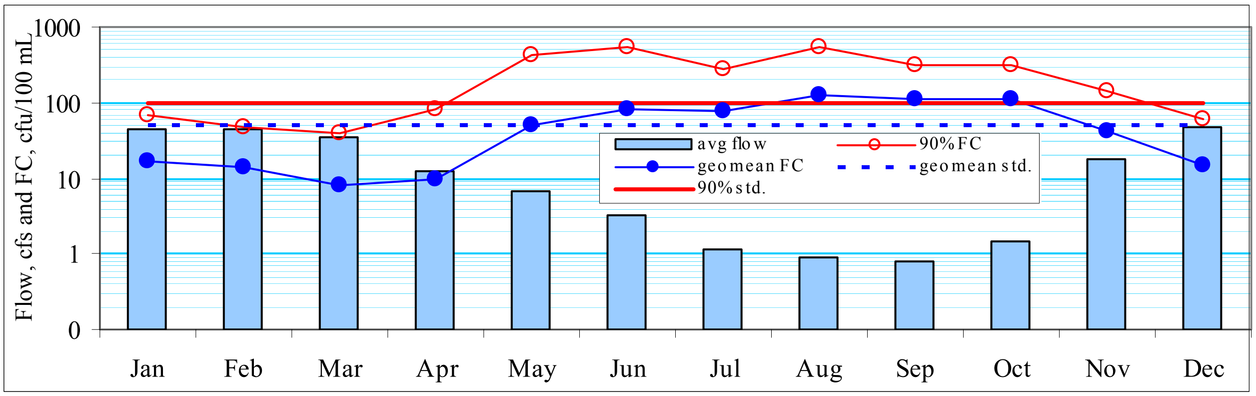


Figure 8. Monthly average flows and fecal coliform concentrations in Schneider Creek (1995-2005).

Figure 9 shows the pattern of fecal coliform concentrations for all months between 1995 and 2005. The numbers in parentheses are the number of data points for each month. Both the geometric mean and the 90$^{th}$ percentile exceeded (did not meet) water quality criteria during June through October, and the 90$^{th}$ percentile also exceeded the criterion in May and November.

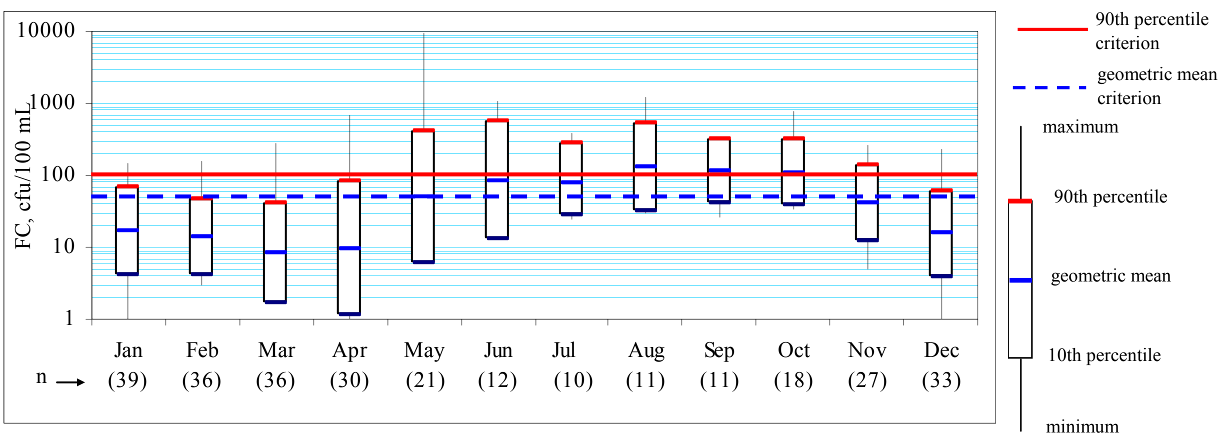


Figure 9. Monthly fecal coliform bacteria patterns in Schneider Creek (1995-2005).

In order to estimate a target reduction in fecal coliform concentrations, the data from July through September were combined due to similarity in average flows. The combined (n = 32) 90$^{th}$ percentile and geometric mean for the July-September period (1995-2005) were 363 and 105 cfu/100 mL, respectively. The percent reduction is therefore 73% based on the 90$^{th}$ percentile concentration needing to meet the water quality standard of 100 cfu/100 mL (Table 5). The loading capacity, based on meeting the 90th percentile standard of 100 cfu/100 mL, and an average flow of 1 cfs during the critical period of July through September, is 2.4 x $10^9$ cfu/day.

Table 5. Target fecal coliform reductions in Schneider Creek (1995-2005).

| Location | Period | Number of samples | Geometric mean (cfu/100 mL) | 90th percentile (cfu/100 mL) | Limiting basis for reduction | Target Reduction (%) |
|---|---|---|---|---|---|---|
| Off Hwy 101, end of Pneumonia Gulch Road | July-Sept | 32 | 105 | 363 | 90th percentile | 73 |

## Burns and Pierre creeks

Under the National Monitoring Program, Burns and Pierre creeks were monitored over ten years (1992 -2002) by Ecology (Batts and Seiders, 2003) and since 1986 by Thurston County (www.geodata.org/swater/summaryaa.asp?site=TOTSC0000) at two locations in Burns Creek: BUR (at mouth on beach, below Oyster Bay Road) and BUR2 (Oyster Bay Road Culvert, 10 meters above BUR); and one location in Pierre Creek (PIE, 80 meters upstream of beach off Oyster Bay Road) (Figure 10). Data are presented in Appendix A. Samples at BUR2 were collected when samples could not be collected at BUR due to high tide. Batts and Seiders (2003) developed a relationship between bacterial concentrations measured at BUR2 and those at BUR. This relationship was used to estimate missing data for station BUR.

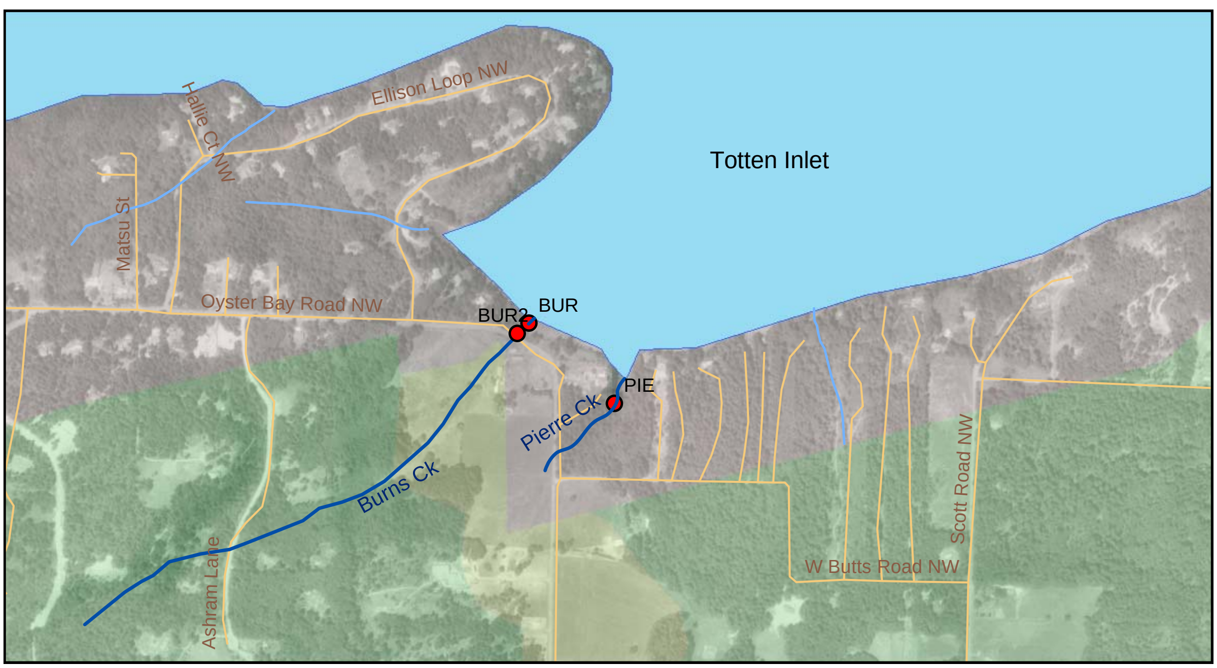


Figure 10. Ecology and Thurston County sampling stations in Burns and Pierre creeks.

A pre- (1989-1993) and post- (1995-1997) evaluation of the effect of watershed-wide BMPs on fecal coliform concentrations showed a decrease in median concentrations for Burns Creek, but the difference was not significant (Seiders, 1999). Beyond 1997, the concentrations appear to have increased. A pre- (1986-1989) and post- (1993-1997) evaluation for Pierre Creek shows a significant increase (375%) in median fecal coliform concentrations (Seiders, 1999). This increase has been attributed to lack of maintenance of existing BMPs, wildlife, and/or climatic effects (Seiders, 1997). To keep data analyses in the post-BMP period, only the data beyond 1995 and 1993 for Burns and Pierre creeks, respectively, were used to set future target reductions.

**Burns Creek**

Figure 11 shows the seasonal pattern of flows and fecal coliform concentrations during 1995-2002 based on data collected by Ecology and Thurston County. Flows measured during this period were averaged for the respective months. Some summer/early fall months were not monitored due to absence of flow in the stream. Bacteria concentrations were the highest during low-flow conditions (Figure 11). Lowest monthly average flows were observed between April and October when the average estimated flows were less than 0.04 cfs.

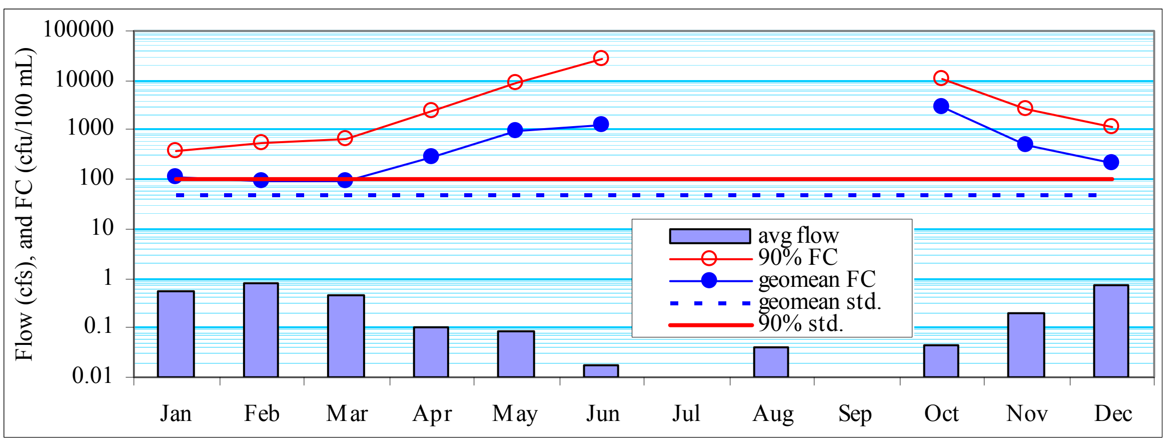


Figure 11. Monthly average flows and monthly geometric mean and 90$^{th}$ percentile fecal coliform concentrations in Burns Creek (1995-2002).

Figure 12 shows the pattern of fecal coliform concentrations for all but three months between 1995 and 2002. The numbers in parentheses are the number of data points for each month. Both the geometric mean and the 90$^{th}$ percentile water quality criteria were exceeded during all the months monitored. Although the fecal coliform geometric mean concentrations were highest in October, there were only four data points. The highest 90$^{th}$ percentile fecal coliform concentration was in June (n = 9), while the highest concentration was observed in May (n = 18). To estimate a target reduction goal, the months of May and June (only 1999-2002, other years did not have any data for these months) were combined (average flow was 0.06 cfs). The target reduction based on these months is approximately 99% (Table 6). Following attainment of this target reduction (i.e., attainment of water quality standards), the bacterial loading would be $1.5 \times 10^8$ cfu/day (at the average flow of 0.06 cfs for May and June).

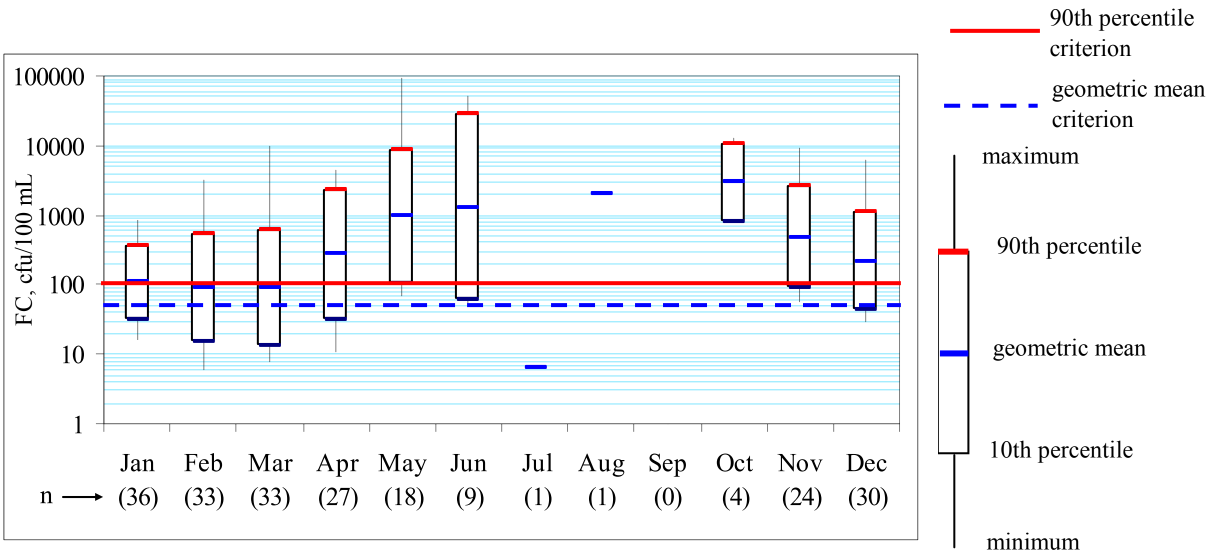


Figure 12. Monthly fecal coliform bacteria patterns in Burns Creek (1995-2002).

Table 6. Target fecal coliform reductions in Burns Creek (1995-2002).

| Location | Period | Number of samples | Geometric mean (cfu/100 mL) | $90^{th}$ percentile (cfu/100 mL) | Limiting basis for reduction | Target reduction (%) |
|---|---|---|---|---|---|---|
| At mouth on beach, below Oyster Bay Road | May-June | 27 | 1052 | 12691 | $90^{th}$ percentile | 99 |

**Pierre Creek**

Figure 13 shows the seasonal pattern of flows and fecal coliform concentrations during 1993-2002 based on data collected by Ecology and Thurston County. Flows measured during this period were averaged for the respective months. Some summer/early fall months were not monitored due to absence of flow in the stream. Bacteria concentrations were the highest during low-flow conditions (Figure 13). Lowest monthly average flows were observed between May and October when the average estimated flows were less than 0.05 cfs.

Figure 14 shows the pattern of fecal coliform concentrations for the months monitored between 1993 and 2002. The numbers in parentheses are the number of data points for each month. The geometric mean water quality criterion was exceeded in May, June, November, and December. The $90^{th}$ percentile water quality criterion was exceeded during all the months monitored, except for July through October when no samples were taken. The highest $90^{th}$ percentile fecal coliform concentration was in June (n = 10), while the highest concentrations were observed in May (n = 17). To estimate a target reduction goal, the months of May and June (only 1999-2002, other years did not have any data for these months) were combined due to very low flows during these months (average 0.03 cfs). The target reduction based on these months is approximately 96% (Table 7). Following attainment of this target reduction (i.e., attainment of water quality standards), the bacterial loading would be $8.2 \times 10^7$ cfu/day (at the average flow of 0.03 cfs for May and June).

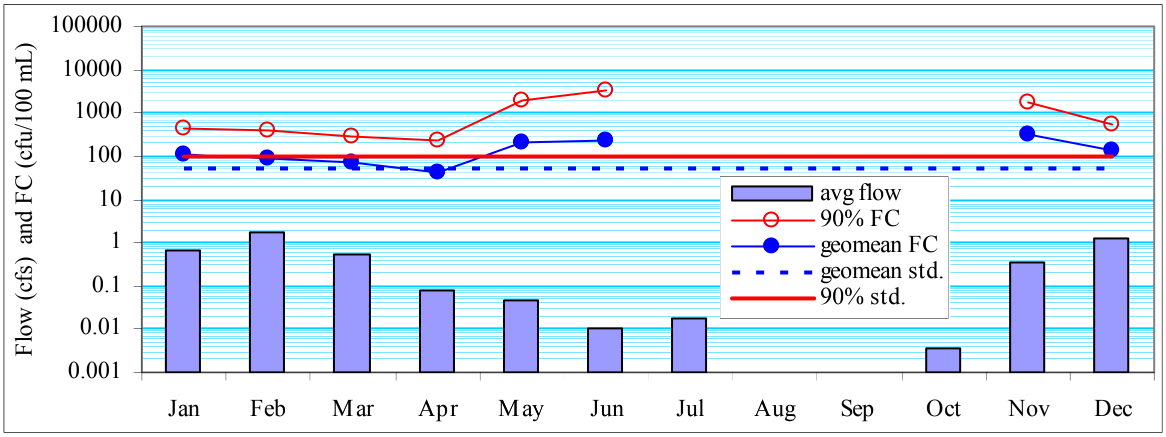


Figure 13. Monthly average flows and monthly geometric mean and 90th percentile fecal coliform concentrations in Pierre Creek (1993-2002).

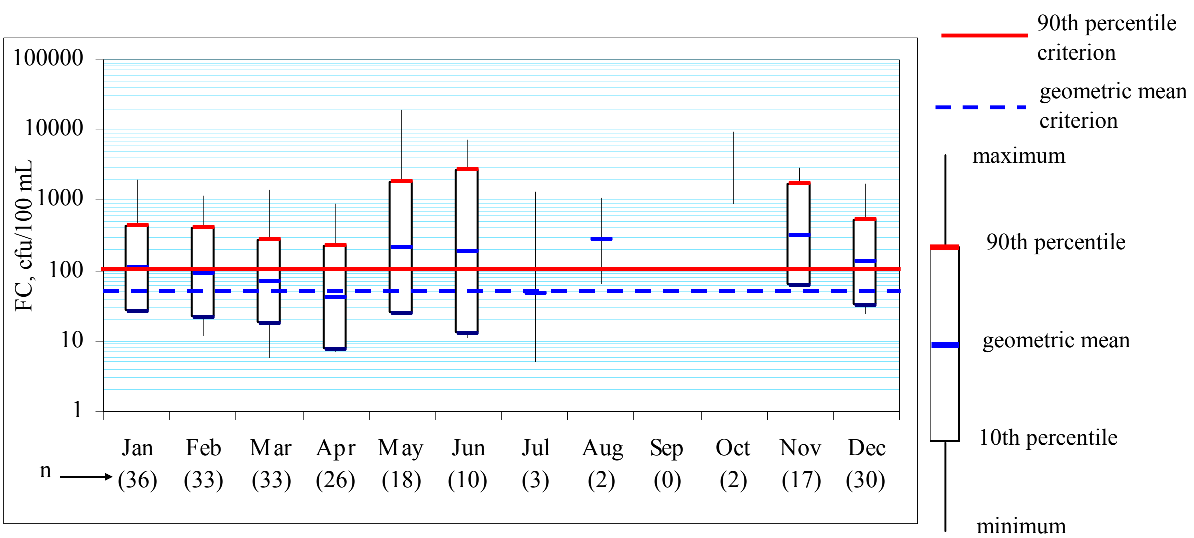


Figure 14. Monthly fecal coliform bacteria patterns in Pierre Creek (1993-2002).

Table 7. Target fecal coliform reductions in Pierre Creek (1993-2002).

| Location | Period | Number of samples | Geometric mean (cfu/100 mL) | 90th percentile (cfu/100 mL) | Limiting basis for reduction | Target reduction (%) |
|---|---|---|---|---|---|---|
| 80 m upstream of beach off Oyster Bay Road | May-June | 28 | 213 | 2,235 | 90th percentile | 96 |

# 2. Tributaries to Eld Inlet

## McLane Creek

Under the National Monitoring Program (Batts and Seiders, 2003), McLane Creek was monitored over ten years (1992 -2002) by Ecology and Thurston County at a location 100 meters downstream of the Delphi Road bridge (Figure 15). Thurston County collected additional data (www.geodata.org/swater/wshed.asp?wshed=ELD) prior to 1992. Samples were also collected near the mouth of Swift Creek (upstream of Delphi Road bridge), a tributary to McLane Creek, between June 2000 and June 2002. In the McLane Creek subbasin, BMPs were implemented over time with about 80% completed by 1995 (Seiders, 1999). Therefore, in establishing target reductions in fecal coliform concentrations, all data following 1995 were considered (Appendix A).

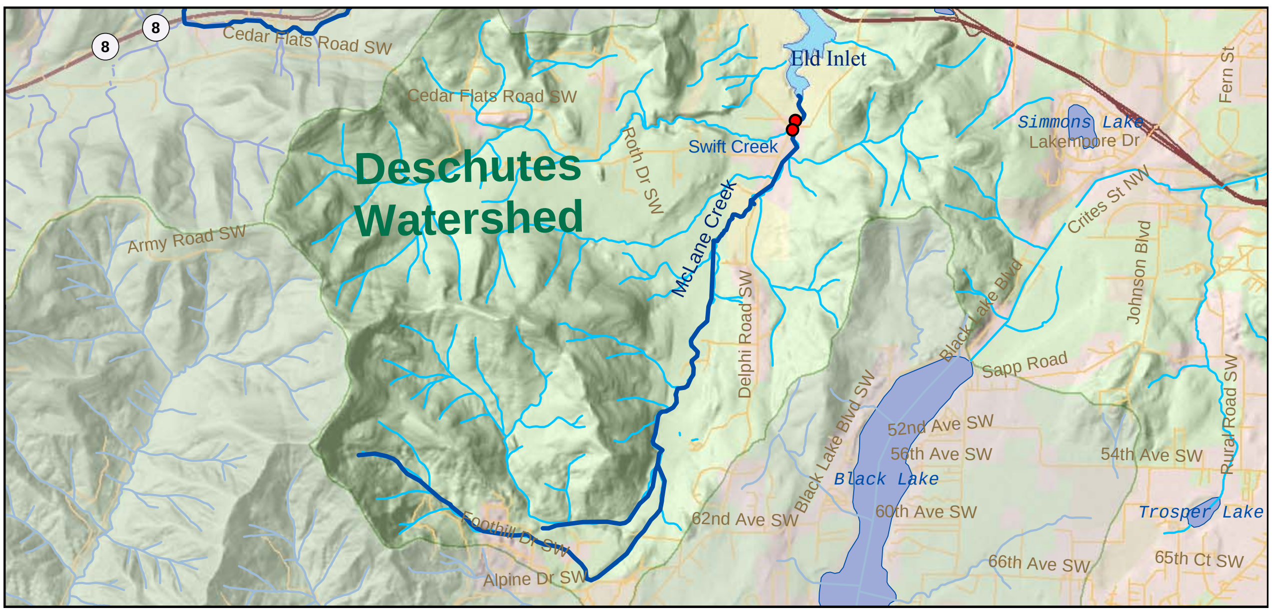


Figure 15. Ecology and Thurston County sampling stations on McLane and Swift creeks.

### McLane Creek

Figure 16 shows the seasonal pattern of flows and fecal coliform concentrations in McLane Creek based on data collected by Ecology and Thurston County between 1995 and 2005. Flows measured during this period were averaged for the respective months. Most of the fecal coliform bacteria exceedances occurred in the summer/early fall months when flow was the lowest.

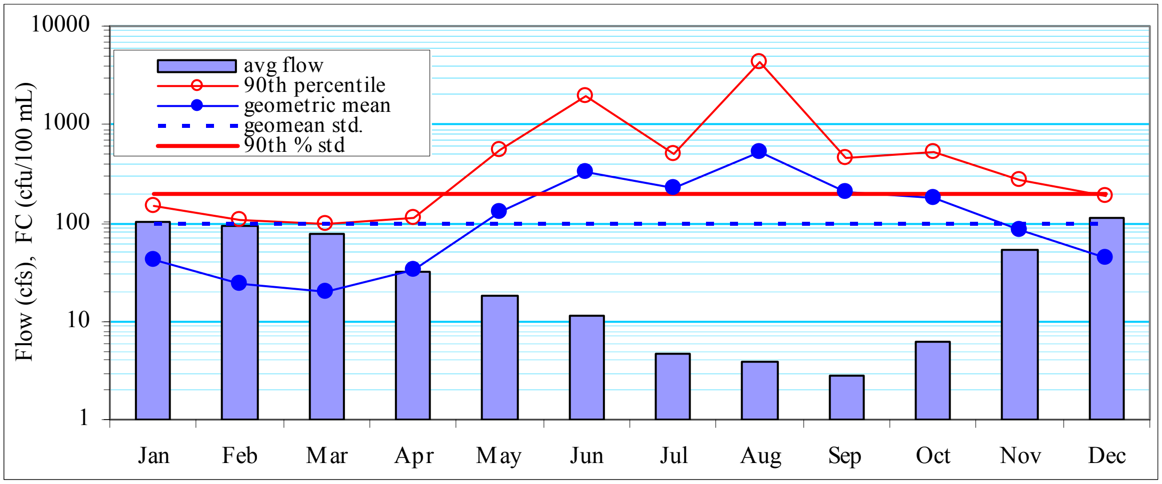


Figure 16. Flows and fecal coliform concentrations in McLane Creek (1995-2005).

Figure 17 shows the pattern of concentrations for all the months between 1995 and 2005. The numbers in parentheses are the number of data points for each month. The least number of data were collected in July (n = 10), and the most data were collected in January (n = 39). Most of the exceedances of water quality criteria occurred in May through November, with August being the most critical month. The target reduction in concentration of fecal coliform bacteria was based on the month of August (only 1995-2004, no data point available in 2005). The long-term 90$^{th}$ percentile and geometric mean for August were 4404 and 520 cfu/100 mL, respectively. The percent reduction is therefore 95% based on the 90$^{th}$ percentile concentration (Table 8). With an average flow of 3.8 cfs in August, the allowable loading (i.e., based on meeting the 90th percentile criterion of 200 cfu/100 mL) for McLane Creek, at the designated location (100 meters downstream of Delphi Road bridge), is 1.9 x $10^{10}$ cfu/day.

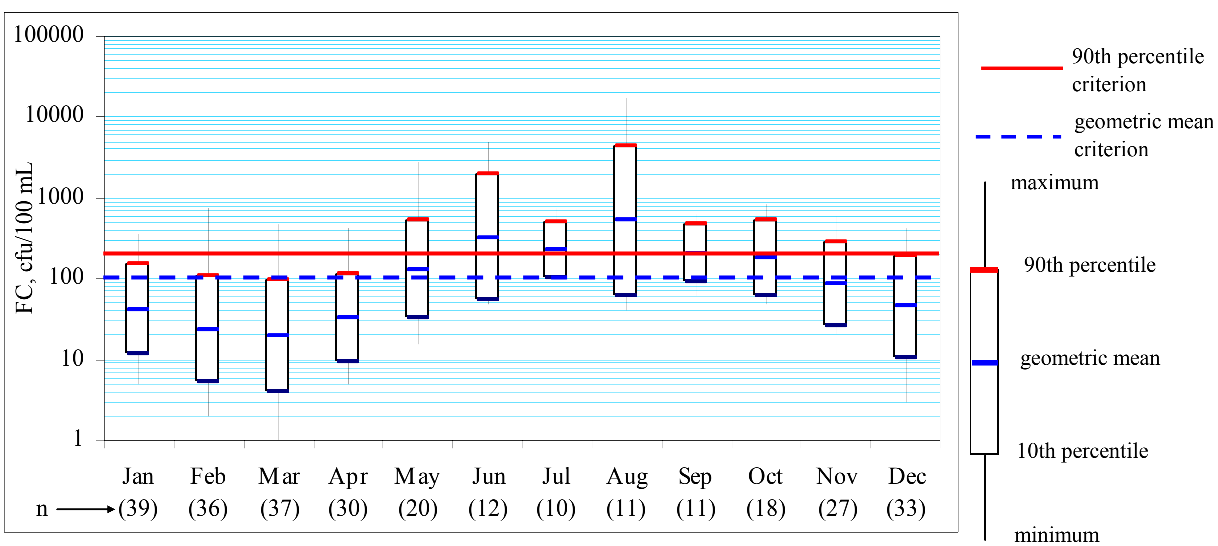


Figure 17. Monthly fecal coliform patterns in McLane Creek (1995-2005).

Table 8. Target fecal coliform reductions in McLane Creek (1995-2004).

| Location | Period | Number of samples | Geometric mean (cfu/100 mL) | $90^{th}$ percentile (cfu/100 mL) | Limiting basis for reduction | Target reduction (%) |
|---|---|---|---|---|---|---|
| 100 m downstream of Delphi Road bridge | August | 11 | 520 | 4404 | 90th percentile | 95 |

## Swift Creek

Swift Creek, a tributary to McLane Creek, was monitored at its mouth above the Delphi Road bridge. As indicated earlier, Swift Creek was monitored between 2000 and 2002, and as such the number of data points was insufficient to evaluate month-to-month variation in fecal coliform concentrations. Several of the adjacent months were pooled based on similarity in flow, and the fecal coliform pattern was evaluated as shown in Figure 18. The numbers in the lower parentheses on the x-axis are the number of data points for each period. Highest fecal coliform concentrations were observed at low flows during the summer-early fall period. The highest concentration (2300 cfu/100 mL) was observed in August. A target reduction for Swift Creek is based on the June - October period as shown in Table 9. With an average flow of 2 cfs in June-October, the allowable loading (based on the $90^{th}$ percentile criterion of 200 cfu/100 mL) for Swift Creek, at the designated location (mouth, upstream of Delphi Road bridge), is $9.8 \times 10^9$ cfu/day.

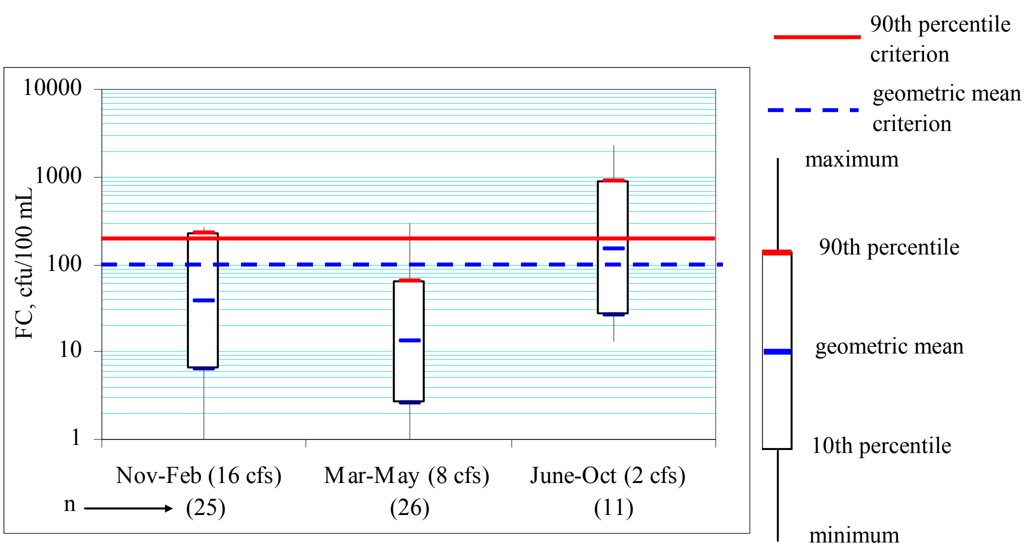


Figure 18. Fecal coliform patterns in Swift Creek (2000-2002).

Table 9. Target fecal coliform reductions in Swift Creek (2000-2002).

| Location | Period | Number of samples | Geometric mean (cfu/100 mL) | $90^{th}$ percentile (cfu/100 mL) | Limiting basis for reduction | Target reduction (%) |
|---|---|---|---|---|---|---|
| At mouth above Delphi Road bridge | June-Oct | 11 | 151 | 886 | $90^{th}$ percentile | 77 |

## Perry Creek

Under the National Monitoring Program (Batts and Seiders, 2003), Perry Creek was monitored over ten years (1992 -2002) by Ecology and Thurston County at a location 100 m above Perry Creek Road, below the foot bridge (Figure 19). In addition, Thurston County monitored for fecal coliform and flow beyond 2002. Thurston County data are available at: www.geodata.org/swater/wshed.asp?wshed=ELD. In the Perry Creek subbasin, BMPs were being implemented over time with about 50% completed by 1995 (Seiders, 1999). Therefore, in establishing target reductions in fecal coliform concentrations, all data following 1995 were considered (Appendix A).

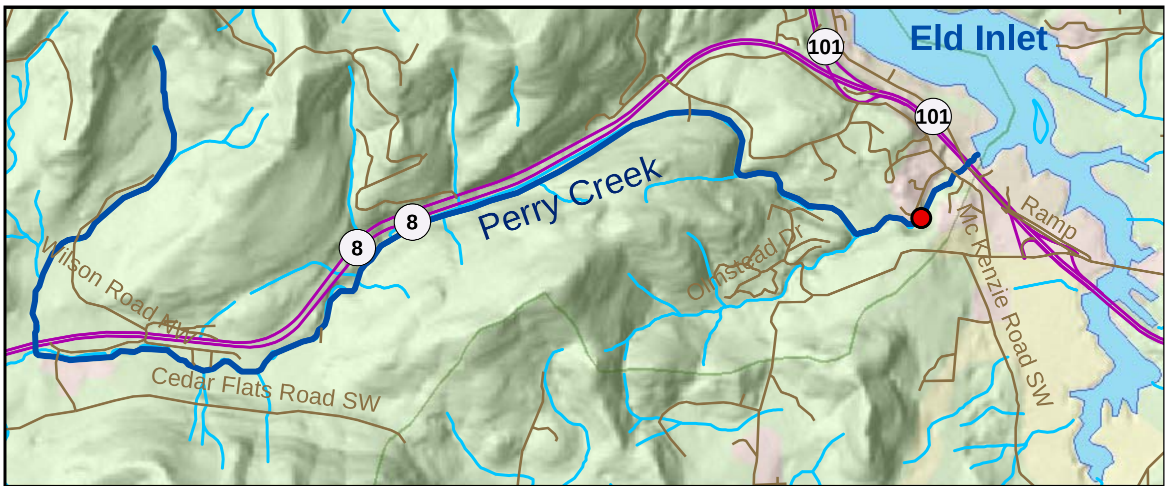


Figure 19. Ecology and Thurston County sampling station on Perry Creek.

Figure 20 shows the seasonal pattern of flows and fecal coliform concentrations in Perry Creek for 1995-2005. The fecal coliform standards (geometric mean and 90$^{th}$ percentile) were met in all months except August, where the 90$^{th}$ percentile standard was exceeded. Flows measured during this period were averaged for the respective months. The long-term average flow in August was 1.3 cfs.

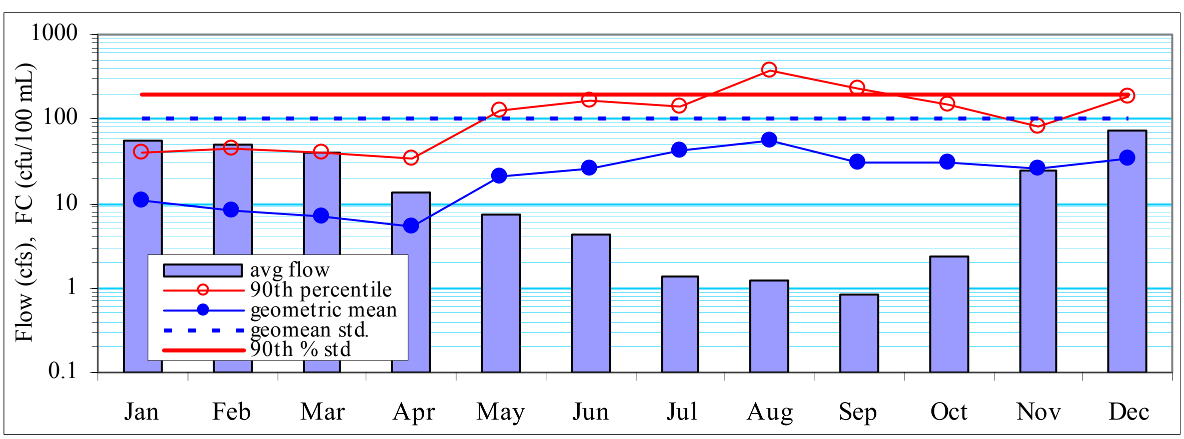


Figure 20. Flows and fecal coliform concentrations in Perry Creek (1995-2005).

Figure 21 shows the pattern of fecal coliform concentrations for all months from 1995 through 2005. The numbers in parentheses are the number of data points for each month. The least number of data were collected in July, August, and September (n = 11 each), and the most data were collected in January (n = 39). A target reduction in concentrations of fecal coliform bacteria was based on the month of August (only 1995-2004, no data point available in 2005). The long-term 90$^{th}$ percentile and geometric mean for August were 368 and 55 cfu/100 mL, respectively. The percent reduction is therefore 46% based on the 90$^{th}$ percentile concentration (Table 10). With an average flow of 1.3 cfs in August and September, the allowable loading (based on 90$^{th}$ percentile criterion of 200 cfu/100 mL) for Perry Creek, at the designated location (400 meters above Perry Creek Road, below foot bridge), is $6.4 \times 10^9$ cfu/day.

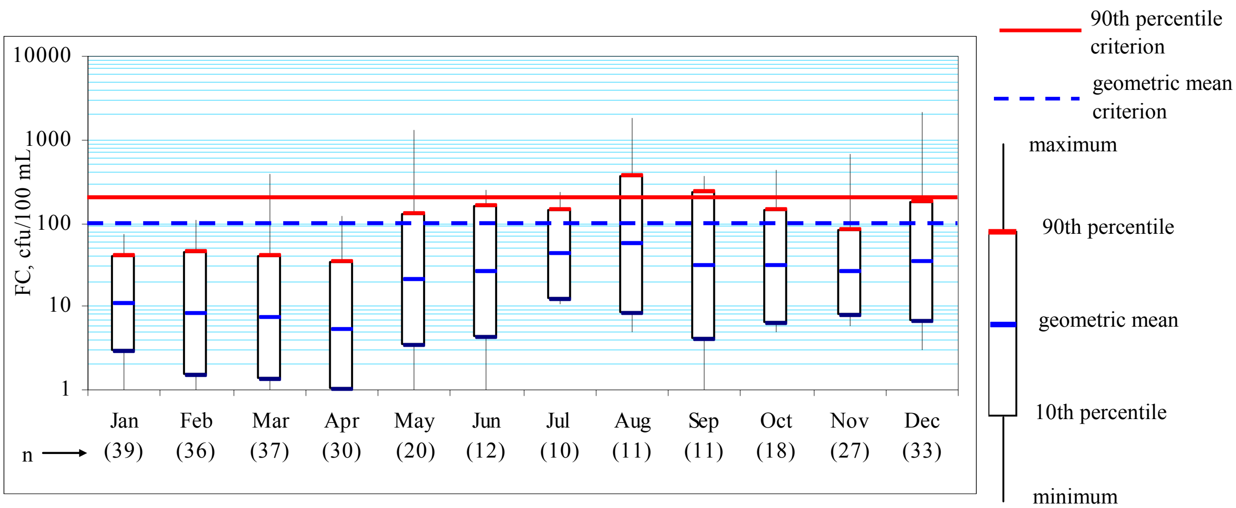


Figure 21. Monthly fecal coliform patterns in Perry Creek (1995-2005).

Table 10. Target fecal coliform reductions in Perry Creek (1995-2004).

| Location | Period | Number of samples | Geometric mean (cfu/100 mL) | 90$^{th}$ percentile (cfu/100 mL) | Limiting basis for reduction | Target reduction (%) |
|---|---|---|---|---|---|---|
| 400 m above Perry Creek Road, below foot bridge | August | 11 | 55 | 368 | 90$^{th}$ percentile | 46 |

# 3. Tributaries to Little Skookum Inlet: Skookum Creek

The mainstem Skookum Creek and its tributaries are shown in Figure 22 along with monitoring stations set up by the Squaxin Island Tribe (SIT). These stations have been monitored by the tribe since 2000. Mason County has also monitored Skookum Creek near the mouth (station MAS1) on Whitener Road, 15 yards downstream of the railroad track, since 2003. The Mason County station is below the current tribal boundary. Since the Washington State water quality standards do not apply within the tribal trust land, target reductions in fecal coliform bacteria will only be established for monitoring stations outside the tribal boundary. The closest monitoring station upstream of the tribal boundary is SKOK3, near the bridge on Highway 8 (see Figure 22). Incidentally, much of the concentrated development in the Skookum Creek watershed occurs below SKOK3 (i.e., within the tribal boundary). Coliform load reductions estimated in this TMDL are limited to areas outside the tribal boundary.

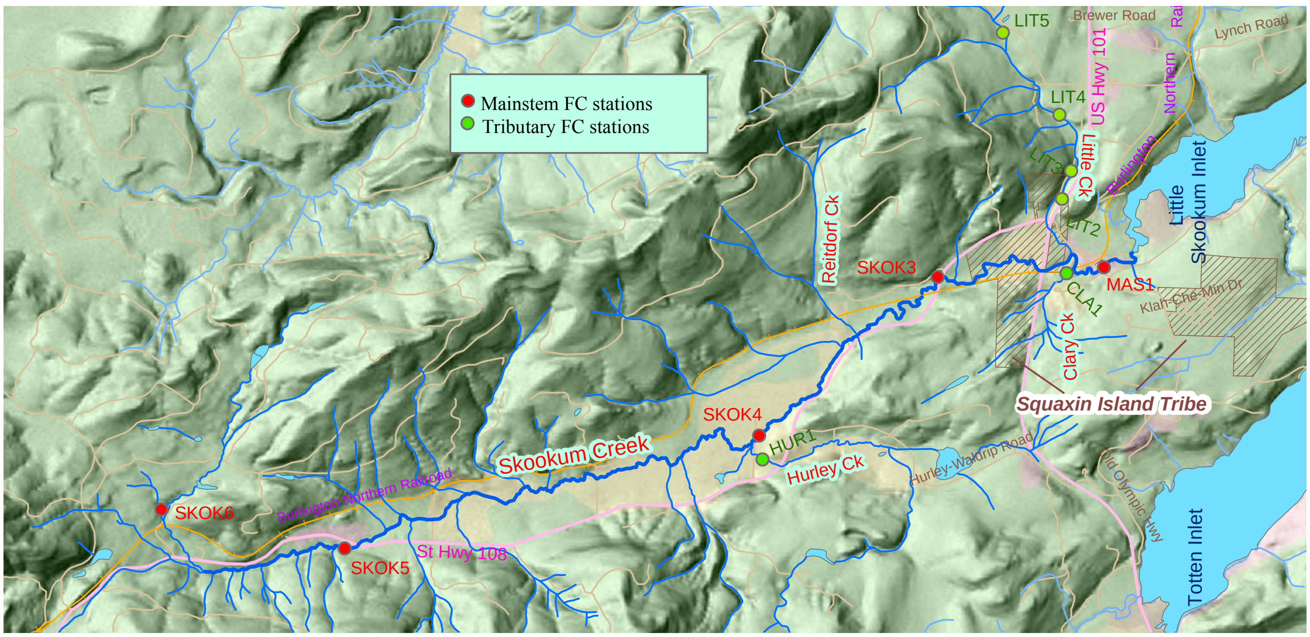


Figure 22. Squaxin Island Tribe sampling stations on Skookum Creek.

Figure 23 shows the monthly fecal coliform patterns in the watershed based on pooled data for 2000-2004. Figure 24 shows the monthly 90th percentile and geometric mean concentrations of fecal coliforms for the same period as well as the minimum monthly flows based on one year (2003-2004) data measured at the new SIT gage, located within the tribal land (near Highway 101). Minimum monthly flow data were used to represent the baseflows, since the mean monthly flows were skewed due to storm events. There were only two coliform data points for November, and a full evaluation for this month could not be done. All exceedances of the geometric mean criterion of 50 cfu/100 mL occurred in July, August, and September. However, the exceedance of the 90th percentile criterion occurred in all months from May through October. The months of July, August, and September also reflected some of the lowest flows of the year (Figure 24).

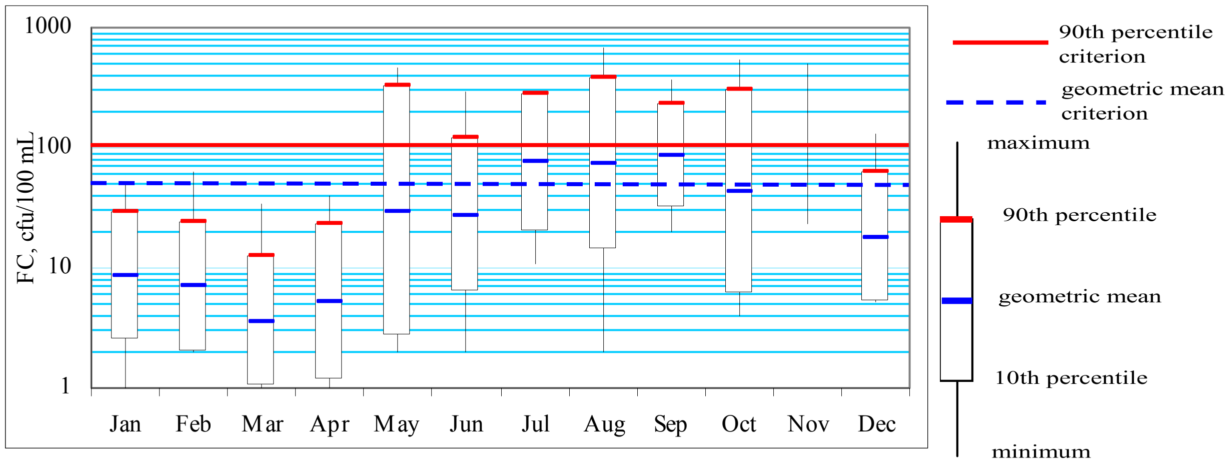


Figure 23. Monthly fecal coliform patterns in the Skookum Creek watershed (2000-2004).

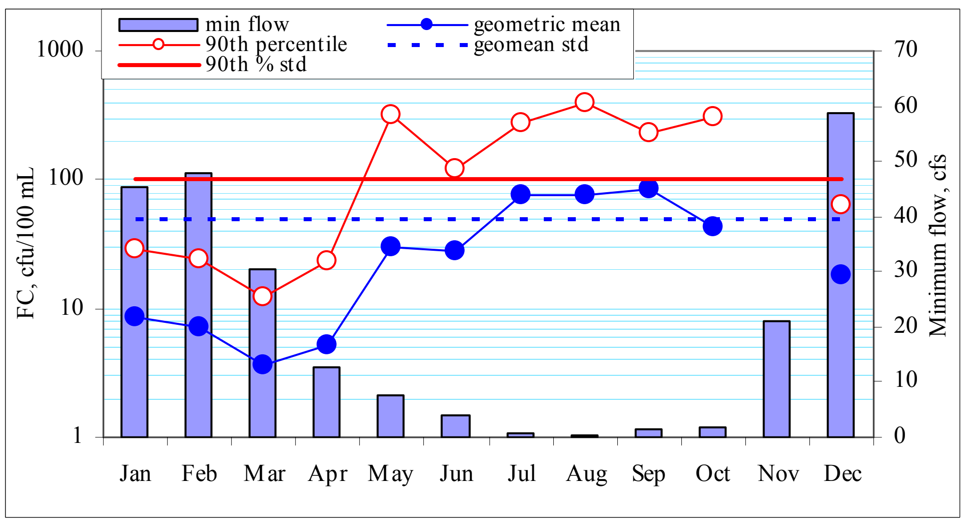


Figure 24. Flows (2003-2004) and fecal coliform concentrations (2000-2004) in the Skookum Creek watershed.

## Target reductions

Target reductions at each of the stations outside the tribal boundary were estimated for the period of May through October. Due to limited data, target reductions for individual months could not be established. Figure 25 shows the data pattern for each of the stations considered during this period. Table 11 shows the target reductions for the Skookum Creek stations. Target reductions for Little Creek and at the mainstem location (MAS1) below the tribal area could not be established due to lack of data.

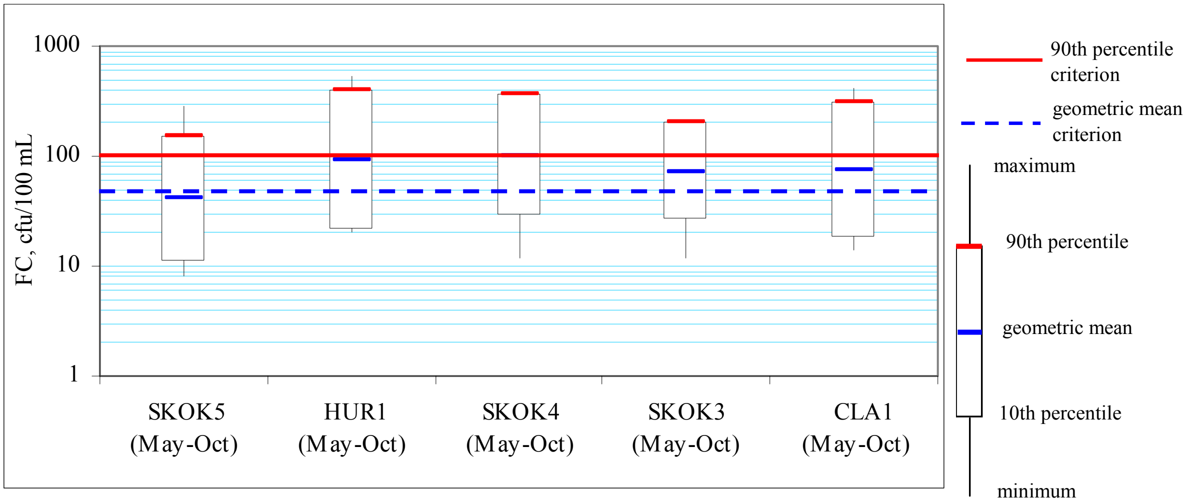


Figure 25. Monthly fecal coliform patterns at the Skookum Creek stations (2000-2004).

Table 11. Target fecal coliform reductions in Skookum Creek (2000-2004).

| Location | Period | Number of samples | Geometric mean (cfu/100 mL) | 90th-percentile (cfu/100 mL) | Limiting basis for reduction | Target reduction (%) |
|---|---|---|---|---|---|---|
| SKOK5, Mainstem at Highway 108 (RM 6.0) | May-Oct | 18 | 41 | 154 | 90th percentile | 35 |
| HUR1, Near mouth of Hurley Creek at Eich Road culvert (Mainstem RM 4.3) | May-Oct | 15 | 92 | 398 | 90th percentile | 75 |
| SKOK4, Mainstem at Eich Road bridge, below Hurley Creek (RM 4.2) | May-Oct | 11 | 102 | 362 | 90th percentile | 72 |
| SKOK3, Mainstem at Highway 108 (RM 2.2) | May-Oct | 18 | 73 | 204 | 90th percentile | 51 |
| CLA1, Near mouth of Clary Creek at railroad crossing (Mainstem RM 1) | May-Oct | 12 | 74 | 306 | 90th percentile | 67 |

Target reductions for Little Creek could not be established due to lack of data at the four stations monitored (Figure 26). Station 4, above Highway 101, did not show any exceedances of the geometric mean and 90th percentile water quality criteria (using both the May-October data (n=12) and all the 21 data points collected in 2000-2004). At other stations, the geometric mean was at or below the water quality criterion (using all available data at each station). However, the 90th percentile concentrations for these stations could not be compared to the 90th percentile water quality criterion due to lack of data (n<10). Further monitoring is recommended for the May-October period.

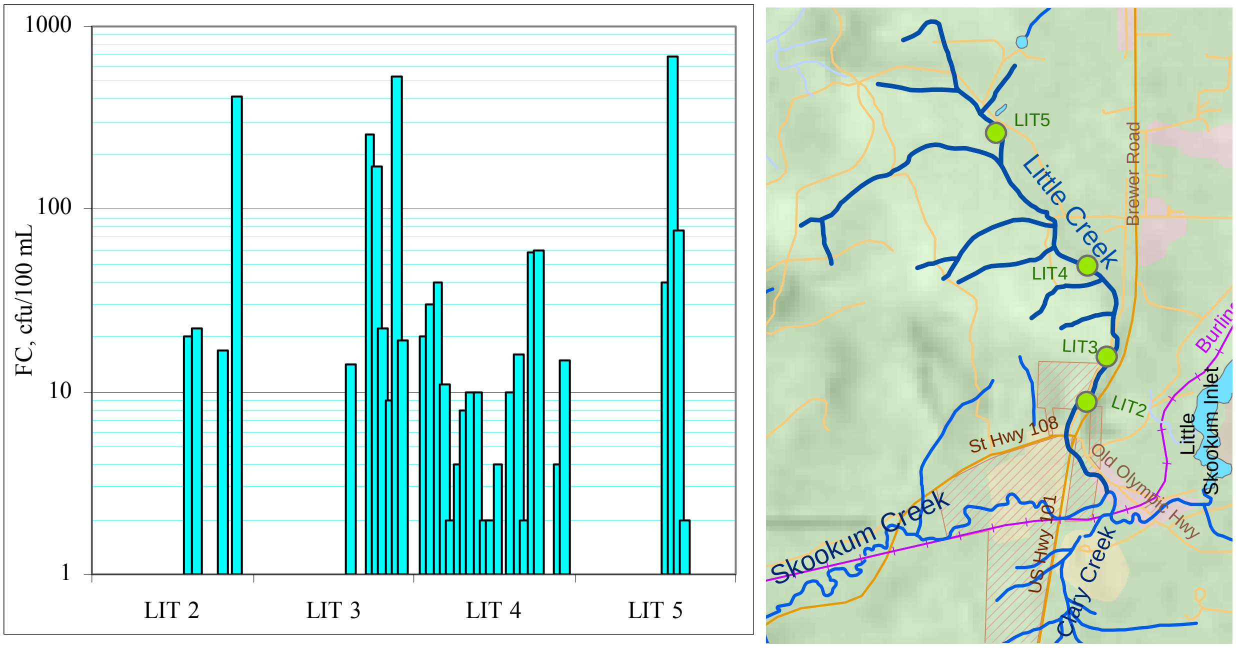


Figure 26. Fecal coliform patterns along Little Creek (stations outside the tribal land).

A target reduction for station MAS1 was also not established due to lack of data during the critical period of May through October. Mason County began monitoring this station in December 2003. Figure 27 shows the spread of data over this period. High concentrations were observed in November and December. However, data were insufficient to establish exceedance of the standards. This station is the closest to the mouth of Skookum Creek and likely reflects the loading of fecal coliform bacteria to the Little Skookum Inlet. Further monitoring of fecal coliform bacteria is recommended at this station.

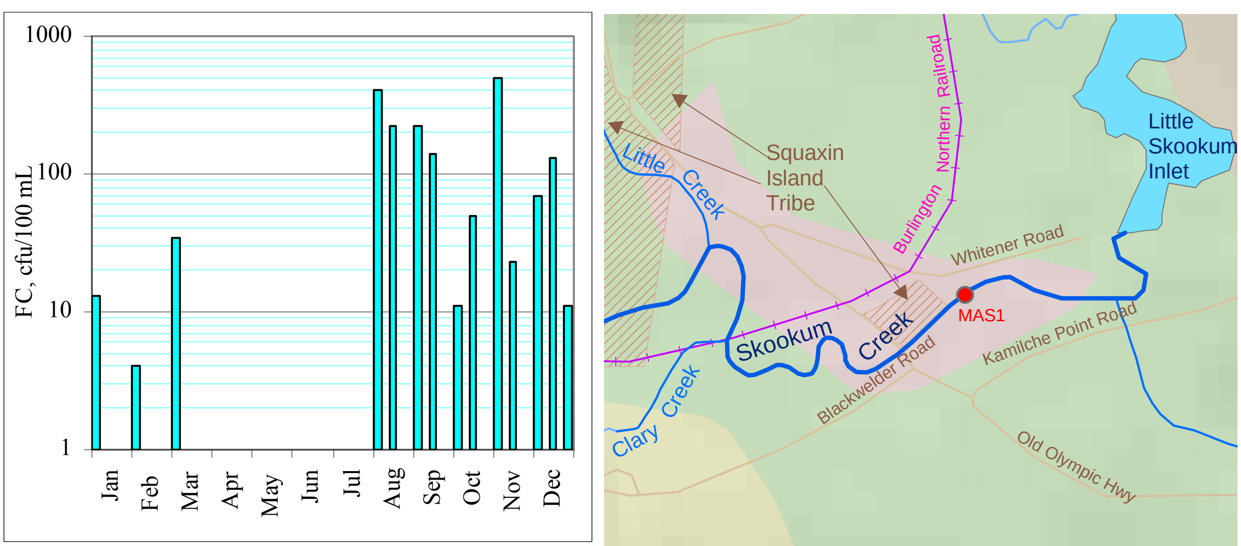


Figure 27. Fecal coliform patterns at Mason County station MAS1.

## Fecal coliform loads

In order to establish bacterial loading for the mainstem Skookum Creek and tributary stations, relationships were developed between flow measured at the various stations in 2004 and flow data at the SIT flow gage near the Highway 101 bridge (~RM 1.3). Based on the relationships, average flows for the selected segments were estimated for the May-October period. It should be noted that flow data available from the SIT gage were only for the 2003-2004 period. However, the minimum flows were very low and likely represented a low-flow year, with the average daily discharge of 49 cfs (2003-2004) compared to the historical USGS average daily discharge of 54.5 cfs (1952-1957).

Table 12 shows the flow relationship between the SIT gage and the various stations as well as the bacteria loading capacity for the average flow during the selected period. Appendix B includes the basis for the flow relationships. Due to limited flow data in Clary Creek, a relationship between gage flow and Clary Creek flows could not be developed. However, the tributary flow was estimated as a percentage of gage flow.

Table 12 also shows the loading capacities for the Skookum Creek mainstem and tributaries and the associated target reductions required to meet the water quality standards. Unlike the tributaries to Totten and Eld inlets, the estimation of bacterial loads for the Skookum Creek mainstem and tributaries were made possible due to availability of data at these locations.

Table 12. Estimated fecal coliform loadings at the mainstem Skookum Creek and tributary stations

| Station | Flow relationship with Squaxin Island Tribe (SIT) gage | $R^2$ | Average gage flow (May-Oct) (cfs) | Average station flow (May-Oct) (cfs) | Loading at existing $90^{th}$ % conc. (cfu/day) | Loading at 90% criterion (cfu/day) | Percent reduction required |
|---|---|---|---|---|---|---|---|
| SKOK5, Mainstem at Highway 108 (RM 6.0) | $Q_{SKOK5}$= 0.42*Qgage+1.12 | 0.95 | 5 | 3.2 | $1.21 \times 10^{10}$ | $7.9 \times 10^{9}$ | 35 |
| HUR1, Near mouth of Hurley Creek at Eich Road culvert (Mainstem RM 4.3) | $Q_{HUR1}$= 0.06*Qgage+0.14 | 0.90 | 5 | 0.4 | $4.3 \times 10^{9}$ | $1.1 \times 10^{9}$ | 75 |
| SKOK4, Mainstem at Eich Road bridge, below Hurley Creek (RM 4.2) | $Q_{SKOK4}$= 1.0*Qgage+0.38 | 0.97 | 5 | 5.4 | $4.8 \times 10^{10}$ | $1.32 \times 10^{10}$ | 72 |
| SKOK3, Mainstem at Highway 108 (RM 2.2) | $Q_{SKOK3}$= 1.18*Qgage-0.15 | 0.99 | 5 | 5.8 | $2.9 \times 10^{10}$ | $1.4 \times 10^{10}$ | 51 |
| CLA1, Near mouth of Clary Creek at railroad crossing (Mainstem RM 1) | $Q_{C1}$=1.2% Qgage | | 5 | 0.1 | $4.5 \times 10^{8}$ | $1.5 \times 10^{8}$ | 67 |

# Fecal Coliform Loading Capacity Summary

Loading capacity means the maximum amount of pollution a waterbody can withstand and still fulfill beneficial uses (i.e., meet Washington State water quality standards). The numeric loading capacity is based on the water quality criterion and the flow in the critical period as discussed earlier under each tributary analysis.

## Load allocation summary

Load allocations are the nonpoint source reductions needed at each station for the load capacity to be met. Individual load allocations for the tributaries and mainstem are summarized below.

Table 13. Summary of target load reductions necessary to comply with the limiting 90th percentile fecal coliform water quality criterion.

| Creeks and tributaries | Existing load[1] (cfu/day) | Loading capacity[2] (cfu/day) | Target reduction (%) | Critical period |
|---|---|---|---|---|
| **Totten Inlet** | | | | |
| Kennedy Creek, 125 m above Old Olympic Highway bridge | $5.4 \times 10^{10}$ | $1.5 \times 10^{10}$ | 73 | Aug-Sept |
| Schneider Creek, end of Pneumonia Gulch Rd | $8.9 \times 10^{9}$ | $2.4 \times 10^{9}$ | 73 | July-Sept |
| Burns Creek, at mouth | $1.9 \times 10^{10}$ | $1.5 \times 10^{8}$ | 99 | May-June |
| Pierre Creek, 80 m upstream of beach | $1.9 \times 10^{9}$ | $8.2 \times 10^{7}$ | 96 | May-June |
| **Eld Inlet** | | | | |
| McLane Creek, below Delphi Rd bridge | $4.1 \times 10^{11}$ | $1.9 \times 10^{10}$ | 95 | August |
| Swift Creek, near mouth, above Delphi Rd bridge | $4.3 \times 10^{10}$ | $9.8 \times 10^{9}$ | 77 | June-Oct |
| Perry Creek, above Perry Creek Rd | $1.2 \times 10^{10}$ | $6.4 \times 10^{9}$ | 46 | August |
| **Little Skookum Inlet** | | | | |
| Skookum Creek (SKOK5) at Highway 108 (RM 6.0) | $1.2 \times 10^{10}$ | $7.9 \times 10^{9}$ | 35 | May-Oct |
| Hurley Creek (HUR1) at Eich Rd culvert (mouth at RM 4.3) | $4.3 \times 10^{9}$ | $1.1 \times 10^{9}$ | 75 | May-Oct |
| Skookum Creek (SKOK4) at Eich Rd bridge (RM 4.2) | $4.8 \times 10^{10}$ | $1.3 \times 10^{10}$ | 72 | May-Oct |
| Skookum Creek (SKOK3) at Highway 108 (RM 2.2) | $2.9 \times 10^{10}$ | $1.4 \times 10^{10}$ | 51 | May-Oct |
| Clary Creek (CLA1) at railroad crossing (mouth at RM 1) | $4.5 \times 10^{8}$ | $1.5 \times 10^{8}$ | 67 | May-Oct |

1. Existing load is based on existing 90th percentile concentrations at average flow for the critical period
2. Loading capacity is based on meeting the 90th percentile criteria at average flows for the critical period

## Wasteload allocation summary

Wasteload allocations are water quality based effluent limits recommended for point sources for meeting water quality standards. Point sources in the watershed are limited to WSDOT outfalls that currently fall within Phase I and Phase II of the municipal stormwater permit program. However, the actual geographic scope of the permit is under discussion, and may be statewide. Wasteload allocations for these outfalls require that the water quality standards be met at each outfall.

It is recommended that BMP implementation requirements be included in the permit so that water quality standards for fecal coliform bacteria are met at each outfall.

If WSDOT outfalls are not within a permitted area, sources will be considered nonpoint, and required actions will be addressed on a project-specific basis.

# Overall Water Quality Impact

Data show that highest fecal coliform bacteria concentrations in all the tributaries occur in the late summer/early fall period. Contamination of streams during wet weather is often associated with runoff that transports fecal bacteria to the streams from failing on-site sewage systems, agricultural operations, and impervious surfaces. However, mechanisms of bacterial contamination during dry weather conditions are not very well understood. Likely causes of bacterial contamination during dry weather low-flow conditions may be:

- Rainfall events
- Failing on-site sewage systems in the vicinity of the riparian corridor
- Recreational uses (swimming, fishing, canoeing, horseback riding) of the stream
- Re-suspension of sediments and associated coliform bacteria
- Wildlife or domesticated animal uses of the stream corridor

## Fecal coliform concentrations and rain during dry weather

Rainfall events, although infrequent, do occur in the watershed during the summer “dry” periods. To evaluate whether high coliform counts were associated with rainfall events, daily precipitations for the critical months were plotted against measured fecal coliform concentrations in Kennedy, Schneider, McLane, Perry, and Skookum creeks. Figure 28 is one such plot. Appendix C contains additional plots for these creeks for several years.

Rainfall measured at the Olympia Airport (www.co.thurston.wa.us/monitoring/Precipitation/NOAA/noaa_.htm) was used to represent the precipitation in all the subbasins.
Although precipitation data were available at the Summit Lake station (www.co.thurston.wa.us/monitoring/Precipitation/Summit%20Lake/summit_lake_precip.htm), which better represents the precipitation in the subbasins, data prior to 2003 were not available. The Green Cove Creek station (www.co.thurston.wa.us/monitoring/Precipitation/Green%20Cove%20Creek%20Basin/green_cove_precip.htm) also lacked continuous rainfall data. Some of the high fecal coliform

concentrations are likely associated with rainfall events (Figure 28 and Appendix C), but other instances of high concentrations do not appear to be related to any rainfall (whether same day or antecedent).

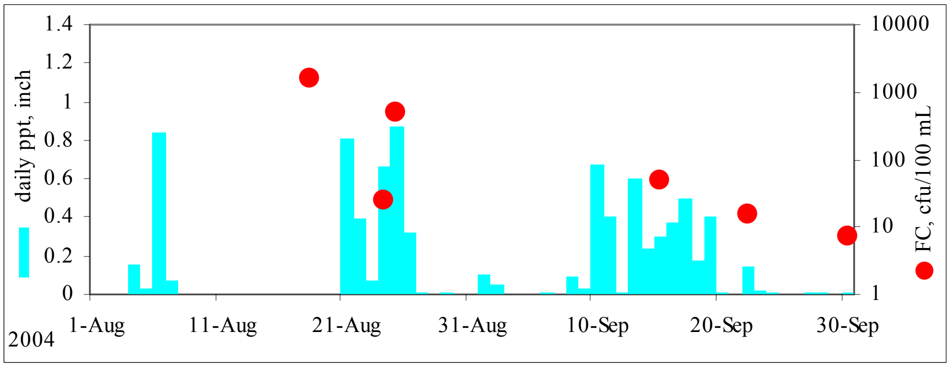


Figure 28. An example of fecal coliform concentrations and rainfall events (Kennedy Creek, Aug-Sept 2004).

## Instream flows and fecal coliform loads

If the fecal coliform loads during all months of the year were more or less the same, it would indicate a constant source, with resulting high instream coliform concentrations at low flow and low concentrations at high flows. To test this hypothesis, loads were calculated for each of the tributaries and plotted along with associated flows. Figure 29 shows the loads and associated flows for Kennedy Creek. Additional plots are included in Appendix D for other creeks. In general, the plots show higher fecal coliform loads at higher flows. However, Figure 29 (and Appendix D) does not show when the higher flows occur. For example, if there is a rainfall event during "dry" weather conditions, the flow and associated load would increase. Although the flow and the load would likely never reach as high as that in winter wet weather conditions, the fecal coliform concentration would tend to be higher due to relatively low volumes in the creek.

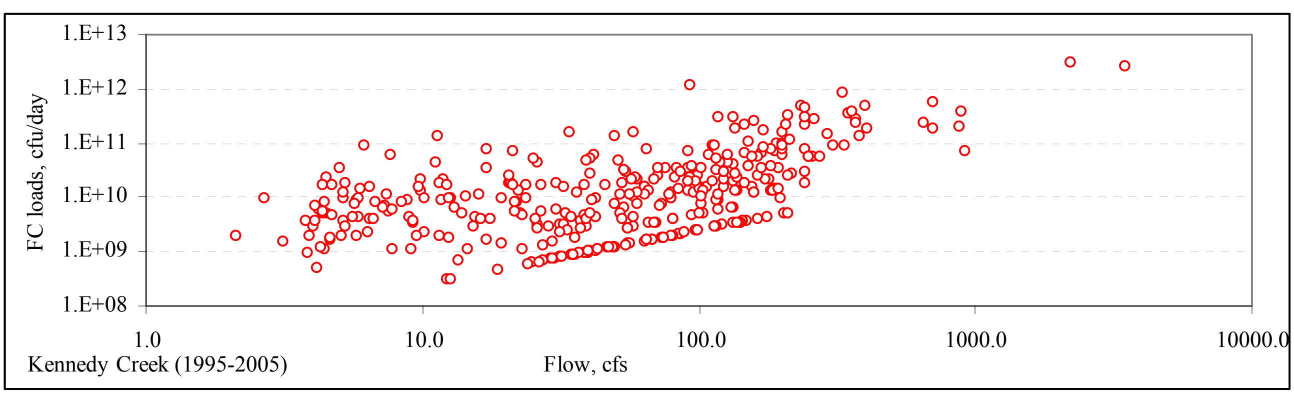


Figure 29. An example of fecal coliform loads and streamflows (Kennedy Creek, 1995-2005).

## Flow and fecal coliform concentrations during the critical period

In developing the target reductions for fecal coliform bacteria, up to ten years of data were used in some instances for a given critical period. Knowing the pattern of fecal coliform concentrations over this period is important, particularly as it relates to when these exceedances occurred and under what flow conditions. BMPs designed to meet the fecal coliform water quality standards during the worst-case scenario would ensure that the standards are met at all times.

Figure 30 shows the fecal coliform concentrations for Kennedy Creek over the last ten years during the critical months of August and September. The associated flows are also shown. Relatively higher concentrations of coliforms have been observed in recent years. Appendix E contains similar plots for other creeks. These plots should be used in conjunction with rainfall-concentration plots, discussed earlier, in order to understand if the observed high coliform concentrations were associated with rainfall events.

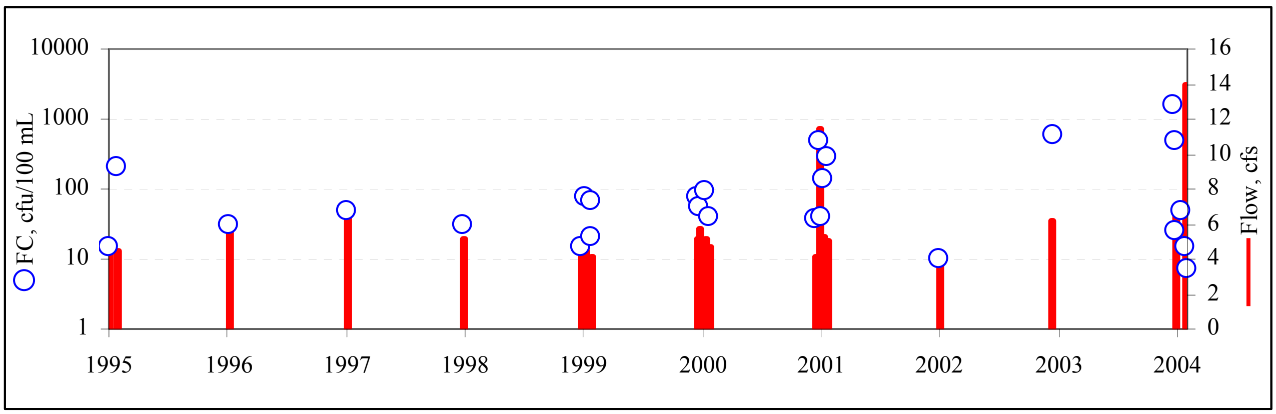


Figure 30. Fecal coliform concentrations and streamflows for the critical period (Kennedy Creek, Aug-Sept, 1995-2004).

## Relative tributary loads to Totten and Eld inlets

Figure 31 shows relative loads to the Totten and Eld inlets based on meeting the 90th percentile water quality standard for each tributary. The loads are proportional to the respective tributary flows during the critical period. Due to relatively higher flows, the majority of the bacterial load to Totten Inlet comes from Kennedy Creek, while half the bacterial load to Eld Inlet comes from McLane Creek.

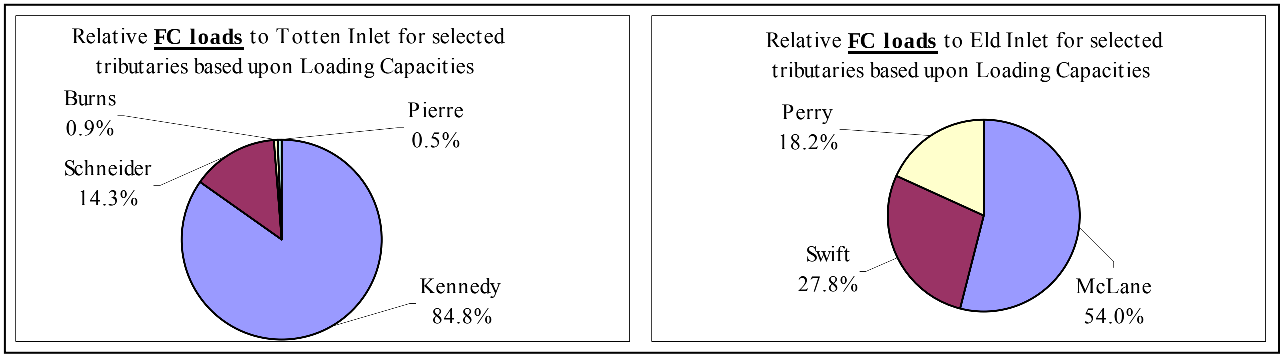


Figure 31. Relative loads to Totten and Eld inlets based on tributary loading capacities.

## Skookum Creek loads

Figure 32 shows the bacteria loading along the creek. There is a large gain in bacteria loading between RM 6 (SKOK5) and RM 4.2 (SKOK4). Although Hurley Creek discharges just above SKOK4 at RM 4.3, the elevated bacteria loading at RM 4.2 cannot be explained by the bacteria loading from Hurley Creek. It is probable that if target reductions are achieved for RM 4.2 (SKOK4), the target reductions for the lower mainstem may also be achieved.

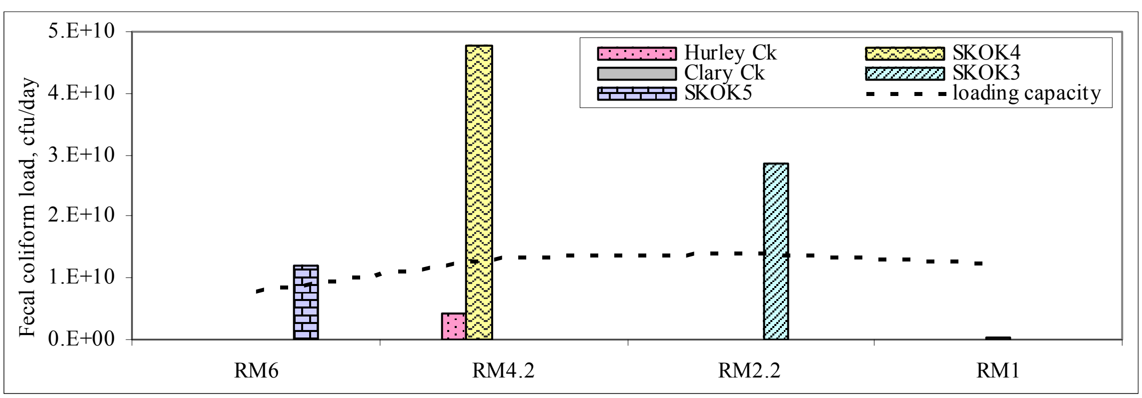


Figure 32. Existing fecal coliform loads and loading capacity along Skookum Creek.

## Margin of Safety for the Fecal Coliform TMDL

The margin of safety for the fecal coliform TMDL is implicit through the use of conservative assumptions, summarized below.

The target reductions recommended in this report for the tributaries are based on observed fecal coliform bacteria concentrations. Compliance with the water quality standards will ultimately be achieved through best management practice (BMP) implementation and a follow-up monitoring plan. However, it is likely that BMPs may reduce bacteria concentrations in excess of the target reductions. For example, if a source of high bacterial concentration is eliminated, higher reduction of bacteria than the target may result.

The estimated targets do not account for any bacterial die-off in the water column or during travel from the source to the stream. As near-stream sources are removed or riparian buffer-strips established, bacterial travel time from the source to the stream during a storm event would increase. This would allow for greater exposure of the bacteria to the environment and potential die-off.

Target reductions were based on seasonal evaluations where sufficient data were available. BMPs based on seasonal targets will substantially reduce the annual load at the various stream segments and tributaries.

Target reductions were based on a $90^{th}$ percentile of fecal coliform pattern which takes into account the variability of the data. This is understood to be more conservative than the $10^{th}$ percentile water quality criterion which allows for 10% of the samples to exceed the criterion without considering the distribution of the data.

## Post-TMDL Monitoring Strategy for Fecal Coliform Bacteria

The tributaries to Totten, Eld, and Little Skookum inlets addressed in this report do not currently meet the Washington State water quality standard for fecal coliform bacteria, and as such are part of the 303(d) list. To address these listings in a comprehensive manner, the following monitoring strategy is recommended:

- Use the highest fecal coliform reduction targets to prioritize where resources should be first invested.
- For Skookum Creek where several load reductions have been established along the stream, begin implementation of best management practices (BMPs) first at the most upstream segment, tributary, or sub-tributary. As the segment, tributary, or sub-tributary with the worst problem is brought into compliance with standards, the monitoring station should be moved to a less severe area where the next set of BMPs would be implemented.
- For tributaries to Totten and Eld inlets, additional monitoring at upstream locations is recommended.

Ongoing monitoring of water quality trends and activity implementation is essential in order to:

- Show where water quality is improving
- Help locate sources of pollution
- Help indicate effectiveness of cleanup activities
- Document achievement of compliance with state water quality standards

For Skookum Creek, in addition to the stations included in Table 11, both Little Creek (all stations) and the mainstem station (MAS1) below the tribal land should be monitored.

A comprehensive monitoring plan will be included in the *Detailed Implementation Plan* for the Totten, Eld, and Little Skookum inlets to be developed by Ecology within one year of the approval date of this TMDL.

If ambient or other monitoring data show that progress towards targets is not occurring or if targets are not being met, a more intensive monitoring of the stream reach should be done. This should include verification of preliminary data followed by identification of specific sources of fecal coliform bacteria. Sampling over time will need to be adjusted to locate the sources by narrowing the geographic area where contamination is occurring.

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# Allowable Loads for Temperature: Skookum Creek

Although riparian shade, stream and groundwater hydrology, stream morphology, climate, and geographic location affect stream temperature, only riparian shade and stream hydrology/ morphology are impacted by land use activities. The increased stream temperature resulting from these anthropogenic activities can be prevented by reversing the process over time (e.g., by increasing riparian shade).

To investigate how much improvement can be made to stream temperature from these preventative measures, a water quality model, QUAL2Kw (Pelletier and Chapra, 2004) was used.

1. The model was calibrated and confirmed using observed data.
2. Critical stream temperature under a reasonable worst-case scenario of flow and weather conditions, but with existing vegetation, was predicted.
3. System-potential temperature was predicted with full potential riparian vegetation under critical conditions.
4. Load allocations were estimated as shade values necessary to bring the stream temperatures to within water quality standards.

Data evaluation graphs and tables are presented in this report for July 2004 to illustrate the quantitative process. Similar data evaluations were conducted for August 2004.

# Water Temperature Data – Continuous Data-loggers

A network of continuous temperature data-loggers were installed in the mainstem Skookum Creek and its tributaries in the summer of 2004 by the Squaxin Island Tribe in accordance with the procedures established in a Quality Assurance Project Plan (Ahmed, 2004c). Nine temperature data-loggers (named S3 through S11) were installed upstream of the Squaxin Island Tribal boundary. The station nomenclature was different than what was used for the fecal coliform TMDL. Figure 33 shows the station locations where data were gathered for the temperature TMDL.

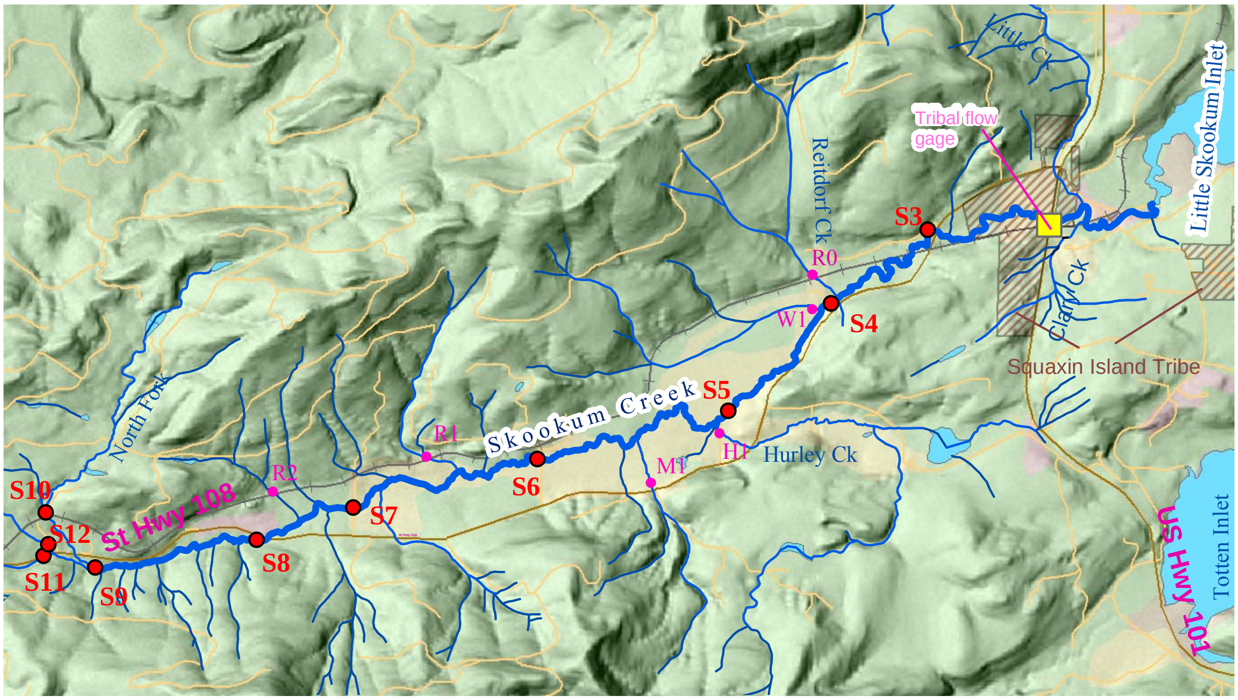
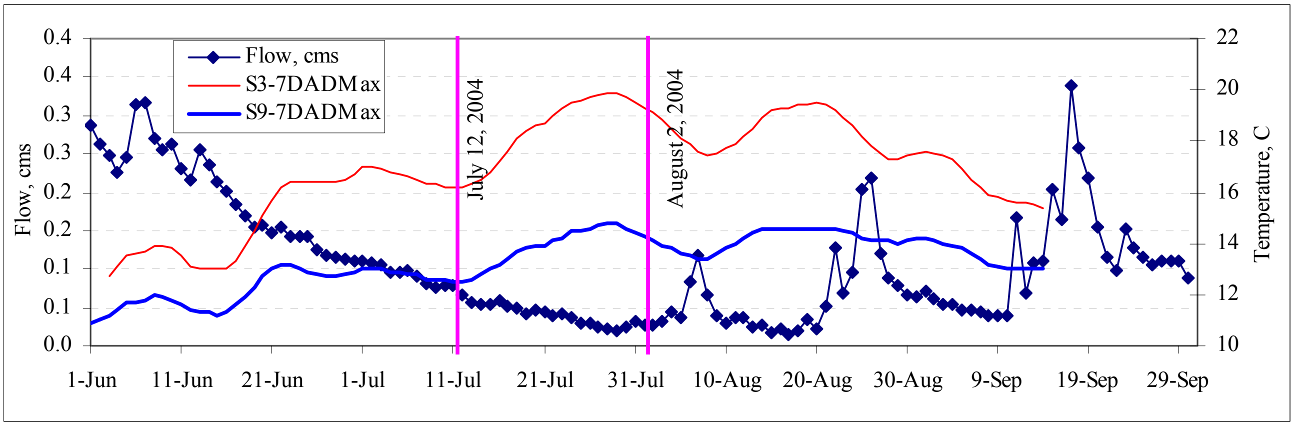



Figure 33. Sampling stations in the Skookum Creek watershed for the temperature TMDL.

Station S3 (2.95 km from mouth) is the lowest downstream station near the tribal boundary. The two upper-most data-loggers (S10 and S11) were in the north and south fork, respectively, while the uppermost mainstem data-logger was S9 (13.35 km from the mouth).

Figure 34 shows the daily maximum and 7-day average of daily maximum (7-DADMax) at the upstream and downstream ends, respectively. The daily flow at the gage (near Highway 101, 1.6 km from mouth) is also shown in Figure 34. As expected, high temperatures are associated with low streamflows. Two dates (July 12 and August 2, 2004) were used for model calibration and confirmation, respectively, as shown in Figure 34. These dates were chosen to reflect high and low temperature periods within the critical season (July-August) and periods of near steady state flow. These dates also coincided with two of the five synoptic surveys conducted in 2004.




cms = cubic meters per second

Figure 34. Gage flows and 7-day averages of daily maximum temperatures at Skookum Creek upstream (S9) and downstream (S3) stations.

To run the QUAL2Kw model (Pelletier and Chapra, 2004), temperatures were averaged over seven days for each of the calibration and verification periods for every hour of the day. The maximum, minimum, and average hourly temperatures at each station were then used for model calibration and verification. The 7-day average temperature profile for the July 12th synoptic survey is shown in Figure 35. The stream temperature increases from upstream to downstream. Similar patterns were observed for the other synoptic surveys.

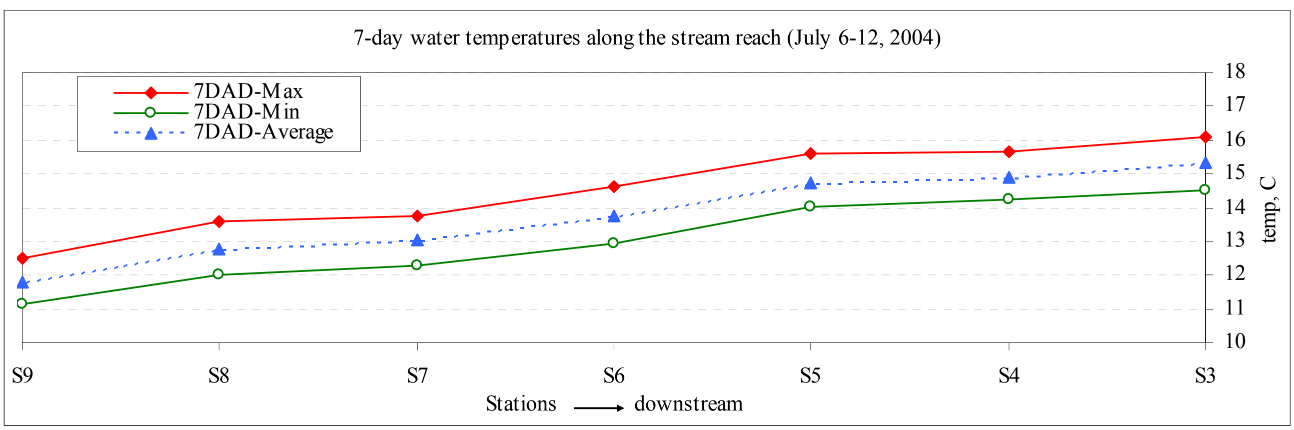



Figure 35. 7-day average, maximum, and minimum water temperature in Skookum Creek for model calibration (July 2-12, 2004).

## Thermal Infrared Survey

Watershed Science Inc. (2005) completed a thermal infrared (TIR) survey of Skookum Creek on August 13, 2004. The TIR survey includes simultaneous thermal infrared and visible video coverage that are geographically linked through a Global Positioning System (GPS) and geo-referenced through a Geographic Information System (ArcView GIS). Visual temperature and riparian vegetation photos are available from this survey at www.ecy.wa.gov/apps/watersheds/temperature/tir/oakland_bay/index.html. Figure 36 shows the longitudinal temperature profile from the TIR survey. There is an approximately 3°C increase in water temperature from the headwaters to the tribal boundary at approximately 3.54 km (RM 2.2). A further increase in temperature was observed within a 1.6 km inter-tidal reach near the mouth. Figure 37 is a plan-view of the temperatures along the stream reach.

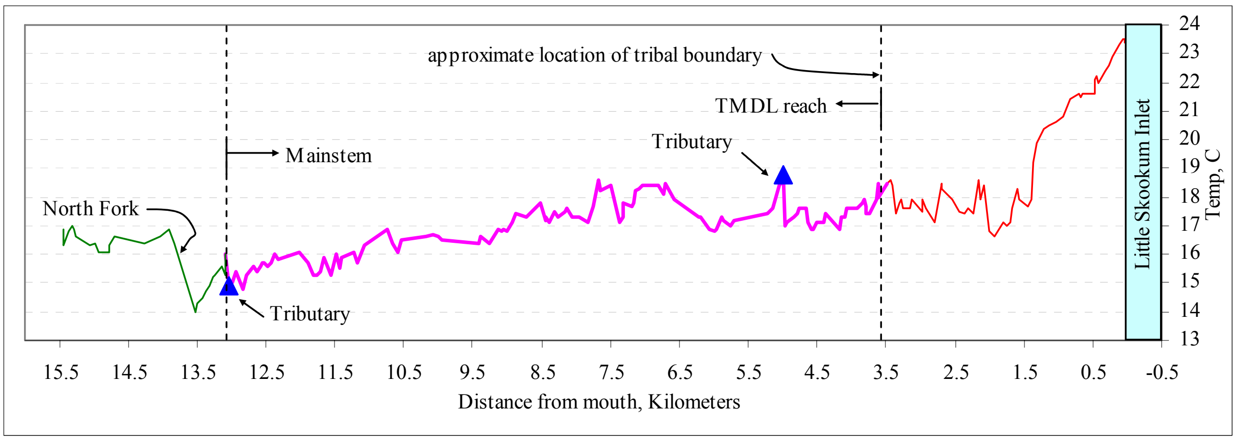



Figure 36. Longitudinal temperature profile in Skookum Creek (August 13, 2004).

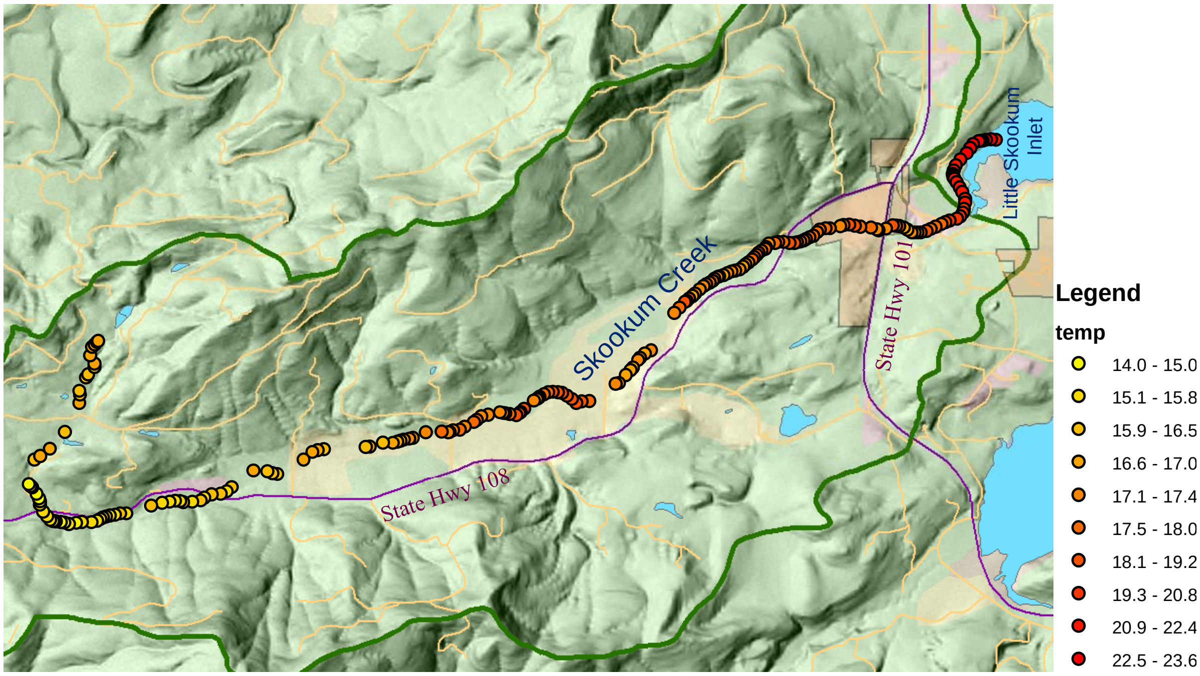



Figure 37. Thermal infrared survey of Skookum Creek showing increasing temperatures downstream.

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Although TIR data reflects surface water temperature only, it does show the general temperature trend, and along with aerial photographs, is a powerful tool to visualize localized temperature peaks and associated riparian vegetation. Figure 38 is an example photograph of the unnamed tributary at RM 3.1 (5 km) showing the associated riparian vegetation. The TIR longitudinal temperature plot at this location shows a drop in temperature below the tributary (see Figure 36), likely due to cooler water from the tributary and/or increased riparian vegetation below the bridge.


Figure 38. Photograph of a tributary to Skookum Creek at RM 3.1 (5 km) and the associated riparian vegetation.

## Groundwater Temperature

Groundwater temperatures were measured with three temperature devices installed in piezometers (Figure 39) at all mainstem stations (see Figure 33). The screened depths of the piezometers varied with the station, but were in the range of 3 feet.

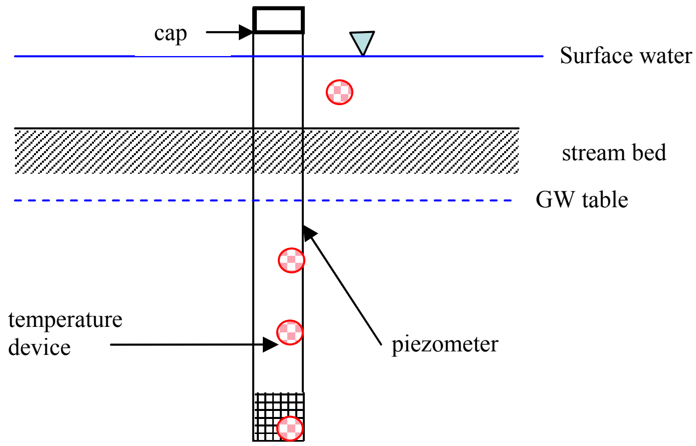


Figure 39. Schematic of piezometers installed at Skookum Creek stations during field work.

Figure 40 shows an example of the 7-day, hourly-average bottom temperature profiles (July 6-12, 2004) at each piezometer except for Station S7, which did not have a bottom temperature device. Groundwater temperatures increased from Station S9 at the headwaters to Station S3 at the downstream end.

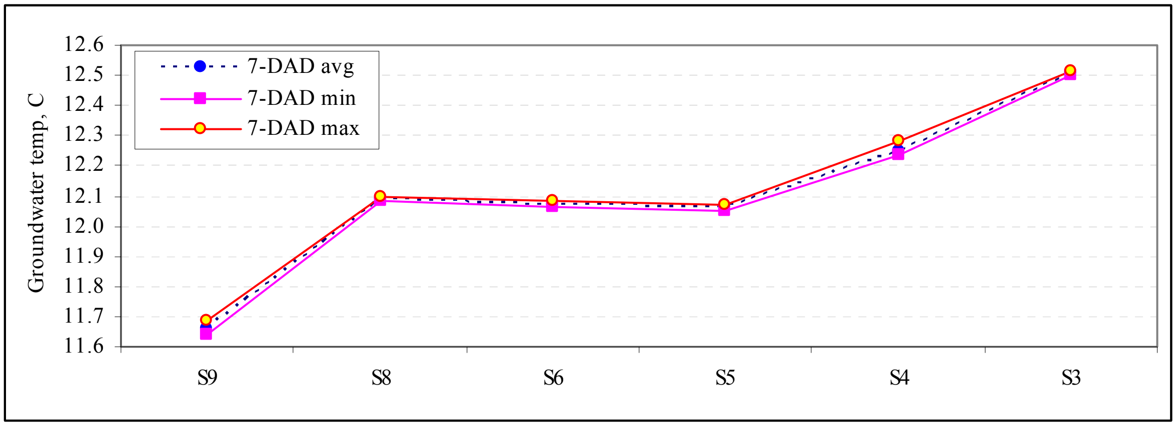


Figure 40. Groundwater temperatures at the Skookum Creek mainstem stations (July 6-12, 2004).

Several factors affect measured groundwater temperatures, including heating of the metal piezometer when exposed to sunlight and/or air. Effects of sunlight and air can be avoided if the piezometer top is well below the stream surface. Temperature devices placed within the piezometer can also be influenced by stream temperatures. To avoid this influence, temperature devices should be installed in the piezometer well below the streambed. Also, the groundwater temperatures are affected by infiltrating surface water for a losing stream. Ecology is in the process of developing draft protocol for piezometer installation. Lessons learned in Skookum Creek will help in this process.

Figure 41 shows the July 2004 temperature profile in groundwater at all mainstem piezometers. The corresponding stream temperatures are also included. At stations S3, S7, and S9, the top temperature devices within the piezometers were mistakenly installed above the streambed but below the groundwater table. The temperature profile for these devices show that groundwater temperatures are either greater than or similar to the stream temperatures (see Figure 41). The average groundwater temperature measured was 12ºC in the bottom temperature devices in all the piezometers. In comparison, the mean annual average air temperature (sometimes used to represent regional groundwater temperature) measured at Sanderson Field Airport weather station in Shelton between 1948 and 1999 was 11ºC. Observed temperature profiles within the piezometers and gradients for each monitoring station are presented in Appendix F.

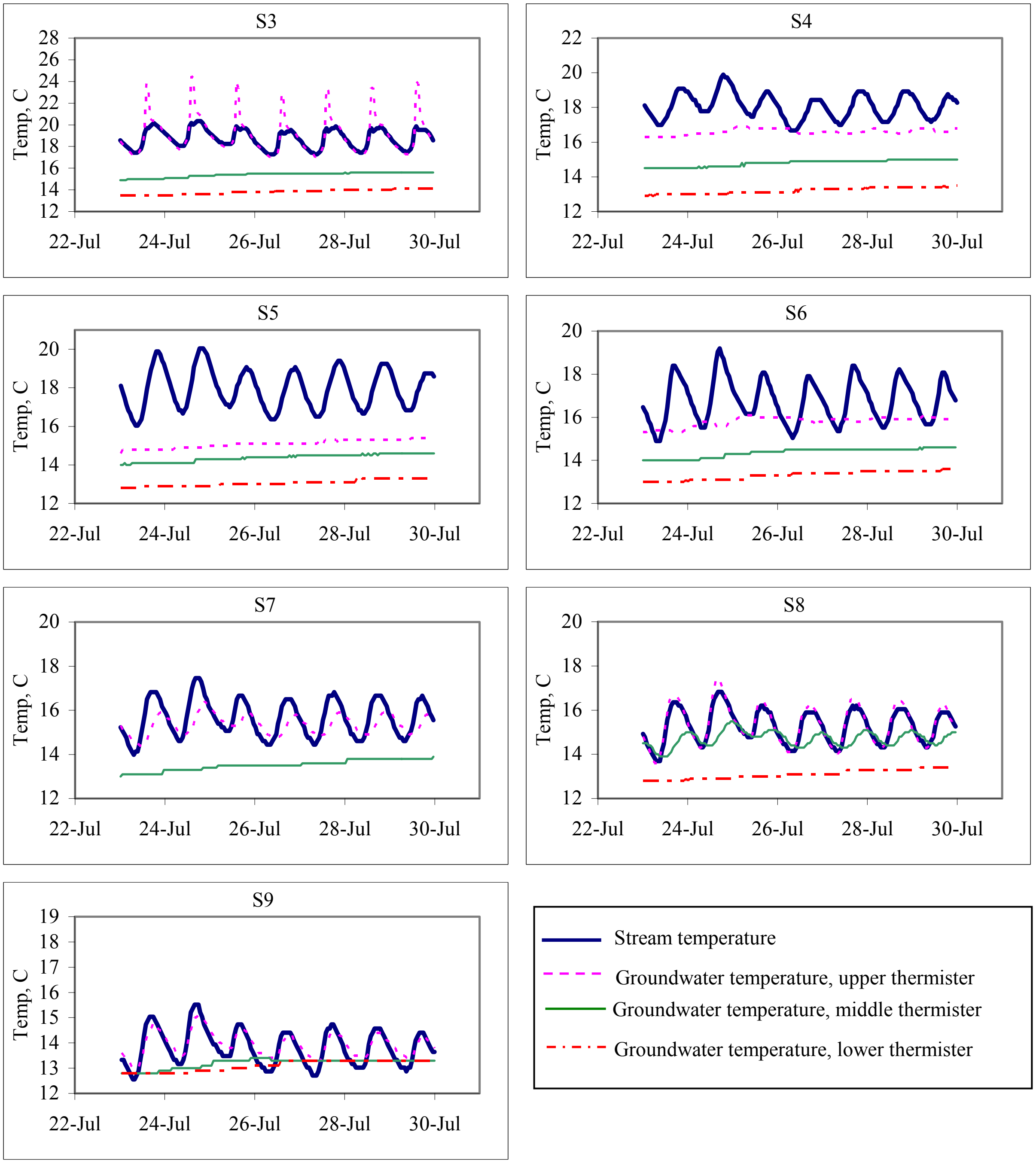


Figure 41. Groundwater temperatures at Skookum Creek stations S3-S9 (July 23-29, 2004).

# Groundwater - Surface Water Interaction

Vertical hydraulic gradient, defined as the ratio of the difference between groundwater and surface water elevations and the effective depth of piezometer below the streambed, gives an indication of whether the stream is gaining (positive hydraulic gradient) or losing (negative hydraulic gradient). Figure 42 shows the vertical hydraulic gradients at the monitoring stations during June-September 2004. The gradients show, in general, that the stream is a losing stream. The average hydraulic gradient, although shown as a continuous line, should not be construed to represent gradients between the stations. The relatively large variation in gradients observed at some stations likely reflects measurements made prior to reaching equilibrium conditions within the piezometers. This would be the case in clayey soils where water levels would take a long time to reach equilibrium following purging of the piezometers.

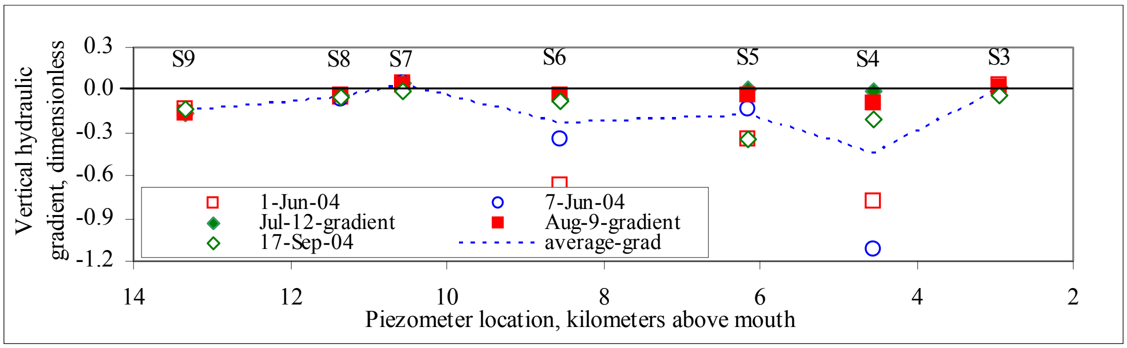


Figure 42. Vertical hydraulic gradient at Skookum Creek stations S3-S9 (2004).

Figure 43 shows an example of the vertical hydraulic gradient, relative gains in flow as measured during seepage runs (discussed later), and the maximum water temperature observed on August 9, 2004. Gains in streamflow follow increases in hydraulic gradients and vice versa as water moves downstream. The maximum gain (from S9 to S7) and loss (from S7 to S5) on August 9, 2004, is 0.6 cfs. Although temperature should increase with decreasing flows and vice versa, the trend is not obvious, likely due to other factors (e.g., riparian shade) affecting temperatures.

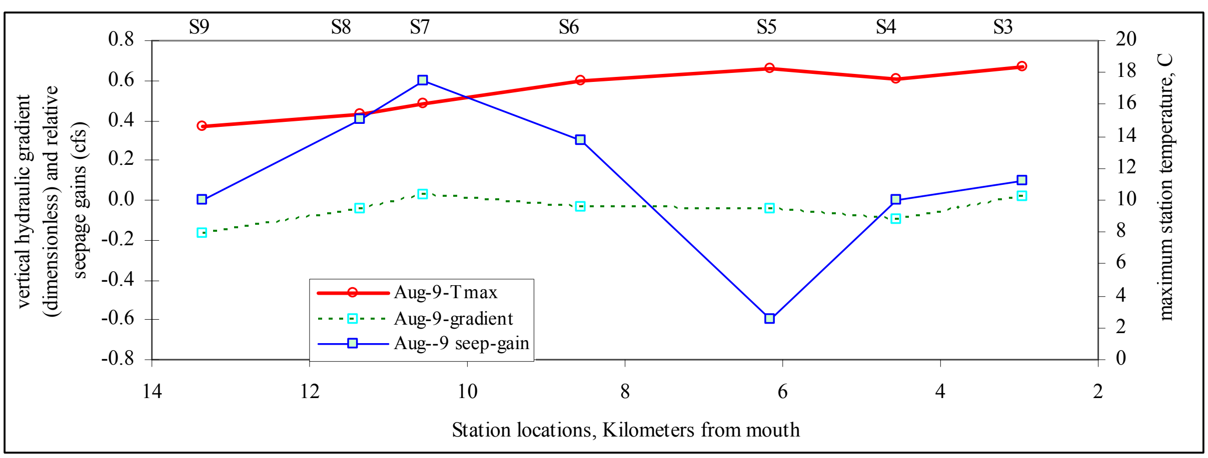


Figure 43. Vertical hydraulic gradient, relative seepage gains, and the maximum water temperature at Skookum Creek stations S3-S9 (August 9, 2004).

## Local Air and Dew-point Temperatures

There were only three stations (S9, S6, and S3) used for measuring local air and dew-point temperatures during the 2004 summer study. The air and dew-point temperatures during calibration and verification model runs were averaged over a 7-day period. To obtain air temperatures at other stations, linear interpolation based on elevation differences between stations was used. The maximum, minimum, and the average air and dew-point temperatures for the model confirmation period of July 6-12, 2004 are shown in Figure 44.

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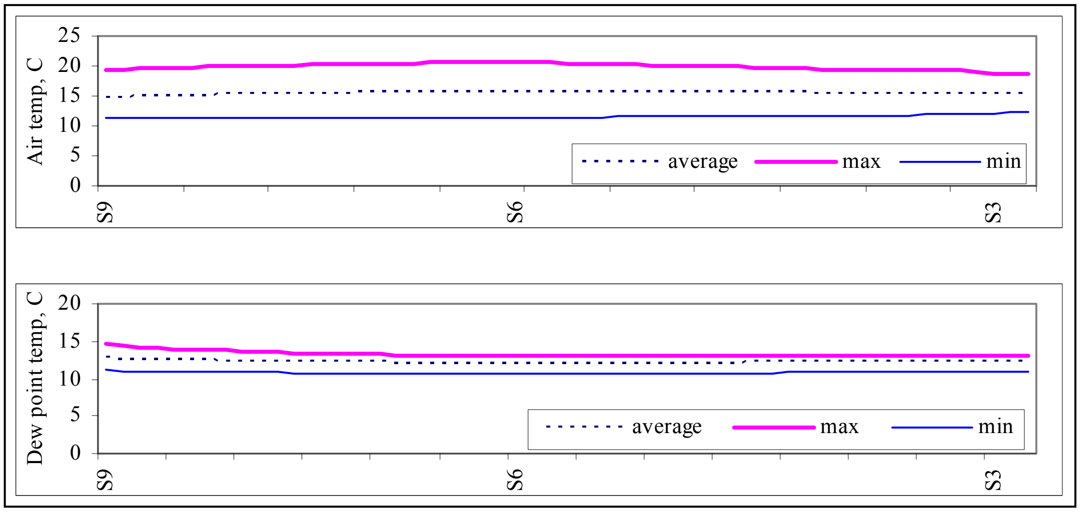


Figure 44. 7-day average of daily maximum, minimum, and average air and dew-point temperatures at Skookum Creek stations for model confirmation: July 6-12, 2004.

## Other Local Meteorological Data

Hourly cloud cover and wind speed data for calibration and verification runs were obtained from the weather station at Sanderson Field Airport in Shelton through the National Climatic Data Center (http://cdo.ncdc.noaa.gov ). Figure 45 shows an example of the cloud cover and wind speeds for July 12, 2004.

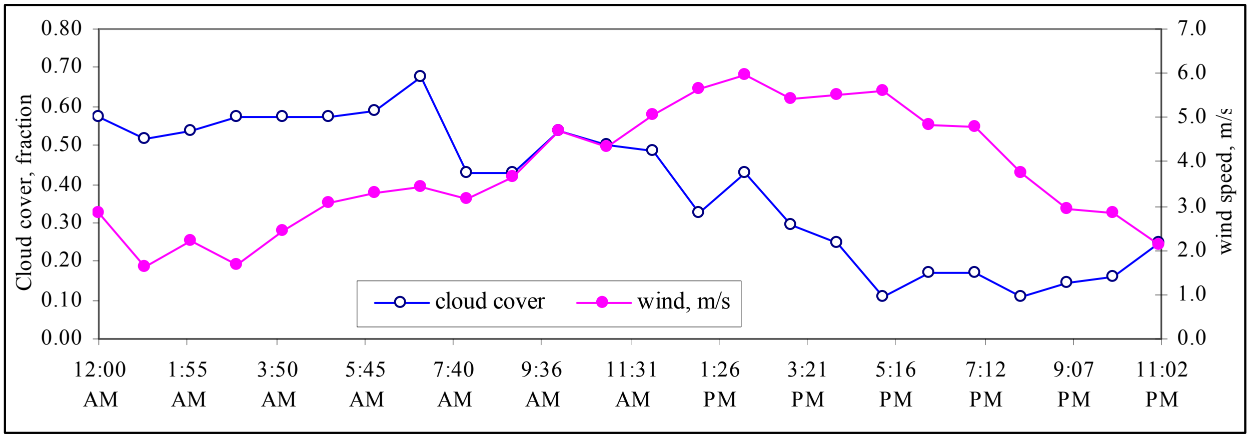


Figure 45. Average wind speed and cloud cover (July 6-12, 2004) based on data from Sanderson Field Airport in Shelton.

The weather station is at an elevation of 85 meters and approximately 8 aerial miles from Skookum Creek. The Skookum Creek reach elevation is 64 meters at the headwaters and 4 meters at the lower end. There is also more vegetation along Skookum Creek than at the weather station. Therefore it is likely that the wind speed measured at the weather station would be somewhat higher than along Skookum Creek. The wind speed was successively reduced until the model was calibrated and confirmed to observed temperatures. Also, the cloud cover data are not exact. For example, for scattered clouds, the range of sky coverage varies from 3/8 to 4/8, which is almost a 30% range. Figure 45 was developed using average cloud cover values. However, during model calibration, a 30% adjustment was applied to the average cloud cover.

## Stream Hydraulics

When running the QUAL2Kw temperature model, stream hydraulic characteristics for existing conditions and for critical conditions (generally 7Q10 flows) must be known. Continuous gage data are limited for Skookum Creek. A USGS gage near RM 3 recorded continuous flow data from 1951-1958. The 7Q10 flow based on the USGS gage was estimated at 1.2 cfs (Taylor et al., 1999). A new flow gage was installed in Skookum Creek near Highway 101 by the Squaxin Island Tribe in 2004. Continuous flow records at this gage shows a low 7-day average flow of 0.022 cms (0.78 cfs) on August 14-20, 2004 (Figure 46). A new 7Q10 will likely be lower than the historic 7Q10 and probably higher than the 7-day low flow of 2004 (since this was a dry year). An average of these two flows of 1 cfs was used as the expected 7Q10 flow for current conditions.

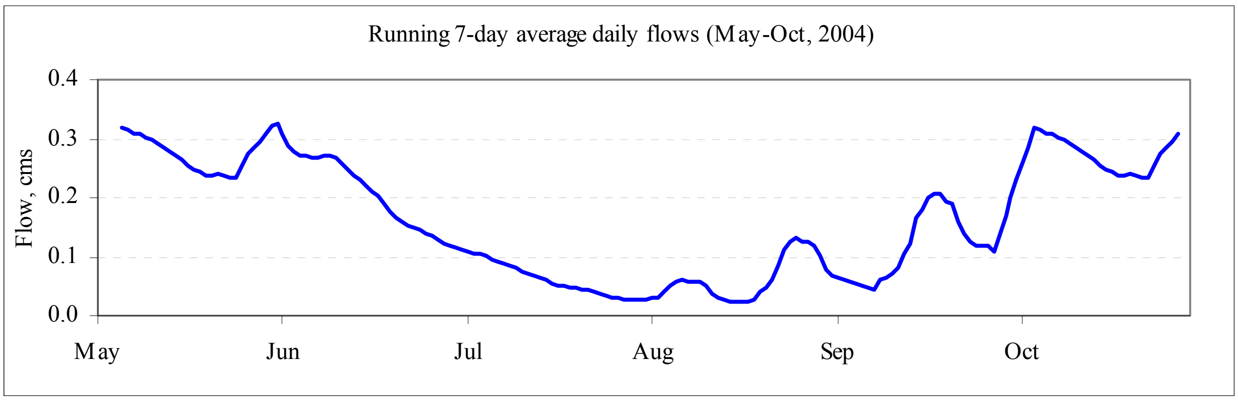


Figure 46. 7-day average of Skookum Creek daily flows at the flow gaging station near Highway 101.

The Washington Administrative Code (WAC) 173-514-030 establishes a minimum instream flow of 3.0 cubic feet per second (cfs) for Skookum Creek between July 15 and October 1, although this standard is seldom met. As a result, Ecology has closed the Skookum Creek watershed for further surface water appropriation from May 1 through October 31 as specified in WAC 173-514-030(2).

## Seepage runs

Seepage runs are synoptic surveys where streamflows are measured at several locations along the stream and near the mouths of tributaries on the same day. Data from the seepage run can be used to estimate net inflow or outflow of groundwater from the difference in measured flows at adjacent stations, accounting for any surface water inflows (e.g., tributaries) or withdrawals (e.g., for irrigation) within the reach. The change of flow (Q) within a reach of length "x", in the absence of tributaries or withdrawals, is given by the following generalized equation (Harvey and Wagner, 2000):

$$\frac{dQ}{dx} = (Qg_{in} - Qg_{out}) + (Qh_{in} - Qh_{out})$$

where,

$\frac{dQ}{dx}$ is the change in flow per unit of stream reach distance

$Qg_{in}, Qg_{out}$ are the reach average groundwater influx and outflux per reach meter, respectively

$Qh_{in} - Qh_{out}$ are the reach average hyporheic influx and outflux per reach meter, respectively

Thus, seepage runs give an estimate of the net change in flows between stations, but the individual subsurface flow components are not estimated. Figure 46 shows instream flows measured at the Skookum Creek stations during five synoptic surveys conducted during the summer of 2004. In general, flow decreased from June through August and increased from August through September. At Station S4 (at Stohr driveway bridge), a pool developed at certain flows which skewed the flow results. In August, flow was measured at two places, at the pool and at a riffle downstream. The downstream riffle flow was more than 1 cfs greater than the measured pool flow. The September flow was measured at the pool which is why the plot (Figure 47) shows a likely artificial dip in the flow pattern.

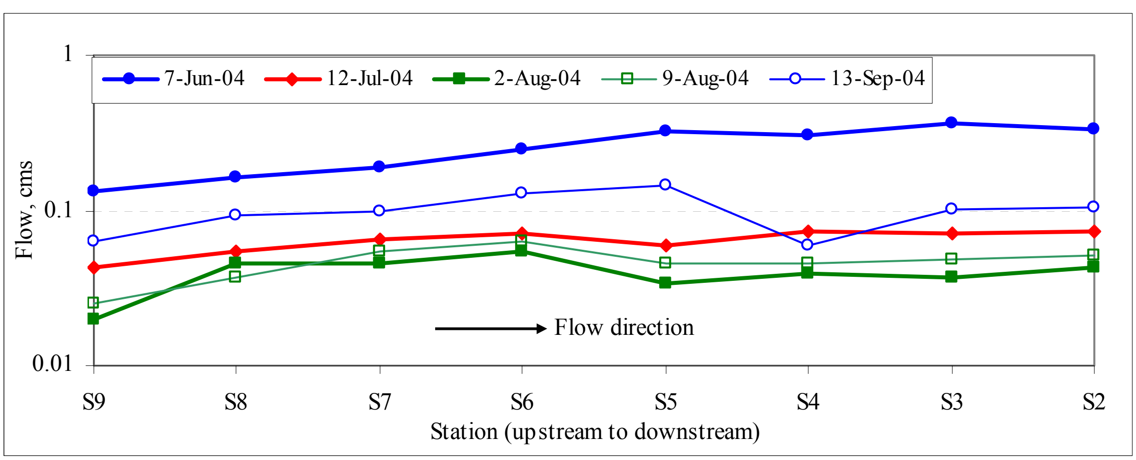


Figure 47. Streamflow seepage runs in Skookum Creek during summer 2004.

## Flow power functions

Flow power functions were also developed for the mainstem stations from intensive survey data collected during June-September 2004. Flow power functions relate stream hydraulic characteristics (velocity, width, and depth) to flow in the channel. Table 14 shows the power functions for width and velocity as a function of flow at the various stations. These relationships were used as starting points to establish stream geometry during model calibration. The velocity relationship was kept the same during the calibration process. However, the coefficient of the width relationship was continuously changed, while the cross-sectional area of the assumed rectangular channel was kept equal to that observed in the field, until a good fit was achieved with the observed temperatures. The distance through which each power function was assumed valid was also changed until a good fit to the depth and velocity data was achieved.

Table 14. Flow power function relationship for the Skookum Creek stations.

| Station | Distance from mouth, km | Width, W (m) | Velocity, V (m/s) |
|---|---|---|---|
| S9 | 13.35 | $5.060\ Q^{0.084}$ | $0.913\ Q^{0.671}$ |
| S8 | 11.55 | $6.197\ Q^{0.17}$ | $1.011\ Q^{0.474}$ |
| S7 | 10.65 | $6.287\ Q^{0.1}$ | $0.288\ Q^{0.196}$ |
| S6 | 8.55 | $6.658\ Q^{0.247}$ | $0.664\ Q^{0.6}$ |
| S5 | 6.15 | $6.811\ Q^{0.16}$ | $0.408\ Q^{0.508}$ |
| S4 | 4.65 | $8.369\ Q^{0.094}$ | $0.254\ Q^{0.715}$ |
| S3 | 2.95 | $6.397\ Q^{0.197}$ | $1.128\ Q^{0.477}$ |
| where flow, Q, is in cms | | | |

## Station-gage flow relationships

For a given gage flow, flows at the stations along Skookum Creek can be estimated based on relationships between station flows and gage flows. These relationships were developed for the Skookum Creek stations as shown in Figure 48. Table 15 shows the flows at the stations as estimated from gage flows and gage-station flow relationships developed in Figure 48.

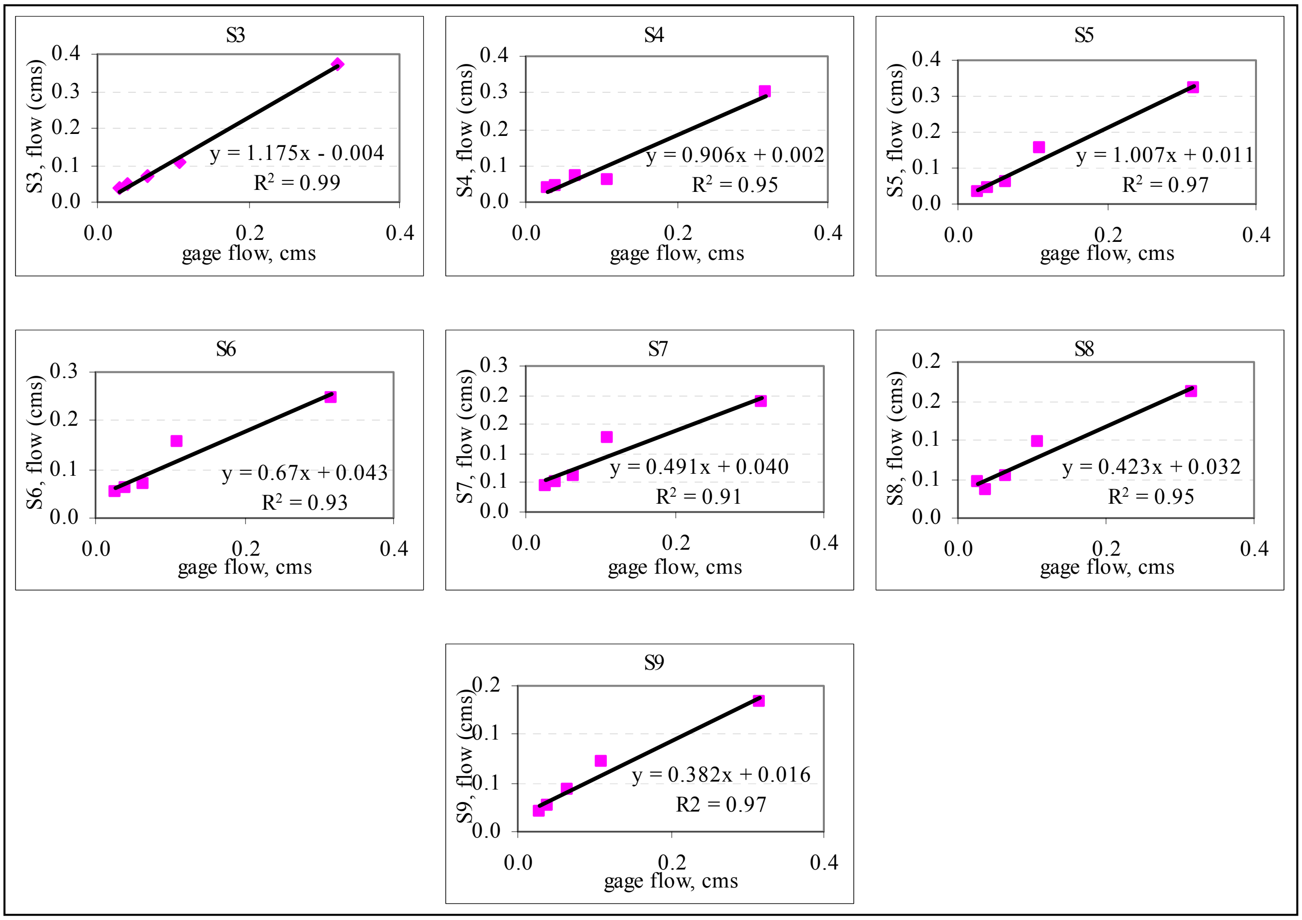


Figure 48. Flow relationship between Skookum Creek station flow and gage flow.

Table 15. Estimated Skookum Creek station flows based on gage flows.

| Station ID | Distance from mouth, km | Flow, cms | | |
|---|---|---|---|---|
| | | 12-Jul | 9-Aug | 2-Aug |
| gage | 1.6 | 0.0657 | 0.0392 | 0.0278 |
| S3 | 2.95 | 0.0732 | 0.0420 | 0.0287 |
| S4 | 4.65 | 0.0614 | 0.0374 | 0.0271 |
| S5 | 6.15 | 0.0769 | 0.0502 | 0.0388 |
| S6 | 8.55 | 0.0866 | 0.0688 | 0.0613 |
| S7 | 10.65 | 0.0727 | 0.0597 | 0.0542 |
| S8 | 11.55 | 0.0594 | 0.0482 | 0.0434 |
| S9 | 13.35 | 0.0413 | 0.0312 | 0.0268 |

## Hyporheic flow

The hyporheic zone is the region beneath and adjacent to streams where surface and groundwater mix (Reidy and Clinton, 2004). The physical conditions required for a hyporheic zone include permeable sediments and differences in pressure head between subsurface and surface water. Changes in the pressure head throughout the stream and riparian zone create upwellings of subsurface water into the stream and downwellings of stream water into the hyporheic zone (Figure 49).

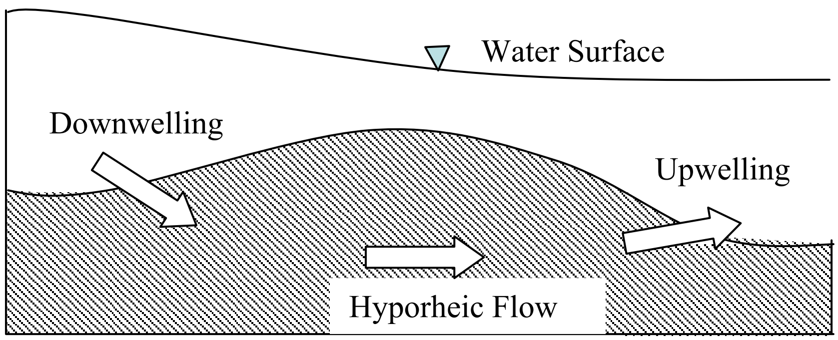


Figure 49. Schematic showing hyporheic flow

The residence time of water in the hyporheic zone varies from minutes to days at the small streambed scale with longer periods (days to hundreds of days) at the larger meander-bend scale, and even longer (more than several hundreds of days) at the floodplain scale (Poole and Berman, 2001). The effective thickness of the hyporheic zone may typically range from about 20% to 300% of the stream depth (Harvey and Wagner, 2000; Gooseff et al., 2003), with higher relative values in smaller streams. Studies conducted in stream headwaters in British Columbia found that a greater hyporheic exchange, relative to surface water flow, existed during low baseflow than high baseflow conditions (Gomi and Moore, 2003). The streamflows measured in the summer 2004 in Skookum Creek were substantially low (low 7-day average of 0.78 cfs) compared to historical records (7Q10 of 1.2 cfs).

Significant amounts of hyporheic flow exchange can occur depending on geomorphic controls. Kasahara and Wondzell (2003) report flow exchange ranging from about 0.6-5% of the total surface flow per 100 meters in fifth-order streams, to up to 76 to >100% of the total surface flow per 100 meters in second-order streams. For the eighth-order Willamette River (in Oregon), Fernald et al. (2001) reported a >72% of the surface flow exchanging with the transient storage and hyporheic zones with a thickness on the order of 20-30% of the stream depth and residence times of 0.2-30 hours over a 26 km reach. In general, smaller streams usually have higher proportions of surface flow in and out of the hyporheic zone compared with larger streams. The hyporheic flows at the 400-meter Skookum Creek segments were in the order of 100% of streamflow per 100 meter as estimated through model calibration during the low-flow conditions of August 2004.

## Hydraulic conductivity and soil thermal properties

In May 2004, piezometers were installed at all mainstem stations where flows and stream temperatures were measured. Within the piezometers, temperature devices were installed at three depths. During each synoptic survey (May-Sept, 2004), depth of groundwater within the piezometer and the depth of stream were measured. The vertical hydraulic gradient was then estimated as the difference between the groundwater and stream depths divided by the effective piezometer length. The hydraulic gradients and temperature data at three depths were used as input parameters to the Variably Saturated 2 Dimensional Heat Interactive (VS2DHI) transport model (Hsieh et al., 2000) to estimate hydraulic conductivities at the piezometer stations. Using the estimated hydraulic conductivity and measured hydraulic gradient, the groundwater movement per unit area of streambed can be estimated.

Due to reasons discussed under the *Groundwater Temperature* section, not all the piezometer data could be used. Figure 50 shows the calibrated VS2DHI model runs for selected stations (S4, S5, S6, and S9) and the associated hydraulic conductivities. The model was run with various hydraulic conductivities and soil thermal properties until the predicted and observed temperature profiles matched for the middle piezometer temperature device. Figure 50 also shows the root mean square error (RMSE) between the observed and predicted temperatures. The RMSE is a measure of the deviation of the of model prediction from the observed data. The lower the RMSE, the lower the difference between the two. The RMSE is calculated as follows:

$$RMSE = \sqrt{\sum \frac{(T_{observed} - T_{predicted})^2}{n}}$$ ; where n is the number of observations

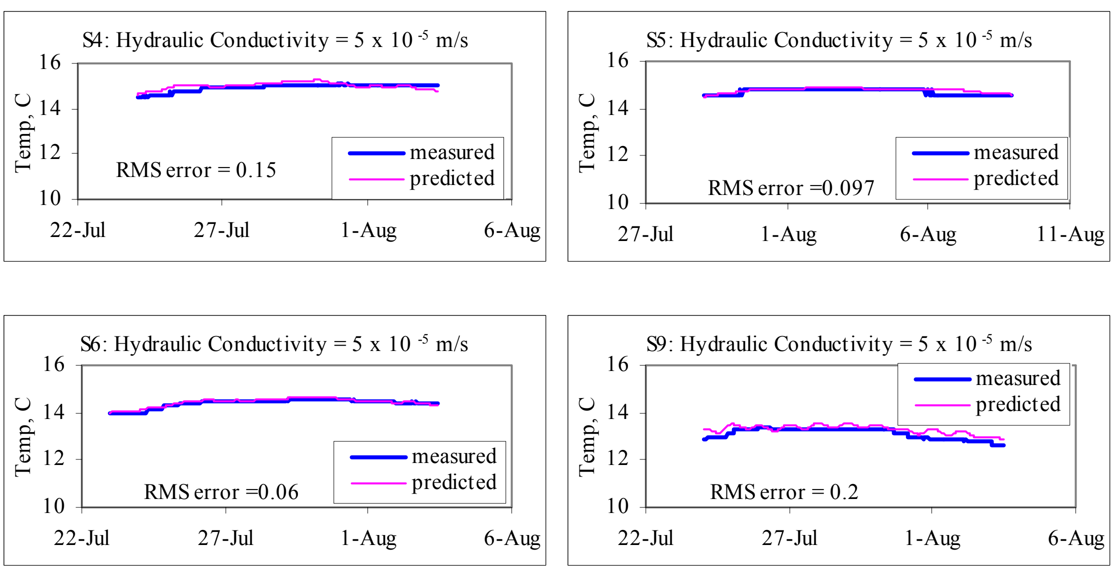


Figure 50. VS2DHI calibrated temperature profiles at mid-depth of piezometers at selected Skookum Creek mainstem stations.

The following aggregate soil properties were established at the end of model calibrations and were used in the QUAL2Kw model:

- hydraulic conductivity, K = $5 \times 10^{-5}$ meters per second
- porosity, p=37.5%
- thermal conductivity $\kappa_S$ =1.8 watt per meter per degree Celsius (W/m/ºC)
- volumetric heat capacity of sediments, Cs = $3.3 \times 10^{6}$ Joule per cubic meter per degree Celsius ($J/m^3/ºC$)
- coefficient of thermal diffusivity, $\alpha_s = \kappa_S / Cs$ = 0.0055 cubic centimeter per second ($cm^2/sec$)

# Riparian Vegetation and Effective Shade

In addition to stream hydrology, stream shade resulting from riparian vegetation and channel morphology are significant factors that influence stream temperature. Estimation of effective shade for both existing and site potential conditions will be discussed next.

## Existing riparian vegetation

To obtain a detailed description of existing riparian conditions, a combination of field data on tree heights and species, interpretation of aerial photography, and Geographical Information System (GIS) analysis were used. The ArcView GIS dynamic segmentation method was used to produce 100-meter stream segments. In addition, a 50-ft (15.2 m), 100-ft (30.5 m), and 150-ft (45.7 meters) buffer from each side of Skookum Creek was delineated, as shown in Figure 51.

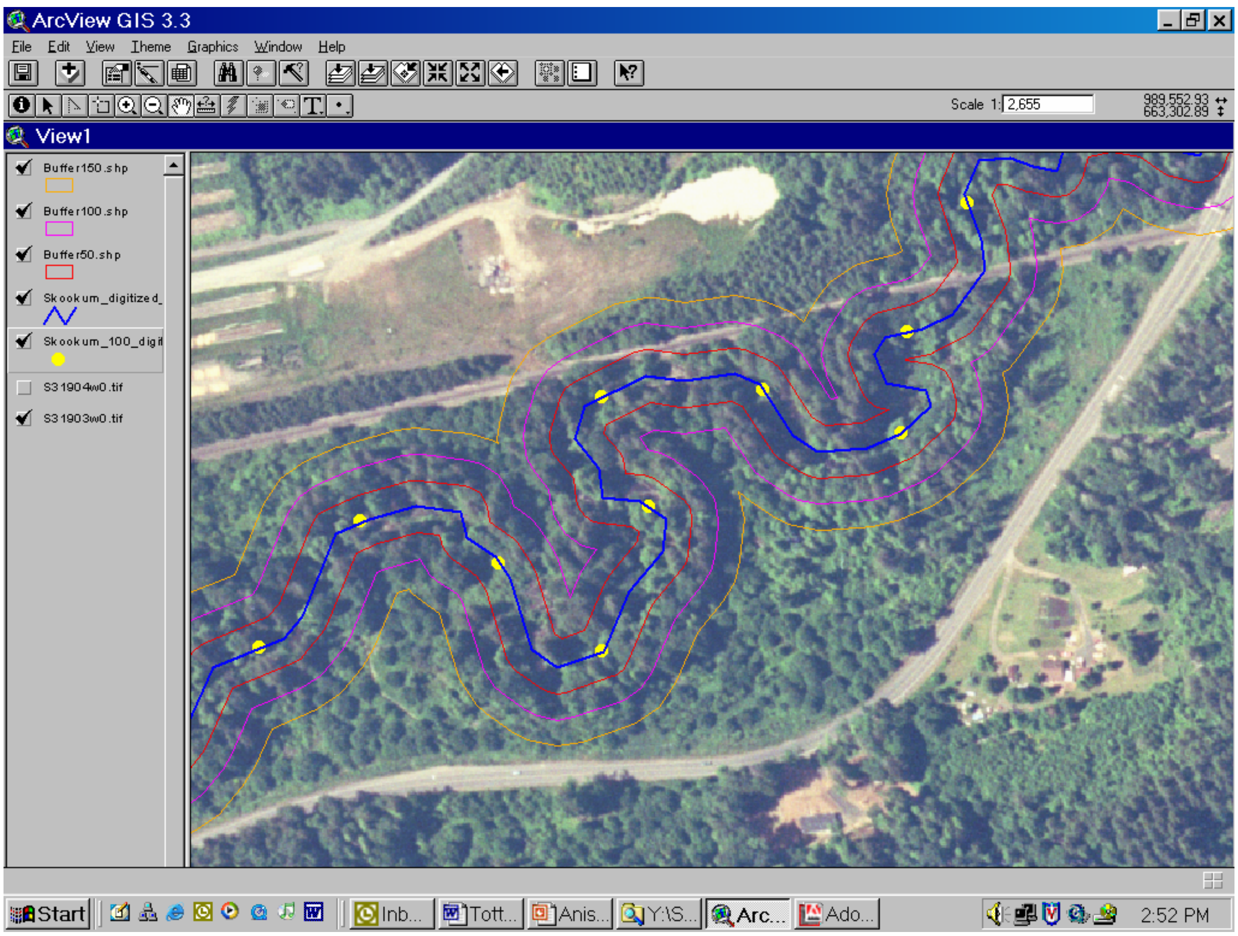


Figure 51. Example of the digital orthophoto quad (DOQ) and digitized channel buffers for Skookum Creek.

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Vegetative polygons made up of stream-segment lengths and the buffers were mapped at 1:3000 scale. A vegetation type code was assigned to each delineated polygon using either a black-and-white or a full-color digital orthophoto quadrangle (DOQ). The original DOQ has a resolution of 3-ft pixel size. No color DOQs were available for upper Skookum Creek. To supplement the black-and-white photos and to increase the accuracy of image interpretation (riparian vegetation type and density), digital photographs acquired during the TIR survey were used. These digital images (about 1020 images) were taken from low altitude (about 366 m) and collected sequentially with about 40% overlap with a ground width of approximately 130 meters. The survey was conducted on August 13, 2004 between 1:45 PM and 3:00 PM. The TIR images were more accurate, and specific details such as tree shadows helped in deciphering the species composition and relative heights. Field observations of vegetation type, height, and density were also compared against digitized GIS data. Appendix G contains field data on tree heights, species, and density, collected on August 16, 2004 and April 28, 2005.

The assigned vegetation code for each vegetation polygon then represented four attributes: tree height, species, percent vegetation overhang, and average canopy density. The above procedure was deemed more accurate and efficient compared to other methods (Cristea, 2004).

## Site potential riparian vegetation and shade

The riparian vegetation potential was estimated based on the expected maximum height of trees (50 years growth) and density. The Washington State Department of Natural Resources provides soil coverage (http://www3.wadnr.gov/dnrapp6/dataweb/dmmatrix.html) containing digitized soil delineations and soil attributes. One of the attributes in the soil coverage is site index data which contains information on the height of the dominant tallest trees in a stand. The age of the trees chosen is 50 years for western Washington.

The soil coverage was used to produce a 150-foot riparian buffer zone along both sides of mainstem Skookum Creek using ArcView GIS. Soil type within the buffer zone is estimated to produce a Douglas fir with a maximum height of 38.6 meters in 50 years. The maximum average height of trees estimated from field data was 30.5 meters. A tree height of 30 meters was used in estimating system potential temperature to provide some factor of safety. The maximum potential density of trees along the stream corridor will vary depending primarily on the presence of roads and tributaries. An 85% density was assumed as an estimate of riparian vegetation density potential. The ortho-photographs showed an excess of 95% tree density in some areas of Skookum Creek. In addition, a 1-meter overhang for coniferous trees was assumed. (The standard overhang for coniferous trees is 3 meters.)

## Effective shade calculations

The attributes of vegetation in the riparian zone on the right and left banks were sampled from GIS coverages of the riparian vegetation along the stream at 100-meter intervals and laterally at 50-ft (15.2 m), 100-ft (30.5 m) to 150-ft (45.7 m) intervals using the Ttools extension for ArcView developed by Oregon Department of Environmental Quality (ODEQ, 2001). The vegetation attributes were codified and entered into the Shade Model (Ecology, 2003). The Shade Model is based on the shade calculation method of Chen (1996). Other spatial data estimated with Ttools at each transect location included stream aspect (streamflow direction in decimal degrees from north), elevation (sampled from 10-meter digital elevation maps), and topographic shade angles to the west, south, and east. These were also input into the Shade Model. Effective shade was estimated at 400-meter intervals along the streams for input to the QUAL2Kw model. The Shade Model estimates stream segment shade levels as aerial percent shade, with 100% meaning that the whole stream segment is shaded. During the QUAL2Kw calibration process, effective shade was allowed to vary up to 30% to account for uncertainties in factors such as estimated canopy densities, tree heights, and overhang.

# QUAL2Kw Model Runs

The QUAL2Kw model (Pelletier and Chapra, 2004) was used to calculate the components of the heat budget and simulate water temperatures along the stream reach. QUAL2Kw simulates diurnal variations in stream temperature for a steady flow condition. QUAL2Kw was applied by assuming that flow remains constant for a given period, but key variables are allowed to vary with time over the course of a day. For temperature simulation, the solar radiation, air temperature, relative humidity, headwater temperature, and tributary water temperatures are specified or simulated as diurnally varying functions. QUAL2Kw uses the kinetic formulations for the components of the surface water heat budget that are described in Chapra (1997). Diurnally varying water temperatures at 400-meter intervals along mainstem Skookum Creek were simulated using a finite difference numerical method.

Shade and QUAL2Kw model inputs such as stream elevation, gradient, aspect, latitude and longitude, and west, east, and south topographic shade angles at every segment were estimated using the Ttools extension for ArcView (ODEQ, 2001) from a 10-meter "digital elevation map" (DEM).

The thermal infrared surveys helped locate stream segments where temperatures are warmer and where riparian vegetation are absent. The survey also showed cooler stream segments resulting from either riparian shade or groundwater. The longitudinal temperature profile developed from the thermal infrared survey provided a basis for comparison and calibration of model-predicted longitudinal temperature profiles.

## Model calibration and confirmation

Two periods were selected for model calibration and confirmation: July 6-12 and July 27-August 2, 2004. A TIR survey was done on August 13, 2004. The genetic algorithm for auto calibration of QUAL2Kw, as developed by Pelletier (2005), was used to calibrate-verify the model to observed temperatures during two synoptic surveys conducted on July 12 and August 2. The Ryan-Stolzenbach solar parameter (used in the Ryan-Stolzenbach solar model, Pelletier and Chapra, 2004) was independently verified as 0.8, by plotting observed cloud-free solar radiation obtained from University of Washington's weather database, "Live from Earth and Mars" (http://www-k12.atmos.washington.edu/k12/grayskies/nw_weather.html), against predicted solar radiation using Solrad (http://www.ecy.wa.gov/programs/eap/models/index.html), a solar radiation calculator developed by Ecology.

During calibration of the QUAL2Kw model, effective shade for each segment was allowed to vary by 30% from the effective shade values obtained from Ecology's Shade Calculator (Ecology, 2003). Cloud cover was also allowed to vary for the whole stream by 30% of the average values obtained from Sanderson Field Airport weather station in Shelton. Both the depth of hyporheic zone and the percent of streamflow in the hyporheic zone were allowed to vary over a range of values (see *Hyporheic Flow* section). Streamflow, cross-sectional area, and velocity were kept constant, but the width was allowed to be 40% less than measured widths. This increased the depth where needed for temperature calibration. This was necessary since a rectangular channel was assumed, the actual configuration of the stream reaches were uncertain, and the temperature devices were installed generally at the deepest end of the creek cross section.

Figure 52 shows the observed and predicted temperatures for August 2, 2004 following calibration of the QUAL2Kw temperature model. The longitudinal temperature profile observed during the TIR flight is also shown in Figure 52. The TIR method measures the water surface temperatures (Watershed Sciences, Inc., 2005), but it shows the general trend along the stream. Model confirmation was done using a lower stream temperature period, i.e., July 12, 2004. Figure 53 shows the observed and predicted stream temperatures for this date. During model confirmation, only the flow and weather conditions were changed.

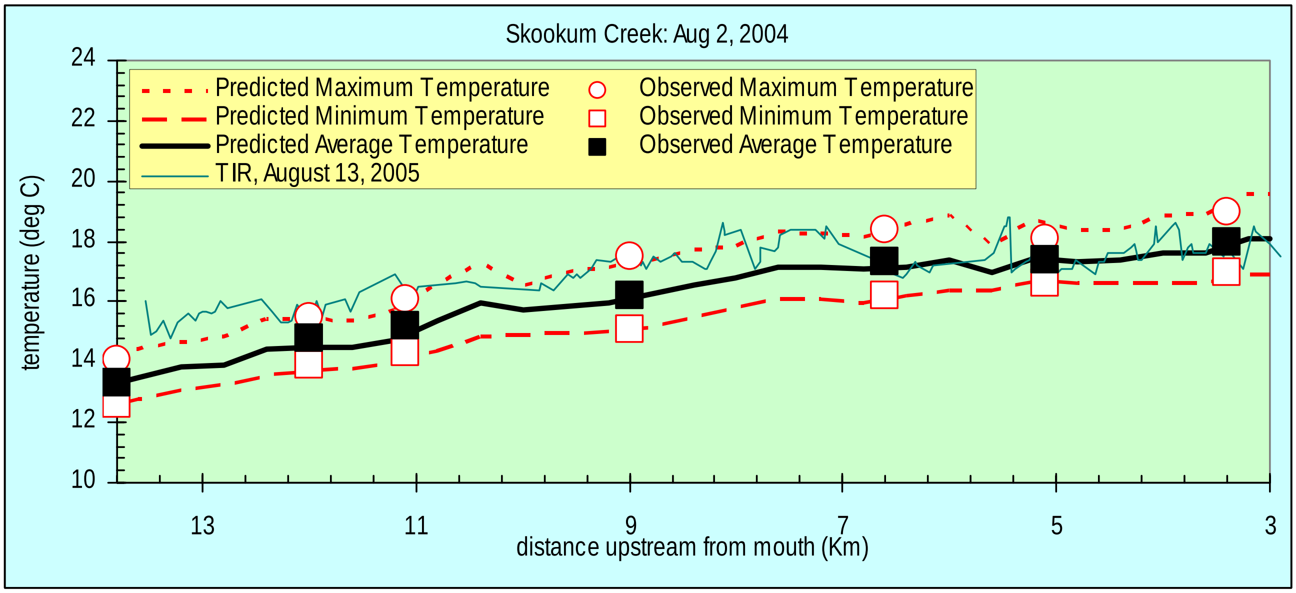


Figure 52. Model calibration: Observed and predicted stream temperatures in Skookum Creek, August 2, 2004.

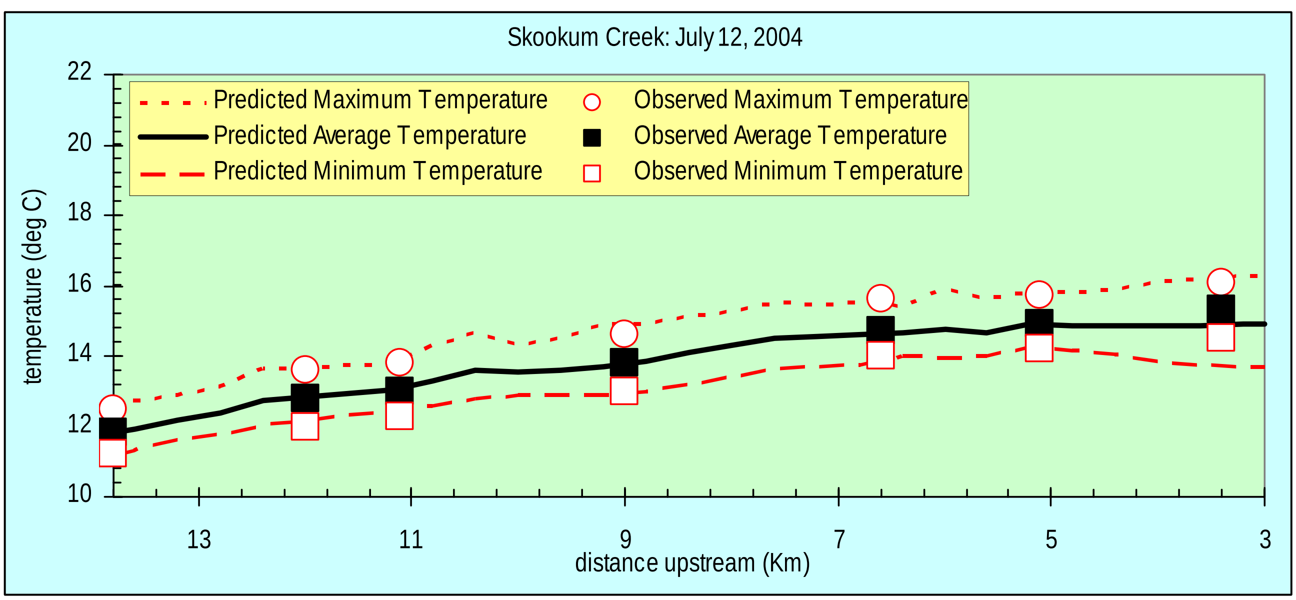


Figure 53. Model confirmation: Observed and predicted stream temperatures in Skookum Creek, July 12, 2004.

Table 16 shows the root mean square error (RMSE) between the observed and predicted temperatures for both model calibration and confirmation. There was good agreement between observed and predicted temperatures during model calibration and confirmation.

Table 16. Summary of the RMSE between observed and predicted Skookum Creek maximum and minimum temperatures.

| Temperature: | Root Mean Square Error, ºC | |
|---|---|---|
| Type: | model calibration | model confirmation |
| Maximum | 0.3 | 0.16 |
| Average | 0.2 | 0.18 |
| Minimum | 0.2 | 0.35 |

## Critical conditions and maximum temperatures under existing conditions

A 7Q10 flow of 1 cfs (0.028 cms) was used for the critical condition. Cloud cover was assumed to be absent (i.e., a clear day was assumed). Regional air temperature was assumed to be the 90$^{th}$ percentile of the last 50 years of 7-day average daily maximum temperatures. The critical local air temperatures at Skookum Creek, based on the 90$^{th}$ percentile regional air temperature, was estimated based on relationships developed for maximum and minimum air temperatures between the Shelton weather station and observed air temperatures at Skookum Creek, as discussed below.

Limited historical air-temperature data were available from Shelton's Sanderson Field weather station (http://cdo.ncdc.noaa.gov). Therefore, long-term historical data from the Olympia Airport weather station (http://www-k12.atmos.washington.edu/k12/grayskies/nw_weather.html ) were used. The two data sets were found to be very closely correlated as shown in Figure 54. The long-term 90$^{th}$ percentile 7-day average of the daily maximum regional air temperature was estimated as 29ºC in August 2002.

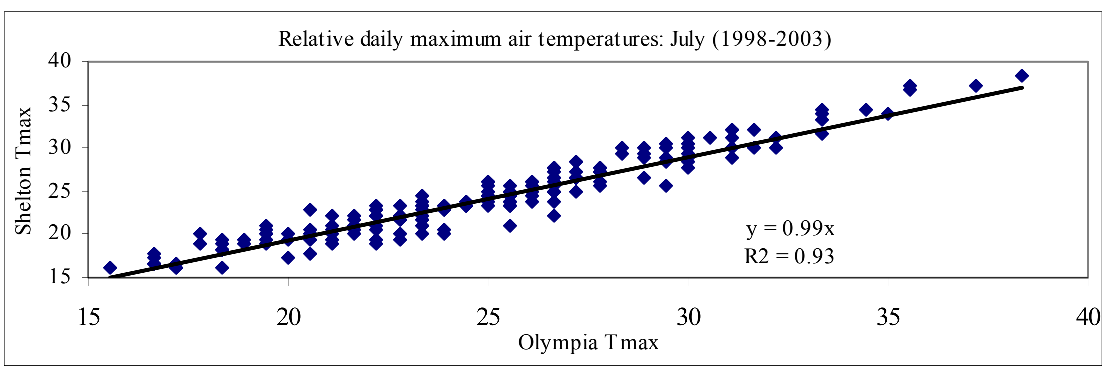


Figure 54. Relative daily maximum air temperatures at Shelton and Olympia weather stations.

The maximum local air temperature at the stream is generally lower relative to the regional air temperature due to the presence of shade along the riparian corridor. Figure 55 shows that the maximum local microclimate air temperatures were on average 1.5ºC cooler compared to Shelton weather station temperatures in summer 2004. On the other hand, the minimum local microclimate air temperatures were either similar to or slightly warmer (air at Station S3 was 1ºC warmer) than regional minimum air temperatures. The relationships in Figure 55 were used to estimate local air temperatures based on regional temperatures during the critical period (July-August). The diurnal air temperature variation during the critical period was assumed to be similar to that observed in the field for the high temperature scenario (i.e., August 2, 2004).

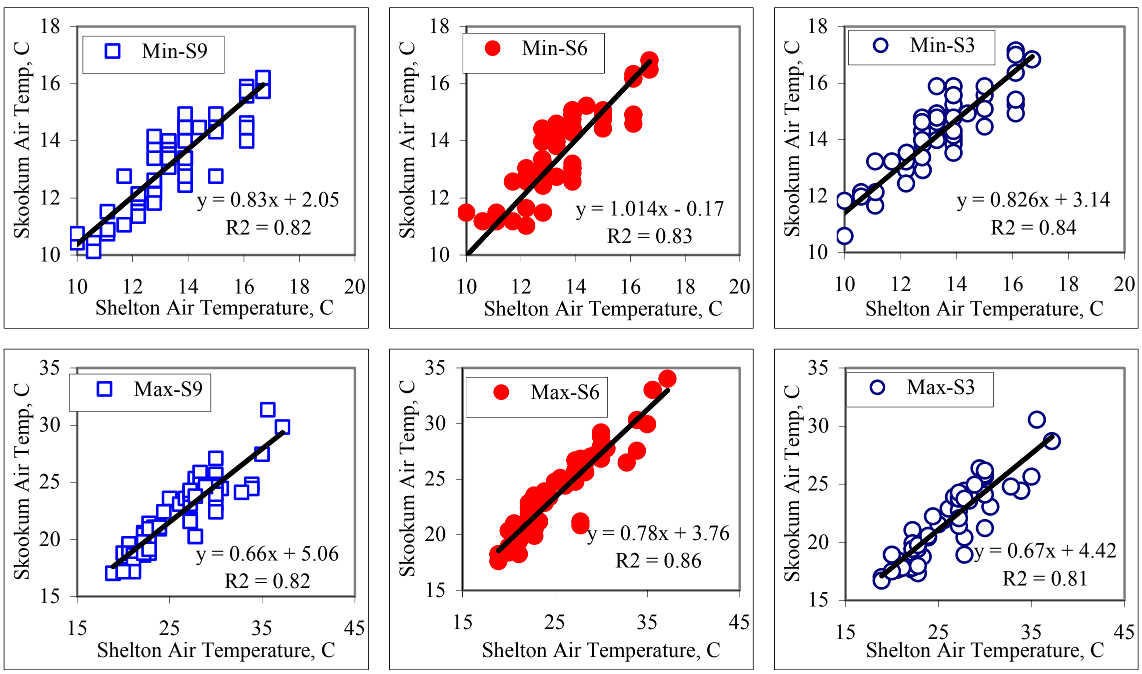


Figure 55. Minimum and maximum microclimate air temperatures at Skookum Creek due to local shade (July-Aug, 2004).

It is likely that as this TMDL is implemented and riparian vegetation matures, the maximum microclimate temperature will get cooler. Bartholow (2000) noted that mature riparian vegetation would reduce local air temperature, decrease local groundwater temperature, and reduce stream widths. All these factors would result in cooler stream temperatures. Estimation of the effects of these factors on temperature, upon implementation of the TMDL, is not possible at this time. Therefore, the cooling tendency of these factors would be considered as part of the margin of safety for this TMDL.

Figure 56 shows the scenario with existing shade under critical conditions. The maximum stream temperature under critical conditions can be as high as 20 ºC.

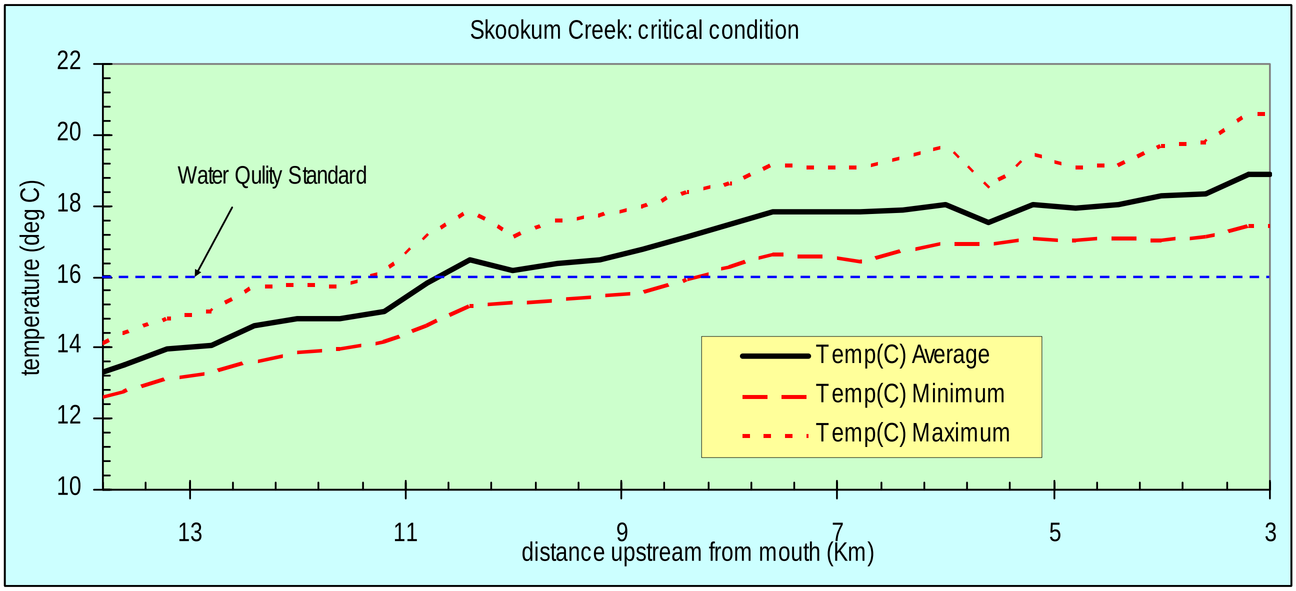


Figure 56. Predicted water temperatures in Skookum Creek under critical conditions.

## System potential temperature

The calibrated and confirmed model was used to predict the system potential temperature under maximum expected shade (see *Site Potential Riparian Vegetation and Shade* section), 7Q10 flow conditions, no cloud cover, and 90$^{th}$ percentile of maximum historical air temperatures. This scenario is the same as the critical condition scenario in the previous section except this scenario has mature riparian vegetation. Figure 57 shows the system potential temperatures with 85% vegetation density with tree heights of 30 meters and an overhang of 1 meter.

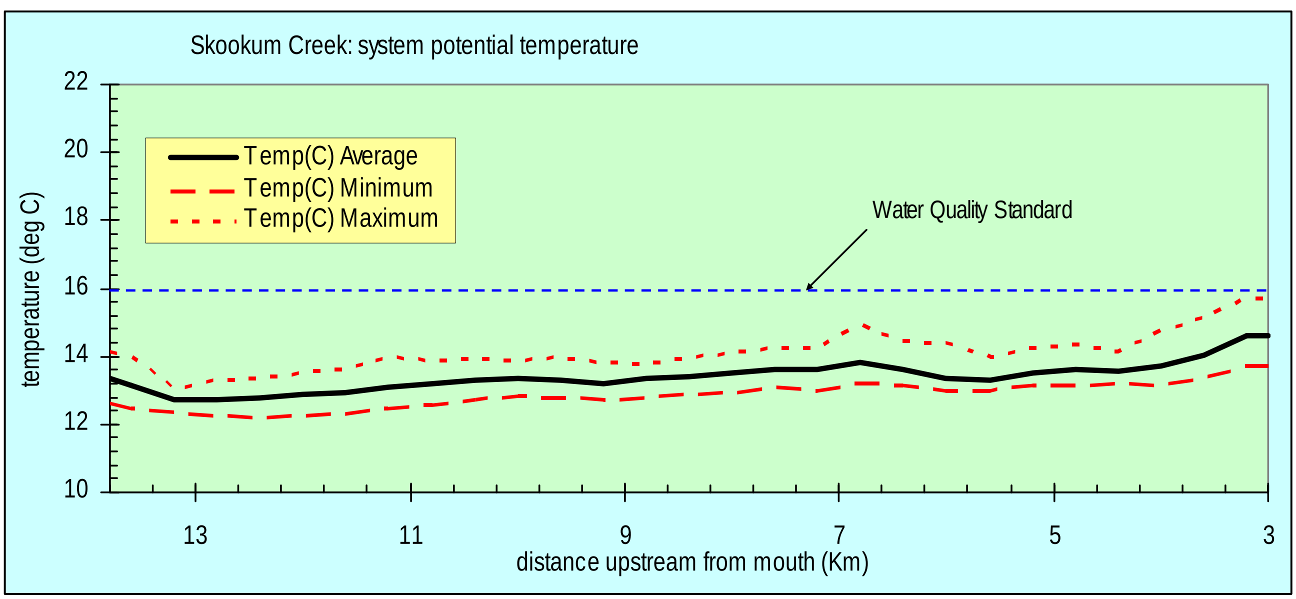


Figure 57. Predicted water temperatures in Skookum Creek under critical conditions with mature vegetation.

## Comparison of increased flow and shade on predicted temperatures

If it were possible to increase flow in the stream under critical conditions, the increased flow alone would not be sufficient to bring water temperatures down to below the water quality criterion of 16 ºC. Figure 58 shows the effect of increased flow on stream temperatures under existing riparian vegetation conditions.

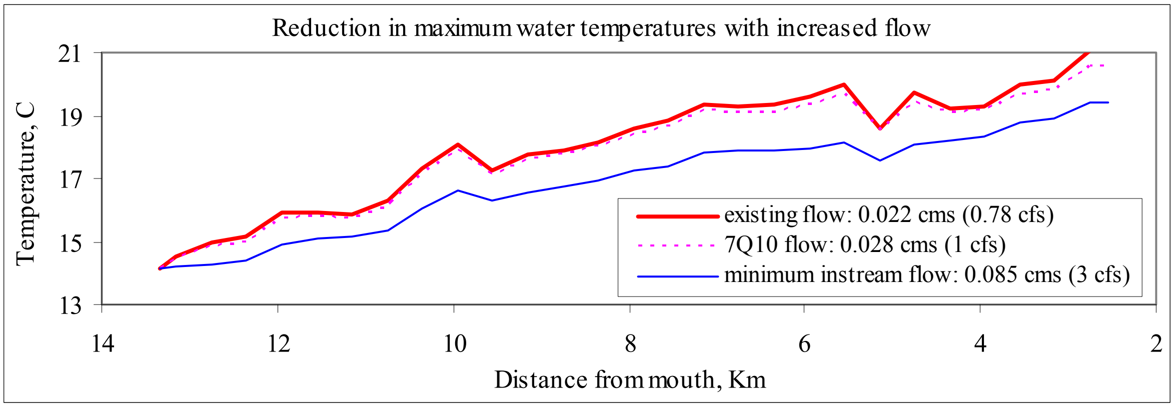


Figure 58. Effect of increased flow on predicted maximum stream temperatures.

Table 17 shows the effect of increasing instream flows and shade on stream temperatures. The impact of potential shade has a relatively significant effect on stream temperature compared to increasing streamflows.

Table 17. Effect of increasing streamflows and shade on predicted temperatures.

| | Temperature (ºC) predicted at stated gage flow and shade conditions | | |
|---|---|---|---|
| Distance (km) | existing shade and 0.028 cms (1 cfs) | potential shade and 0.022 cms (1 cfs) | existing shade and 0.085 cms (3 cfs) |
| 13.35 | 14.1 | 14.1 | 14.1 |
| 13.15 | 14.4 | 14.0 | 14.2 |
| 12.75 | 14.8 | 13.1 | 14.3 |
| 12.35 | 15.0 | 13.3 | 14.4 |
| 11.95 | 15.7 | 13.3 | 14.9 |
| 11.55 | 15.8 | 13.5 | 15.1 |
| 11.15 | 15.7 | 13.6 | 15.1 |
| 10.75 | 16.1 | 14.0 | 15.3 |
| 10.35 | 17.1 | 13.9 | 16.1 |
| 9.95 | 17.9 | 13.9 | 16.6 |
| 9.55 | 17.1 | 13.9 | 16.3 |
| 9.15 | 17.6 | 14.0 | 16.6 |
| 8.75 | 17.7 | 13.8 | 16.8 |
| 8.35 | 18.0 | 13.8 | 17.0 |
| 7.95 | 18.4 | 14.0 | 17.2 |
| 7.55 | 18.6 | 14.1 | 17.4 |
| 7.15 | 19.1 | 14.2 | 17.8 |
| 6.75 | 19.1 | 14.3 | 17.9 |
| 6.35 | 19.1 | 14.9 | 17.9 |
| 5.95 | 19.3 | 14.5 | 18.0 |
| 5.55 | 19.7 | 14.4 | 18.1 |
| 5.15 | 18.5 | 14.0 | 17.6 |
| 4.75 | 19.4 | 14.3 | 18.1 |
| 4.35 | 19.1 | 14.3 | 18.2 |
| 3.95 | 19.1 | 14.1 | 18.3 |
| 3.55 | 19.7 | 14.8 | 18.8 |
| 3.15 | 19.8 | 15.1 | 18.9 |
| 2.75 | 20.6 | 15.7 | 19.4 |
| 2.55 | 20.6 | 15.7 | 19.4 |

## Temperature Loading Capacity and Load Allocations

Loading capacity in a temperature TMDL means the maximum amount of thermal pollution a waterbody can withstand and still meet state water quality standards. In the absence of point sources, as is the case with Skookum Creek, only load allocations are assigned.

Load allocations are the shade values necessary within each segment to bring stream temperature within water quality standards under critical conditions. The site-potential shade values are used as load allocations.

Table 18 shows the shade loading capacities along each stream reach required to bring the stream temperature to below water quality standards.

Table 18. Load allocations for effective shade for Skookum Creek.

| Stations and Landmarks | Upstream (km) | Downstream (km) | Average Target Effective Shade (%) | |
|---|---|---|---|---|
| | | | Potential | Deficit |
| S9, below confluence of N and S forks | 13.35 | 12.95 | 90% | 20% |
| | 12.95 | 12.55 | 90% | 40% |
| | 12.55 | 12.15 | 90% | 20% |
| | 12.15 | 11.75 | 90% | 40% |
| S8, upstream of upper Hwy 108 bridge | 11.75 | 11.35 | 80% | 30% |
| | 11.35 | 10.95 | 90% | 25% |
| | 10.95 | 10.55 | 90% | 20% |
| | 10.55 | 10.15 | 90% | 50% |
| | 10.15 | 9.75 | 80% | 50% |
| | 9.75 | 9.35 | 90% | 5% |
| | 9.35 | 8.95 | 90% | 30% |
| | 8.95 | 8.55 | 90% | 40% |
| | 8.55 | 8.15 | 85% | 30% |
| | 8.15 | 7.75 | 80% | 50% |
| | 7.75 | 7.35 | 80% | 35% |
| | 7.35 | 6.95 | 80% | 40% |
| | 6.95 | 6.55 | 90% | 30% |
| S5, below Eich Road bridge | 6.55 | 6.15 | 90% | 40% |
| | 6.15 | 5.75 | 90% | 35% |
| | 5.75 | 5.35 | 90% | 40% |
| | 5.35 | 4.95 | 90% | 20% |
| S4, bridge at Stohr driveway | 4.95 | 4.55 | 90% | 40% |
| | 4.55 | 4.15 | 85% | 40% |
| | 4.15 | 3.75 | 90% | 50% |
| | 3.75 | 3.35 | 90% | 40% |
| S3, upstream of lower Hwy 108 bridge | 3.35 | 2.95 | 80% | 30% |
| Squaxin Island Tribal boundary | 2.95 | 2.55 | 70% | 40% |

## Margin of Safety for a Temperature TMDL

The margin of safety for this temperature TMDL is implicit through the use of conservative assumptions, summarized below.

- Shade loadings were based on system potential using existing average maximum tree heights, 85% vegetation density, and 1-meter canopy overhang. Conservative assumptions were made in estimating all these values.
- The critical conditions for load allocations used the lowest 7-day average flow with a 10-year recurrence interval.
- The critical condition air temperatures were 90$^{th}$ percentile of historical 7-day average of daily maximum temperatures.
- Mature riparian vegetation would reduce local air temperature, decrease local groundwater temperatures, and reduce stream widths. These factors would result in cooler stream temperature than those predicted, providing an additional factor of safety.

## Post-TMDL Monitoring Strategy for a Temperature TMDL

To determine the effects of improved shade through managed riparian vegetation, regular monitoring of Skookum Creek is recommended. Continuously-recording temperature devices should be used between July and August to capture critical conditions. At a minimum, a downstream location near Highway 8 (Station S3) should be monitored. In addition, other upstream locations may also be used.

The recommended effective shade will take many years to develop through mature riparian vegetation; therefore, monitoring is recommended at the stream segments at intervals of five to ten years. A report card should be maintained to track the following:

- Type and extent of existing vegetation
- Type, extent, and dates when new vegetation was planted
- Type and extent of riparian vegetation (at five-year increments)
- Riparian erosion
- Temperature improvement, if available
- Effective shade improvement, if available

The data from the report card can be used to manage riparian vegetation growth, make improvements where vegetation is not growing as expected, deploy temperature measuring devices where needed, and stabilize banks where erosion is observed.

# Implementation Strategy

This strategy describes the framework for improving water quality in seven streams that drain to Totten, Eld, and Little Skookum inlets. It describes the types of activities that will be conducted and the entities, authorities, and programs that will be used. Ultimately, the actions of individual landowners determine water quality.

## Background

Need to reduce bacteria:

- McLane Creek
- Schneider Creek
- Perry Creek
- Kennedy Creek
- Pierre Creek
- Burns Creek
- Skookum Creek

Needs to reduce temperature:

- Skookum Creek

These streams flow into marine water, where bacteria concentrations can affect shellfish harvest. In the creeks themselves, the amount of bacteria indicates a potential health risk to recreational users. In addition to having too much bacteria, water temperature is too warm in Skookum Creek to support a diverse and healthy environment for aquatic animals. Salmon, especially, require cool water.

Local jurisdictions, the Squaxin Island Tribe, landowners, and citizens groups have been working to protect and restore these areas since the 1980s. Watershed Action Plans were completed for Totten/Little Skookum and Eld inlets in 1989. These plans have helped guide a variety of water quality improvement actions including dye testing of septic systems, availability of low-interest loans for septic system repair, conservation planning, installation of best management practices (BMPs), education and outreach, riparian restoration, and water quality monitoring.

Eld Inlet, in particular, has experienced fluctuations in bacteria levels that have affected commercial shellfish harvest. In 1983, the state Department of Health downgraded shellfish growing areas in the south end of the inlet from *Approved* to *Conditionally Approved*. Major sources of bacteria were identified as on-site septic systems and poor livestock keeping practices. Since 1993, Thurston County has adopted a nonpoint pollution control ordinance, set rural residential density at one unit per five acres in most areas, and revised its on-site sewage code. In the mid-1990s, Thurston County Health District staff conducted rigorous inspections of on-site sewage systems along the marine shoreline. Thurston Conservation District focused efforts on livestock sources in the Eld Inlet watershed in the mid-1990s, conducting surveys and outreach, developing conservation plans, and installing BMPs. These efforts, with the support of landowners, resulted in the upgrade of 450 acres of growing area in 1998.

Grant funding to support much of the work of Thurston Conservation District and Thurston County ended in the late 1990s. In 2002, areas of Eld Inlet were placed back on Department of Health's *Threatened* list. Data from 1999-2004 show increasing fecal coliform levels at the three most southerly stations (Sargeant, 2005). Thurston Conservation District continues to provide technical assistance to landowners in the area, upon request.

Historically, water quality has been good in Totten and Little Skookum inlets. In 1993 the Totten-Little Skookum Shellfish Protection Area (more commonly called a Clean Water District) was formed. As a result, Mason County received funding to perform extensive dye tests of septic systems in the area. The dye testing and repair goals were accomplished by the mid-1990s. During this same period, Mason Conservation District was working with livestock owners in the watershed, evaluating properties and prioritizing potential water quality impacts. Guided by these priorities, they worked with landowners to provide technical assistance, develop farm plans, and design and implement best management practices (BMPs). Since grant funding to support this work ended, water quality improvement work in this area has been greatly reduced.

## What Needs to be Done?

### Fecal coliform bacteria

Cleanup activities will first target the most likely human-related sources of bacteria, and will focus on those areas shown by the technical analysis to be the biggest sources of bacteria:

- *Livestock waste* is suspected of being the largest contributor of bacteria to creeks in this area *(Little Skookum Inlet Watershed Assessment,* Taylor, Moreland and Stevie, Squaxin Island Tribe, February 1999). Management practices to reduce the amount of bacteria going into streams typically include:
  - restricting livestock access to creeks
  - riparian restoration
  - good pasture management
  - controlling roof runoff, and
  - other manure management measures.

  An important first step will be to evaluate the improvements made in the 1990s. Are they still in place? Are they still effective? Have land uses changed?

  Technical assistance and, when possible, cost-share incentives will be the primary approach to reducing bacteria from livestock. Education outreach will also be important, to build awareness of issues and involve landowners in developing solutions.

  Where known sources exist and voluntary approaches are insufficient, enforcement is possible by both county and state jurisdictions.

- *Failing septic systems* can leak bacteria and other pathogens into nearby waterbodies. Activities to reduce this source include:
  - investigation to identify sources (may include dye testing, sampling seeps or stream segments, or other methods)
  - using local regulations to initiate corrections
  - education and outreach.

  As funding opportunities allow, support may be available to help landowners take care of problems. This might include, for instance, inspection or pumping incentives, providing risers, and the availability of low interest loans for repairs.

- *Pet waste* can contribute significant amounts of bacteria when left on a beach, along a creek shoreline, or near enough to a drainage ditch, storm drain, or watercourse to be washed in by runoff from rainfall. Outreach efforts will highlight the importance of managing this bacteria source. In some areas there may be a need and opportunity for structural solutions such as signs and pet waste stations. Large quantities of unmanaged waste, or intentional dumping could result in enforcement.

Following Environmental Protection Agency approval of this *Water Quality Improvement Report,* participating stakeholders will develop a detailed plan for improving water quality. We will identify and prioritize specific responsibilities, actions, and BMPs, and describe a general timeline and potential funding sources.

Improving water quality will be an iterative process of evaluating and prioritizing potential sources, taking appropriate action, evaluating results and determining next steps. We may identify the need for additional actions during the detailed planning process, or as ongoing monitoring evaluates the effectiveness of actions taken. The entities described in the *Who Will Participate* section below, and possibly others, will work together to coordinate the process.

The technical analysis in this report evaluates data from Ecology, the Squaxin Tribe, and local jurisdictions. It provides an analysis of bacteria concentrations, guidance on how much reduction is needed in order to meet water quality standards, and a relative look at how much bacteria the tributaries contribute to the marine environment (loading). These analyses, combined with local knowledge of land use, will be used to target resources and activities.

On Skookum Creek water quality was monitored at several locations. The other creeks were monitored only at the mouth. Therefore, the technical analysis for those creeks provides evaluation of water quality and pollution loads only at the creek mouths. Many questions remain unanswered about specific sources and source areas. In some cases, conclusions from the analysis cannot be easily explained by observed land use patterns. Other questions will arise during the course of the cleanup. Monitoring, investigation, and evaluation will be an ongoing need. This might include water quality sampling, land use surveys, creek walks, dye testing of on-site septic systems and other methods as identified by the coordinating group. Monitoring will likely be accomplished through a combined effort involving the counties, state, volunteers, and student groups.

Additional studies may also be needed. For example:

- Several waterbodies in this region exhibit elevated late summer bacteria concentrations that cannot be readily explained by land use. The technical advisory committee believes that the elevated summer bacteria levels may not be caused by the sources typically associated with wet weather runoff such as on-site sewage systems, agriculture, and stormwater. The need for a region-wide study of this dry weather phenomenon in rural streams has been discussed.
- Kennedy Creek is a relatively undeveloped watershed with few traditional sources to explain the elevated bacteria levels. Sampling for klebsiella may be advisable. Klebsiella is a type of coliform bacteria often associated with wood waste. With typical laboratory analytical methods, it can show up as fecal coliform bacteria. Since klebsiella is not regulated under Washington's water quality standards, its presence can create a "false" violation. On the other hand, federal standards governing DOH's regulation of commercial shellfish harvest do not allow for a distinction between klebsiella coliforms and fecal coliforms, so the effect on shellfish harvest can still be negative.
- Microbial source tracking study may be warranted. These studies can identify source types (i.e., human, canine, bird, cow), but they are not able to quantify the sources, so they are typically used later in the cleanup process when more conventional approaches have not proven adequate.

In addition to Totten/Eld/Little Skookum, a number of other water quality improvement efforts are underway in both Mason and Thurston counties. Basic funding to agencies is not enough to adequately address all the needs. Area-wide priorities and the availability of funding for water quality activities will affect the level and timing of efforts in the area.

### Temperature

Shade and the amount of flow are the two most significant factors affecting stream temperature in Skookum Creek. Modeling demonstrates that higher streamflows will cool the water, but the incremental improvement is much smaller than increasing shade. Modeling shows that temperatures in Skookum Creek will be lowered to healthy levels by restoring the riparian areas. This report expresses the required temperature improvements in terms of needed shade. Technical and cost share assistance is available to landowners.

## Who Will Participate?

The people who live in and use the Totten/Eld watershed will ultimately be responsible for improving water quality. The following agencies and groups will be working, in the various roles described below, to help landowners recognize and make needed changes.

### Environmental Protection Agency (EPA)

EPA is ultimately responsible for seeing that the federal Clean Water Act is implemented, and water quality is restored. EPA must approve TMDL technical analyses. They also provide water quality-related funding.

## Mason Conservation District (MCD)

Mason Conservation District, under the authority of Ch. 89.08 RCW, develops farm plans to protect water quality by providing education and technical assistance to residents. Their work is non-regulatory.

They work with landowners to develop BMPs that realize maximum productivity while protecting the quality of both surface and underground water resources. The Mason Conservation District is able to provide financial support for BMPs to some landowners through cost share programs which are funded by state and federal agencies. When developing farm plans, the district uses guidance and specifications from the U.S. Natural Resource Conservation Service.

The Mason County Board of Commissioners established a special assessment under RCW 89.08.400 for natural resource protection. Through an inter-local agreement, this assessment provides funding to both the Conservation District and Mason County Health Services and gives them the responsibility to conduct programs and activities to address resource protection issues. The District also receives grants from the Conservation Commission, Ecology, the Salmon Recovery Funding Board, and others.

Landowners may receive a Notice of Correction from Ecology if management practices on their land could potentially pollute waterbodies (for instance, livestock in the creek or lack of vegetation along a streambank). Typically, the notice will refer the landowner to Mason Conservation District for assistance.

## Mason County

The Mason County Department of Community Development regulates land use and development in the Totten and Little Skookum watersheds through the Mason County Comprehensive Plan, Mason County Development Regulations, and the Mason County Resource Ordinance in compliance with Washington State's Growth Management Act, Ch. 36.70A. The fish and wildlife habitat conservation chapter of the resource ordinance addresses buffers widths for streams, lakes, and saltwater shorelines. These regulations apply to development activities in Mason County.

Mason County water quality improvement programs are funded through an Intergovernmental Agreement between the Mason Conservation District and Mason County Health Services (MCHS). The Intergovernmental Agreement gives the county responsibility to monitor surface and groundwater by and near assessed parcels and to investigate water quality complaints.

In accordance with the Intergovernmental Agreement, Mason County Health Services maintains a water quality resource protection program that includes a county-wide surface water monitoring program. Long-term ambient monitoring data are collected for 36 major streams. In any given month an additional 30 to 50 sites may be selectively monitored to help provide more in-depth assessment of specific water quality issues. This level of sampling is short term only and fluctuates according to need, funding, and staff availability.

Mason County currently monitors Kennedy Creek, Skookum Creek, and a tributary to Schneider Creek as part of the ambient monitoring program. Monitoring is for pH, turbidity, dissolved oxygen, temperature, conductivity, and fecal coliform. The County may undertake dye tracing of septic systems that are believed to be related to poor water quality.

Minimum on-site septic system requirements are established by Washington Department of Health (DOH) in Chapter 246-272A WAC. Mason County has established further requirements under Mason County Code Chapter 6.76. Code requires that an operations and maintenance (O&M) report of every septic system be submitted to Mason County Health Services at least once every five years as part of a county-wide septic system O&M program. On-site staff investigate on-site septic system complaints and unsatisfactory septic O&M reports. They use appropriate enforcement action as outlined in MCHS on-site policies as needed. The on-site program and O& M programs are fee supported.

## Natural Resources Conservation Service (NRCS)

The NRCS works in partnership with Mason and Thurston Conservation Districts to improve water quality and conservation. Resources are targeted to address water quality priorities identified through watershed planning, Washington Department of Health surveys, TMDLs, and other planning processes. The NRCS administers all of the programs in the 2002 Farm Bill, including:

- Conservation of Private Grazing Land Initiative
- Conservation Security Program
- Conservation Technical Assistance
- Environmental Quality Incentives Program
- Emergency Watershed Protection Program
- Farm and Ranch Lands Protection Program
- Grassland Reserve Program
- Plant Material Program
- Resource Conservation and Development Program
- Snow Survey and Water Supply Forecasts Program
- Soil Survey Programs
- Technical Service Providers
- Wetlands Reserve Program
- Wildlife Habitat Incentives Program

These programs are available to landowners in both Mason and Thurston counties. Several of the programs provide cost-share incentives to landowners who commit to implementing certain conservation practices. For more information on Farm Bill programs, go to www.wa.nrcs.usda.gov/programs/index.html

In addition to these programmatic resources, the NRCS provides staff time and technical expertise to support restoration efforts.

## Puget Sound Water Quality Action Team

The Puget Sound Water Quality Action Team, under authority of Chapter 90.71 RCW, works with governments and organizations across the region to carry out the Puget Sound Water Quality Management Plan. Under different parts of the plan, agencies and governments provide technical and financial assistance to control pollution from septic systems, farm animal wastes and stormwater runoff. Support staff of the Action Team assist directly with programs to protect and restore shellfish harvesting in Puget Sound. The Action Team also administers grant funds for public involvement and education projects.

## Southwest Puget Sound Watershed Council

The purposes of the citizen-based Southwest Puget Sound Watershed Council include:

- Maintaining and restoring a healthy ecosystem throughout the Southwest Puget Sound watershed by developing public awareness and a sense of stewardship among residents, landowners and other users of the watershed
- Encouraging sound land-use practices that protect water quality and the natural resources of the watershed
- Identifying and promoting projects to improve recreational opportunities and the environmental and economic health of the watershed
- Providing advocacy for the watershed

The Council provides watershed resident representation and perspective to the cleanup effort. They will participate in cleanup oversight and cleanup activities, as they deem appropriate to their mission.

## Thurston Conservation District (TCD)

Thurston Conservation District under authority of Ch. 89.08 RCW, works in a non-regulatory way to provide education and technical assistance to residents, develop conservation plans, and assist with design and installation of best management practices. When developing conservation plans, the district uses guidance and specifications from the U.S. Natural Resources Conservation Service. Landowners in Thurston County who receive a Notice of Correction from Ecology will normally be referred to Thurston Conservation District for assistance.

Thurston Conservation District is funded by a county-wide district assessment, in accordance with Chapter 89.08.400 RCW. The district regularly receives funding from the Conservation Commission, and grant funding from Ecology, the Salmon Recovery Funding Board, and others.

The Conservation District conducts a yearly native plant sale, and provides funding for South Sound GREEN. South Sound GREEN is a student-based volunteer monitoring and education program. In addition to monitoring, students sometimes participate in restoration and planting activities and other water quality related activities. Funding to the TCD for Project Green is provided by the local jurisdictions (Cities of Olympia, Lacey, and Tumwater, and Thurston County.

## Thurston County

Thurston County has maintained a county-wide ambient surface water monitoring program for over 15 years. Focused mostly on the more urbanized north part of the county, the program includes approximately 20 sites, and tracks flow, macroinvertebrates, and ambient water quality. Site selection is part of an inter-jurisdictional local agreement, and is reviewed yearly and amended as appropriate, based on issues, needs, and funding. Urban areas of Thurston County will be regulated under the Clean Water Act Phase II NPDES stormwater permit, expected to be final by mid 2006.

The county regulates land use in unincorporated areas through zoning regulations and a Critical Areas Ordinance (CAO) (Ch. 18E.60.050), in accordance with Washington State's Growth Management Act, Ch. 36.70A. The ordinance is currently undergoing an update. The update proposes a significant increase to riparian and wetland buffer requirements along all classes of streams and wetlands, as well along marine shorelines. Thurston County is currently reviewing all comments received during the public comment and hearing process, and will report any proposed changes and updates to the draft CAO.

The county has created a Low Impact Development Advisory Committee to investigate the feasibility of developing Low Impact Development regulations and standards. The county was one of the jurisdictions chosen by the Puget Sound Action Team to receive technical and planning assistance from a consultant. The advisory committee is currently waiting for the consultant to provide the information necessary to move on to developing code revision language. The committee plans to develop a proposed action plan for the Board of County Commissioners in early 2006.

Minimum on-site requirements are established by Washington Department of Health (DOH) in Chapter 246-272A WAC, and the county has established further standards under Article IV of the Thurston County Sanitary Code. County compliance staff deal with on-site failures, usually in response to complaints. In addition, the health department conducts on-site investigations. These investigations are usually grant-funded, and conducted in response to known problems with specific geographic focus. Thurston County maintains a low-interest loan fund for repair of on-site septic systems, or to correct failing on-site sewage systems by connection to municipal sewer service where available.

Environmental Health educators conduct an on-going education program consisting of workshops, newspaper articles, displays with information racks, brochures, and a website. Each year eight "Septic Sense" workshops are held at community meeting locations throughout the county. The workshops are free to the homeowner. Typically 200 residents attend each year. Educational brochures are mailed with operational certificate renewals and to new residents.

Article VI, 4.2, of Thurston County Sanitary Code, requires landowners to prevent domestic animal waste from being washed into surface water, requires that manure be applied at agronomic rates, and prohibits intentional dumping of pet waste that will affect surface or storm water. Compliance with the ordinance is achieved through education, referrals to the Thurston Conservation District for technical assistance, and finally through legal action when necessary.

A review and update of this ordinance is planned in 2006. The County also provides educational brochures to Animal Services to be mailed with annual animal licenses.

## Squaxin Island Tribe

The Tribe has monitored water quality in this watershed since 1998. Using EPA Tribal grants, they track water quality, streamflows, shellfish health, and salmon productivity at key locations to identify emerging problems. They have monitored water quality in Skookum Creek since 1998. They are currently developing a set of water quality standards for Tribal lands that will meet or exceed Washington State water quality standards. The Tribe is active in shellfish and salmon habitat protection and restoration throughout South Puget Sound. They implement projects to improve water quality and benefit the Squaxin Island Tribe and the area's natural resources.

The Tribe has funding available to support riparian restoration.

## Washington Department of Agriculture

Under RCW 90.64, Washington Department of Agriculture Livestock Nutrient Management Program is responsible for regulating nutrient management activities related to all dairy and combined animal feeding operations (CAFOs) in Washington State. The goal of the Livestock Nutrient Management Program is to work with producers and stakeholders to protect water quality, promptly respond to complaints and concerns related to dairy and CAFO livestock operations, and promote a healthy dairy and livestock industry.

When the Department of Agriculture Livestock Nutrient Management Program confirms that poor farm management practices on dairies and CAFO livestock operations are likely to be adversely affecting surface waters, landowners are referred to local conservation districts for technical assistance. If necessary, the Nutrient Management Program can require specific actions under the Water Pollution Control Act (Ch. 90.48 RCW), such as implementation of an approved Nutrient Management Plan, updates to existing Nutrient Management Plans, Notices of Violation, Administrative Orders and Penalties to correct problems that impact water quality.

## Washington Department of Ecology (Ecology)

Washington Department of Ecology has been delegated responsibility under the federal Clean Water Act by the U.S. Environmental Protection Agency to establish water quality standards, coordinate water quality improvement projects (TMDLs) on waterbodies that fail to meet water quality standards, and enforce water quality regulations under the Water Pollution Control Act, Chapter 90.48 RCW. In addition to this regulatory role, Ecology provides financial assistance to local governments, tribes, conservation districts, and citizens groups for water quality projects. Projects that implement water cleanup plans for TMDLs are a high priority for funding.

For agricultural problems other than dairies or confined animal feeding operations, farmers may be referred to conservation districts for technical assistance if Ecology confirms that poor farm management practices are likely to be polluting surface waters. If necessary, Ecology can require specific actions under Ch. 90.48 RCW, such as implementation of an approved farm plan, to correct the problem.

Ecology is currently developing stormwater municipal NPDES Phase I and II permits. These permits cover nonpoint pollution in urbanizing areas. They are expected to be final in 2006.

Ecology issued Phase II of the Construction Stormwater NPDES Permit on November 16, 2005 and the new permit became effective on December 16, 2005. The permit is now required during the construction period on construction sites that will disturb 1 or more acre of land area.

## Washington Department of Health (DOH)

The Washington Department of Health (DOH), under authority of Ch. 43.70 RCW, regulates commercial shellfish harvest. As part of this program, they monitor marine water quality in commercial shellfish growing areas of the state including Totten, Eld, and Little Skookum inlets.

DOH establishes minimum on-site sewage system requirements in Chapter 246-272A WAC. DOH has recently revised this regulation. Different parts of the regulations are scheduled to take effect at different times. The majority of the revised sections will be in effect by July 1, 2007. One significant revision in WAC 246-272A-0015 requires local health jurisdictions in the Puget Sound region to develop comprehensive management plans for on-site systems by July 1, 2007. These management plans are expected to include, but are not limited to, requirements and activities related to operation and maintenance of on-site septic systems.

## Washington Department of Transportation (WSDOT)

WSDOT manages transportation systems and services that meet public needs. WSDOT manages storm water from state highways, including in this watershed:

- Highway 101, which crosses north-south over Perry, Schneider, Kennedy, and Skookum creeks. There are several roadside storm drains along Highway 101 (see Figure 1) that belong to Washington State Department of Transportation (WSDOT) that discharge to Schneider and Perry creeks.
- Highway 8, which runs east-west crossing Kennedy and Perry watersheds and connecting with Highway 101 near the mouth of Perry Creek.
- Highway 108, which runs northeast-southwest along Skookum Creek connecting with Highway 101 near the mouth of Skookum Creek.

WSDOT is required to have an NPDES stormwater permit in areas covered by Phase I and Phase II of the municipal stormwater permit program. The permit will cover stormwater runoff from state highways, rest areas, scenic viewpoints, park-and ride-lots, ferry terminals, and maintenance facilities.

The actual geographic scope of the permit is under discussion, and may be statewide. If WSDOT's discharges into Perry and Schneider creeks are not within a permitted area, sources will be considered nonpoint and required actions will be addressed on a project specific basis.

The target date for issuance of the new permit and approval of the WSDOT Stormwater Management Program is late fall 2006.

## Washington Sea Grant Program

The mission of the Washington Sea Grant Program is to encourage the understanding, use, conservation, and enhancement of marine resources and the marine environment through research, education, outreach, and technology transfer. Washington Sea Grant works with individuals and groups to better understand and conserve marine and coastal resources. The program strives to meet the needs of ocean users while enhancing the environment and economy of the state, region, and nation. Washington Sea Grant Program extends its capabilities through partnerships with agencies, industries, and citizen groups.

A team of water quality education specialists provides technical assistance, public involvement and education programs and materials to local governments, tribes, industries, schools, and other water resource users in this community. Through its outreach efforts, the team takes an active role in reducing nutrient and pathogen water pollution from failing on-site sewage systems, stormwater, and other nonpoint pollution generators. The annual Kids' Day at OysterFest event brings to life nonpoint pollution education for 500 fourth grade students within Mason County each year.

## Washington State University (WSU) Extension

WSU water quality programs in Thurston and Mason counties work proactively to better protect water resources. Primary program efforts include:

- The WSU Water Resources Real Estate Professional Education program provides information to associates, brokers, developers, and appraisers about water resource issues. The purpose is to assist these real estate professionals and their clients to make sound decisions regarding modifying the landscape. Instruction by local experts covers the issues and related best available science, as well as regulatory and non-regulatory ways water resources can be protected. Courses provide clock hours towards professional license re-certification. A total of 220 participants have been involved during the past year.

- The Native Plant Salvage Project is directly affiliated with WSU Extension, however funding is provided by local jurisdictions, grants, state, and federal agencies. The program educates residents and developers about retaining vegetation to reduce stormwater, increase groundwater recharge, provide filtration and reduce pesticide use. The program has involved over 1200 individuals in its educational programs during the past year and has 250 volunteers.

- On a bi-monthly basis WSU convenes the Environmental Education Technical Advisory Committee, which serves to coordinate and foster collaborative efforts for the educational activities of the non-profits, jurisdictions, and agencies serving the region.

### Water Resource Inventory Area (WRIA) 14 Planning Unit

The WRIA 14 Planning Unit formed in response to state legislation passed in 1998. ESHB (engrossed substitute house bill) 2514, set a framework for developing local solutions to watershed issues on a watershed basis. The law provides a process to allow citizens in a watershed to join together to assess the status of the water resources in their watershed and determine how best to manage them. They are required to address water quantity. Optional elements that may be addressed in the plan include instream flow, water quality, and habitat. WRIA 14 planning unit has chosen to address water quality in their plan.

The Planning Unit expects to complete the Comprehensive Watershed Plan in early 2006. They are currently developing plan recommendations. Planning Unit meetings are open to the public and are generally held at least once a month. Work on this *Tributaries to Totten, Eld, and Little Skookum Inlets TMDL* will be coordinated with the WRIA 14 Planning Unit.

## What is the Schedule for Achieving TMDL Reductions?

We anticipate achieving fecal coliform bacteria reductions by 2015 (i.e., eight years following completion of the *Water Quality Improvement Plan).* Fifty percent reduction is anticipated by 2011.

Achieving temperature reductions is a long-term goal, requiring time for plantings to become mature. Within three years, implementing agencies anticipate restoring vegetation to 85% of degraded riparian areas (replanting as necessary for mortalities). Temperature goals are anticipated to be achieved when tree height reaches 30 meters, estimated as approximately 50 years.

## Adaptive Management

Achieving improvement in water quality will be an iterative process of evaluating information, taking action, evaluating results and deciding what comes next. The involved organizations will work together to manage the cleanup.

## Summary of Public Involvement Methods

Stakeholders have been involved in development of this report including participating in finalizing the project plan, contributing data, assisting with field work, and commenting on analysis and conclusions. They will have an additional review/comment opportunity during the public comment period.

Ecology will hold a thirty day public comment period on the draft final *Water Quality Improvement Report.* Notice of the public comment period, including the Executive Summary, is being mailed to riparian landowners along the seven creeks. Display ads will be placed in the

Shelton/Mason County Journal and the Olympian. The notice and ads will offer that project staff can meet with groups who are interested in a chance to learn more about the report.

During the comment period the report will be available on the internet. Hard copies will also be placed in the Olympia and Shelton Timberline Libraries for public review.

# Potential Funding Sources

Potential funding sources:

- *Centennial/State Revolving Fund (SRF)/319* – These three funding sources are managed by Ecology through one combined application program. Funds are available to public entities as grants or low-interest loans. Grants require a 25% match. They may be used to provide education/outreach, technical assistance for specific water quality projects, or as seed money to establish various kinds of water quality related programs or program components. Grant funds may not be used for capital improvements to private property. However, riparian fencing, riparian re-vegetation, and alternative stock watering are grant-eligible, if a landowner easement is given.

  Low-interest loans are available to public entities for all of the above uses, and have also been used as "pass-through" to provide low-interest loans to homeowners for septic system repair or agricultural best management practices. Loan money can be used for a wider range of improvements on private property.

- *Conservation Reserve Enhancement Program* (CREP) – This program provides incentives to restore and improve salmon and steelhead habitat on private land. This is a voluntary program to establish forested buffers along streams where streamside habitat is a significant limiting factor for salmonids. In addition to providing habitat, the buffers improve water quality and increase stream stability. Land enrolled in CREP is removed from production and grazing, under 10-15 year contracts. In return, landowners receive annual rental, incentive, maintenance and cost share payments. The annual payments can equal twice the weighted average soil rental rate (incentive is 110% in areas designated by Growth Management Act). CREP is administered by the Natural Resources Conservation Service.

- *Conservation Reserve Program (CRP)* – A voluntary program that offers annual rental payments, incentive payments for certain activities, and cost-share assistance to establish approved cover on eligible cropland. Assistance is available in an amount equal to not more than 50% of the participant's costs in establishing approved practices; contract duration between 10-15 years. The program is administered through the conservation district.

- *Environmental Protection Agency* – The EPA provides funding to Tribes and others to apply toward water quality improvement. There are also specific grants such as the Watershed Initiative Grant which can provide substantial funding.

- *Environmental Quality Incentives Program (EQIP)* - This federally funded program is also managed by Natural Resources Conservation Service:

- Provides technical assistance, cost share payments and incentive payments to assist crop and livestock producers with environmental and conservation improvements on the farm.
- $5.8 billon over next 6 years (nationally).
- 75% cost sharing but allows 90% if producer is a limited resource or beginning farmer or rancher.
- Program funding divided 60% for livestock-related practices, 40% for crop land.
- Contracts are one to ten years.
- No annual payment limitation, but sum not to exceed $450,000 per individual/entity.

- *WRIA 14 Planning Unit* – Through this planning process, citizens and agencies are evaluating and making recommendations for the water resources in watersheds around the state (which have an administrative designation as Water Resource Inventory Areas, or WRIAs).

- *Shellfish Protection District* - The legislative body of any county can establish a shellfish protection district to include areas which threaten water quality. Among other things, the legislation allows the collection of fees and charges, but does not give the general authority to tax.

- *The Public Involvement and Education (PIE)* program is administered by the Puget Sound Action Team. PIE dollars help citizens, schools, businesses, nonprofits, local and tribal governments to:
  - Create solutions to local pollution problems;
  - Protect, preserve, and restore habitat;
  - Motivate people to be environmental stewards;
  - Partner with others for lasting results.

  PIE is not a grant program. Instead, through personal services contracts, the Puget Sound Water Quality Action Team obtains the services of individuals and organizations to educate and involve residents of Puget Sound as they carry out the Puget Sound Water Quality Work Plan. The Action Team staff provides guidance on fulfilling a state contract as well as technical assistance related to the project.

- *Salmon Recovery Fund* - The state's Salmon Recovery Fund is used to protect and restore high priority salmon stocks. Funded projects may also reduce bacteria.

- *United States Department of Agriculture (USDA)* - Rural Housing Repair and Rehabilitation Loans are loans funded directly by the federal government. These loans are available to very low-income rural residents who own and occupy a dwelling in need of repairs. Funds are available for repairs to improve or modernize a home, or to remove health and safety hazards. This loan is a 1% loan that may be repaid over a 20-year period.

  To obtain a loan, homeowner-occupants must be unable to obtain affordable credit elsewhere and must have very low incomes, defined as below 50% of the area median income. They must need to make repairs and improvements to make the dwelling more safe and sanitary or to remove health and safety hazards. Grants are only available to homeowners who are 62 years old or older and cannot repay a Section 504 loan.

- *Wetland Reserve Program (WRP)* – A voluntary program to restore and protect wetlands on private property (including farmland that has become a wetland as a result of flooding). Landowners can receive financial incentives to enhance wetlands in exchange for retiring marginal agricultural land. Landowner limits future use of the land, but retains ownership, controls access, and may lease the land for undeveloped recreational activities and possibly other compatible uses. This is a USDA program administered by the Natural Resources Conservation Service.

## Next Steps

Ecology will submit this *Water Quality Improvement Report* to the Environmental Protection Agency for approval. Following approval, local and state agencies, the Squaxin Tribe, the Southwest Puget Sound Watershed Council, and local citizens will develop a detailed plan for improving water quality. That *Water Quality Implementation Plan* is anticipated to be complete by fall 2007.

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# Appendices

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# Appendix A. Fecal Coliform Data Used in This TMDL

Table A-1. Kennedy Creek (FC= cfu/100 mL; Q=cfs), 1986-2004: Ecology (Nov-April), Thurston County (May-Oct), Mason County (2004).

| Date | FC | Q | Date | FC | Q | Date | FC | Q | Date | FC | Q |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3-Jan-95 | 4 | 137.39 | 17-Feb-98 | 11 | 115.74 | 4-Apr-00 | 1 | 40.77 | 12-Feb-02 | 4 | 102.23 |
| 10-Jan-95 | 10 | 92.99 | 24-Feb-98 | 4 | 135.84 | 11-Apr-00 | 1 | 30.25 | 19-Feb-02 | 6 | 78.14 |
| 17-Jan-95 | 3 | 117.52 | 3-Mar-98 | 2 | 104.70 | 18-Apr-00 | 1 | 29.522 | 26-Feb-02 | 2 | 132.00 |
| 24-Jan-95 | 2 | 66.20 | 10-Mar-98 | 7 | 137.54 | 25-Apr-00 | 5 | 34.5444 | 5-Mar-02 | 1 | 56.01 |
| 31-Jan-95 | 17 | 895.93 | 17-Mar-98 | 1 | 75.02 | 2-May-00 | 1 | 34.41 | 11-Mar-02 | 51 | 241.04 |
| 7-Feb-95 | 1 | 97.43 | 24-Mar-98 | 8 | 135.39 | 9-May-00 | 50 | 40.75 | 20-Mar-02 | 5 | 209.14 |
| 14-Feb-95 | 1 | 43.23 | 31-Mar-98 | 5 | 79.09 | 16-May-00 | 1 | 35.0618 | 27-Mar-02 | 1 | 74.59 |
| 21-Feb-95 | 3 | 924.37 | 7-Apr-98 | 1 | 43.52 | 23-May-00 | 5 | 26.04 | 2-Apr-02 | 1 | 54.51 |
| 28-Feb-95 | 1 | 143.99 | 14-Apr-98 | 1 | 38.87 | 30-May-00 | 16 | 23.68 | 9-Apr-02 | 5 | 40.81 |
| 7-Mar-95 | 1 | 73.54 | 26-Aug-98 | 30 | 5.16 | 6-Jun-00 | 34 | 21.09 | 16-Apr-02 | 2 | 197.69 |
| 14-Mar-95 | 11 | 708.73 | 2-Oct-98 | | 4.38 | 20-Jun-00 | 8 | 26.78 | 24-Apr-02 | 3 | 58.19 |
| 21-Mar-95 | 18 | 146.70 | 7-Oct-98 | 150 | 4.70 | 11-Jul-00 | 40 | 8.90 | 30-Apr-02 | 1 | 43.29 |
| 28-Mar-95 | 1 | 88.83 | 13-Oct-98 | 180 | 17.22 | 25-Jul-00 | 30 | 7.53 | 8-May-02 | 19 | 32.32 |
| 4-Apr-95 | 3 | 39.44 | 20-Oct-98 | 61 | 5.76 | 15-Aug-00 | 76 | 5.19 | 14-May-02 | 2 | 29.76 |
| 11-Apr-95 | 1 | 55.35 | 27-Oct-98 | 150 | 4.40 | 22-Aug-00 | 55 | 5.69 | 21-May-02 | 16 | 21.54 |
| 18-Apr-95 | 1 | 39.98 | 3-Nov-98 | 22 | 5.28 | 6-Sep-00 | 92 | 5.19 | 28-May-02 | 49 | 20.59 |
| 28-Apr-95 | | 37.64 | 11-Nov-98 | 310 | 7.63 | 20-Sep-00 | 41 | 4.72 | 4-Jun-02 | 28 | 16.03 |
| 31-Aug-95 | 15 | 4.65 | 17-Nov-98 | 9 | 42.30 | 3-Oct-00 | 32 | 5.63 | 11-Jun-02 | 3 | 14.57 |
| 25-Sep-95 | 205 | 4.51 | 23-Nov-98 | 22 | 214.67 | 10-Oct-00 | 32 | 7.76 | 29-Jul-02 | 100 | 6.02 |
| 14-Nov-95 | 33 | 200.00 | 1-Dec-98 | 72 | 241.34 | 17-Oct-00 | 64 | 11.50 | 28-Aug-02 | 10 | 3.87 |
| 20-Nov-95 | 4 | 72.02 | 8-Dec-98 | 6 | 165.17 | 24-Oct-00 | 15 | 9.27 | 17-Dec-02 | 40 | |
| 28-Nov-95 | 40 | 350 | 15-Dec-98 | 8 | 184.22 | 31-Oct-00 | 16 | 9.31 | 28-Jan-03 | 1 | |
| 5-Dec-95 | 3 | 193.10 | 22-Dec-98 | 8 | 65.80 | 7-Nov-00 | 30 | 11.76 | 19-Feb-03 | 15 | 57.37 |
| 12-Dec-95 | 20 | 291.17 | 29-Dec-98 | 22 | | 14-Nov-00 | 30 | 12.74 | 17-Mar-03 | 5 | |
| 19-Dec-95 | 5 | 173.44 | 4-Jan-99 | 18 | 115.30 | 20-Nov-00 | 8 | 9.65 | 21-Jul-03 | 50 | 4.38 |
| 26-Dec-95 | 14 | 71.26 | 11-Jan-99 | 7 | 63.81 | 28-Nov-00 | 4 | 42.41 | 12-Aug-03 | 605 | 6.17 |
| 2-Jan-96 | 14 | 127.49 | 19-Jan-99 | 11 | 339.67 | 5-Dec-00 | 4 | 26.16 | 8-Dec-03 | 40 | |
| 9-Jan-96 | 12 | 200.00 | 26-Jan-99 | 5 | 147.27 | 12-Dec-00 | 11 | 15.58 | 16-Dec-03 | 15 | 155.54 |
| 16-Jan-96 | 5 | 244.05 | 2-Feb-99 | 44 | 357.54 | 19-Dec-00 | 37 | 50.98 | 21-Jan-04 | 520 | 93.08 |
| 23-Jan-96 | 12 | 305.34 | 9-Feb-99 | 3 | 242.01 | 26-Dec-00 | 14 | 86.57 | 13-Jan-04 | 65 | |
| 30-Jan-96 | 5 | 96.31 | 16-Feb-99 | 14 | 163.91 | 2-Jan-01 | 8 | 60 | 10-Feb-04 | 2 | |
| 6-Feb-96 | 48 | 398.84 | 23-Feb-99 | 8 | 275.57 | 9-Jan-01 | 12 | 69.58 | 17-Feb-04 | 1 | 136.92 |
| 13-Feb-96 | 3 | 158.79 | 2-Mar-99 | 9 | 250.20 | 16-Jan-01 | 4 | 39.61 | 1-Mar-04 | 2 | |
| 20-Feb-96 | 3 | 190.00 | 9-Mar-99 | 1 | 141.71 | 23-Jan-01 | 5 | 59.74 | 15-Mar-04 | 15 | 46.1 |
| 27-Feb-96 | 1 | 116.10 | 17-Mar-99 | 1 | 115.27 | 30-Jan-01 | 24 | 53.59 | 5-Apr-04 | 2 | |
| 5-Mar-96 | 2 | 81.32 | 23-Mar-99 | 2 | 70.07 | 6-Feb-01 | 5 | 103 | 19-Apr-04 | 1 | 26.51 |
| 12-Mar-96 | 1 | 79.41 | 30-Mar-99 | 3 | 182.20 | 13-Feb-01 | 1 | 48.88 | 17-May-04 | 30 | 12.5 |
| 19-Mar-96 | 1 | 49.77 | 6-Apr-99 | 1 | 64.70 | 20-Feb-01 | 1 | 0.4 | 22-Jun-04 | 40 | 10.13 |
| 26-Mar-96 | 1 | 35.38 | 13-Apr-99 | 2 | 55.253 | 27-Feb-01 | 1 | 42.8 | 15-Jul-04 | 65 | 9.66 |
| 2-Apr-96 | 1 | 35.95 | 19-Apr-99 | 9 | 41.39 | 6-Mar-01 | 1 | 47.34 | 18-Aug-04 | 1601 | |
| 9-Apr-96 | 1 | 24.36 | 27-Apr-99 | 6 | 33.03 | 12-Mar-01 | 1 | 31.85 | 24-Aug-04 | 25 | 6.64 |
| 16-Apr-96 | 11 | 82.40 | 5-May-99 | 3 | 37.58 | 20-Mar-01 | 1 | 65.28 | 25-Aug-04 | 500 | |
| 4-Sep-96 | 30 | 5.88 | 11-May-99 | 5 | 38.42 | 27-Mar-01 | 14 | 53.21 | 15-Sep-04 | 50 | |
| 12-Nov-96 | 67 | 26.22 | 18-May-99 | 1 | 36.97 | 3-Apr-01 | 8 | 56 | 22-Sep-04 | 15 | 13.9 |
| 19-Nov-96 | 31 | 91.44 | 24-May-99 | 2 | 27.19 | 9-Apr-01 | 1 | 40.09 | 30-Sep-04 | 7 | |
| 25-Nov-96 | 63 | 211.00 | 1-Jun-99 | 1 | 18.87 | 17-Apr-01 | 3 | 33.59 | 11-Oct-04 | 50 | |
| 3-Dec-96 | 17 | 183.41 | 9-Jun-99 | 9 | 10.19 | 24-Apr-01 | 3 | 31.60 | 19-Oct-04 | 105 | 50.08 |
| 10-Dec-96 | 36 | 244.10 | 21-Jun-99 | 6 | 12.43 | 1-May-01 | 47 | 64.8 | 26-Oct-04 | 22 | |
| 17-Dec-96 | 19 | 127.84 | 20-Jul-99 | 62 | 7.45 | 8-May-01 | 2 | 36.0 | 2-Nov-04 | 90 | |
| 22-Dec-96 | 15 | 119.18 | 28-Jul-99 | 40 | 7.32 | 15-May-01 | 50 | 39.28 | 9-Nov-04 | 60 | |
| 7-Jan-97 | 30 | 369.00 | 24-Aug-99 | 15 | 5.12 | 22-May-01 | 6 | 25.93 | 29-Nov-04 | 30 | |
| 14-Jan-97 | 14 | 101.99 | 7-Sep-99 | 76 | 4.42 | 29-May-01 | 10 | 21.8 | 6-Dec-04 | 23 | |
| 21-Jan-97 | 15 | 200.31 | 21-Sep-99 | 68 | 4.12 | 5-Jun-01 | 8 | 15.23 | 13-Dec-04 | 10 | |
| 28-Jan-97 | 33 | 112.83 | 22-Sep-99 | 20 | 3.89 | 11-Jun-01 | 190 | 34.1 | 10-Jan-05 | 20 | 71.04 |
| 4-Feb-97 | 1 | 122.50 | 6-Oct-99 | 11 | 4.28 | 19-Jun-01 | 7 | 11.6 | 15-Feb-05 | 18 | 38.51 |
| 11-Feb-97 | 1 | 68.37 | 12-Oct-99 | 66 | 5.87 | 17-Jul-01 | 53 | 12.4 | 4-Mar-05 | 10 | 16.34 |
| 18-Feb-97 | 4 | 155.20 | 19-Oct-99 | 16 | 4.65 | 23-Jul-01 | | 35 | 12-Apr-05 | 10 | 122.81 |
| 25-Feb-97 | 6 | 100.31 | 26-Oct-99 | 14 | 5.79 | 14-Aug-01 | 37 | 4.13 | 10-May-05 | 110 | 58.31 |
| 4-Mar-97 | 3 | 160.00 | 2-Nov-99 | 2 | 13.62 | 22-Aug-01 | 470 | 11.4 | 7-Jun-05 | 130 | 21.27 |
| 11-Mar-97 | 3 | 184.45 | 9-Nov-99 | 14 | 36.38 | 28-Aug-01 | 40 | 8.46 | 11-Jul-05 | 155 | 11.13 |
| 18-Mar-97 | 13 | 241.00 | 16-Nov-99 | 18 | 76.56 | 4-Sep-01 | 140 | 5.28 | | | |
| 25-Mar-97 | 2 | 133.01 | 22-Nov-99 | 40 | 170.73 | 18-Sep-01 | 290 | 5.00 | | | |
| 1-Apr-97 | 2 | 81.40 | 30-Nov-99 | 29 | 151.70 | 2-Oct-01 | 46 | 4.36 | | | |
| 8-Apr-97 | 6 | 49.54 | 7-Dec-99 | 41 | 208.85 | 16-Oct-01 | 37 | 2.11 | | | |
| 15-Apr-97 | 4 | 51.93 | 14-Dec-99 | 18 | 409.11 | 23-Oct-01 | 80 | 25.45 | | | |
| 4-Sep-97 | 50 | 6.77 | 21-Dec-99 | 3 | 186.00 | 30-Oct-01 | 28 | 23.95 | | | |
| 11-Nov-97 | 7 | 58.58 | 28-Dec-99 | 2 | 68.90 | 6-Nov-01 | 23 | 22.52 | | | |
| 18-Nov-97 | 6 | 79.96 | 4-Jan-00 | 18 | 199.82 | 13-Nov-01 | 33 | 21.31 | | | |
| 24-Nov-97 | 16 | 169.62 | 11-Jan-00 | 8 | 170.44 | 19-Nov-01 | 65 | 158.425 | | | |
| 2-Dec-97 | 6 | 132.91 | 18-Jan-00 | 3 | 193.35 | 27-Nov-01 | 33 | 113.45 | | | |
| 9-Dec-97 | 10 | 63.96 | 25-Jan-00 | 2 | 100.08 | 4-Dec-01 | 14 | 385.04 | | | |
| 16-Dec-97 | 100 | 330.40 | 1-Feb-00 | 43 | 260.85 | 11-Dec-01 | 89 | 132.73 | | | |
| 22-Dec-97 | 7 | 123.01 | 8-Feb-00 | 3 | 116.53 | 18-Dec-01 | 33 | 707.51 | | | |
| 29-Dec-97 | 7 | 112.69 | 15-Feb-00 | 1 | 63.62 | 26-Dec-01 | 16 | 94.13 | | | |
| 6-Jan-98 | 25 | 372.93 | 22-Feb-00 | 3 | 53.06 | 2-Jan-02 | 7 | 85.32 | | | |
| 12-Jan-98 | 8 | 98.05 | 29-Feb-00 | 20 | 172.92 | 8-Jan-02 | 9 | 881.54 | | | |
| 20-Jan-98 | 84 | 236.5 | 7-Mar-00 | 1 | 114.33 | 15-Jan-02 | 10 | 123.20 | | | |
| 27-Jan-98 | 9 | 248.72 | 14-Mar-00 | 1 | 99.49 | 22-Jan-02 | 4 | 118.66 | | | |
| 3-Feb-98 | 3 | 101.64 | 21-Mar-00 | 1 | 139.40 | 29-Jan-02 | 1 | 210 | | | |
| 10-Feb-98 | 9 | 91.42 | 28-Mar-00 | 1 | 68.17 | 5-Feb-02 | 100 | 117.89 | | | |

Table A-2. Schneider Creek (FC= cfu/100 mL; Q=cfs), 1995-2005: Ecology (Nov-April 1995-2003), Thurston County (May-Oct 1995-2005).

| Date | FC | Q | Date | FC | Q | Date | FC | Q | Date | FC | Q |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3-Jan-95 | 15 | 17.01 | 20-Jan-98 | 23 | 49.42 | 11-Jan-00 | 16 | 47.64 | 16-Oct-01 | 140 | 0.6382 |
| 10-Jan-95 | 38 | 32.52 | 27-Jan-98 | 11 | 63.25 | 18-Jan-00 | 16 | 51.58 | 23-Oct-01 | 560 | 3.27 |
| 17-Jan-95 | 13 | 24.83 | 3-Feb-98 | 7 | 23.49 | 25-Jan-00 | 24 | 22.71 | 30-Oct-01 | 92 | 2.09 |
| 24-Jan-95 | 31 | 16.93 | 10-Feb-98 | 15 | 23.01 | 1-Feb-00 | 140 | 106.34 | 6-Nov-01 | 80 | 1.75 |
| 31-Jan-95 | 150 | 131.28 | 17-Feb-98 | 15 | 31.06 | 8-Feb-00 | 14 | 31.35 | 13-Nov-01 | 180 | 2 |
| 7-Feb-95 | 17 | 23.57 | 24-Feb-98 | 3 | 30.5 | 15-Feb-00 | 10 | 20.11 | 19-Nov-01 | 100 | 19.59 |
| 14-Feb-95 | 14 | 14.78 | 3-Mar-98 | 5 | 28.48 | 22-Feb-00 | 46 | 20.2 | 27-Nov-01 | 20 | 18.37 |
| 21-Feb-95 | 23 | 94.45 | 10-Mar-98 | 15 | 36.78 | 29-Feb-00 | 30 | 64.38 | 4-Dec-01 | 19 | 36.98 |
| 28-Feb-95 | 6 | 22.33 | 17-Mar-98 | 6 | 18.38 | 7-Mar-00 | 3 | 30.14 | 11-Dec-01 | 47 | 25.32 |
| 7-Mar-95 | 8 | 16.44 | 24-Mar-98 | 34 | 38.06 | 14-Mar-00 | 11 | 27.47 | 18-Dec-01 | 31 | 163.3 |
| 14-Mar-95 | 30 | 92.33 | 31-Mar-98 | 3 | 21.4 | 21-Mar-00 | 2 | 31.45 | 26-Dec-01 | 7 | 19.36 |
| 21-Mar-95 | 20 | 80.71 | 7-Apr-98 | 7 | 9.3 | 28-Mar-00 | 7 | 15.21 | 2-Jan-02 | 30 | 45.49 |
| 28-Mar-95 | 2 | 18.83 | 14-Apr-98 | 1 | 9.14 | 4-Apr-00 | 13 | 9.06 | 8-Jan-02 | 37 | 193.90 |
| 4-Apr-95 | 16 | 12.58 | 26-Aug-98 | 165 | 1.26 | 11-Apr-00 | 1 | 6.15 | 15-Jan-02 | 68 | 26.52 |
| 11-Apr-95 | 9 | 12.56 | 7-Oct-98 | 180 | 0.99 | 18-Apr-00 | 8 | 5.84 | 22-Jan-02 | 27 | 23.99 |
| 18-Apr-95 | 5 | 10.57 | 13-Oct-98 | 750 | 2.43 | 25-Apr-00 | 670 | 8.28 | 29-Jan-02 | 12 | 41.49 |
| 31-Aug-95 | 180 | 0.47 | 20-Oct-98 | 49 | 0.73 | 2-May-00 | 9100 | 6.82 | 5-Feb-02 | 24 | 24.49 |
| 25-Sep-95 | 240 | 0.79 | 27-Oct-98 | 93 | 0.54 | 9-May-00 | 140 | 10.7 | 12-Feb-02 | 5 | 2.45 |
| 14-Nov-95 | 21 | 34.86 | 3-Nov-98 | 48 | 0.64 | 16-May-00 | 60 | 7.34 | 19-Feb-02 | 16 | 34.24 |
| 20-Nov-95 | 7 | 14.4 | 11-Nov-98 | 100 | 1.07 | 23-May-00 | 17 | 4.05 | 26-Feb-02 | 5 | 13.82 |
| 28-Nov-95 | 52 | 61.96 | 17-Nov-98 | 65 | 7.08 | 30-May-00 | 91 | 3.86 | 5-Mar-02 | 6 | 76.68 |
| 5-Dec-95 | 4 | 52.86 | 23-Nov-98 | 260 | 55.59 | 6-Jun-00 | 800 | 3.99 | 11-Mar-02 | 160 | 62.62 |
| 12-Dec-95 | 28 | 102.17 | 1-Dec-98 | 220 | 78.65 | 20-Jun-00 | 66 | 4.39 | 20-Mar-02 | 3 | 62.62 |
| 19-Dec-95 | 12 | 40.4 | 8-Dec-98 | 9 | 46.44 | 11-Jul-00 | 43 | 1.22 | 27-Mar-02 | 5 | 18.38 |
| 26-Dec-95 | 6 | 13.07 | 15-Dec-98 | 15 | 54.8 | 25-Jul-00 | 125 | 1.09 | 2-Apr-02 | 7 | 11.34 |
| 2-Jan-96 | 26 | 30.49 | 22-Dec-98 | 17 | 8.43 | 15-Aug-00 | 37 | 0.9 | 9-Apr-02 | 48 | 8.16 |
| 9-Jan-96 | 13 | 51.96 | 29-Dec-98 | 67 | 170.75 | 22-Aug-00 | 30 | 0.79 | 16-Apr-02 | 12 | 37.58 |
| 16-Jan-96 | 24 | 60.77 | 4-Jan-99 | 6 | 26.18 | 6-Sep-00 | 220 | 0.76 | 24-Apr-02 | 10 | 12.37 |
| 23-Jan-96 | 12 | 93.42 | 11-Jan-99 | 17 | 14.29 | 20-Sep-00 | 37 | 0.63 | 30-Apr-02 | 18 | 8.52 |
| 30-Jan-96 | 22 | 25.34 | 19-Jan-99 | 35 | 131.24 | 3-Oct-00 | 44 | 0.76 | 8-May-02 | 43 | 7.34 |
| 6-Feb-96 | 160 | 219.36 | 26-Jan-99 | 4 | 34.16 | 10-Oct-00 | 180 | 1.46 | 14-May-02 | 7 | 4.3 |
| 13-Feb-96 | 4 | 36.62 | 2-Feb-99 | 71 | 141.86 | 17-Oct-00 | 120 | 2.15 | 21-May-02 | 18 | 3.8 |
| 20-Feb-96 | 11 | 62.95 | 9-Feb-99 | 11 | 67.06 | 24-Oct-00 | 57 | 1.06 | 28-May-02 | 27 | 3.96 |
| 27-Feb-96 | 7 | 35.58 | 16-Feb-99 | 32 | 57.01 | 31-Oct-00 | 64 | 1.38 | 4-Jun-02 | 27 | 2.78 |
| 5-Mar-96 | 11 | 23.75 | 23-Feb-99 | 18 | 120.85 | 7-Nov-00 | 56 | 1.43 | 11-Jun-02 | 40 | 2.18 |
| 12-Mar-96 | 16 | 30.25 | 2-Mar-99 | 6 | 81.63 | 14-Nov-00 | 24 | 1.09 | 29-Jul-02 | 25 | 0.82 |
| 19-Mar-96 | 2 | 15.06 | 9-Mar-99 | 9 | 32.65 | 20-Nov-00 | 69 | 0.96 | 28-Aug-02 | 180 | 0.85 |
| 26-Mar-96 | 2 | 11.23 | 17-Mar-99 | 5 | 28.88 | 28-Nov-00 | 120 | 16.32 | 17-Dec-02 | 30 | 44.66 |
| 2-Apr-96 | 31 | 11.99 | 23-Mar-99 | 3 | 19.26 | 5-Dec-00 | 8 | 3.07 | 28-Jan-03 | 45 | 74.48 |
| 9-Apr-96 | 2 | 8.11 | 30-Mar-99 | 59 | 69.67 | 12-Dec-00 | 3 | 1.91 | 19-Feb-03 | 35 | 16 |
| 16-Apr-96 | 49 | 19.92 | 6-Apr-99 | 1 | 16.57 | 19-Dec-00 | 9 | 9.25 | 21-Jul-03 | 385 | 1.14 |
| 4-Sep-96 | 145 | 0.84 | 13-Apr-99 | 3 | 15.45 | 26-Dec-00 | 6 | 14.81 | 12-Aug-03 | 358 | 0.82 |
| 12-Nov-96 | 48 | 4.81 | 19-Apr-99 | 310 | 10.94 | 2-Jan-01 | 4 | 9.33 | 16-Dec-03 | 20 | 41.74 |
| 19-Nov-96 | 21 | 14.1 | 27-Apr-99 | 9 | 8.66 | 9-Jan-01 | 1 | 10.59 | 21-Jan-04 | 10 | 21.15 |
| 25-Nov-96 | 34 | 27.45 | 5-May-99 | 14 | 7.45 | 16-Jan-01 | 9 | 6.53 | 17-Feb-04 | 5 | 37.49 |
| 3-Dec-96 | 19 | 43.12 | 11-May-99 | 36 | 7.44 | 23-Jan-01 | 3 | 18.37 | 15-Mar-04 | 10 | 10.32 |
| 10-Dec-96 | 15 | 62.35 | 18-May-99 | 26 | 7.17 | 30-Jan-01 | 59 | 14.92 | 19-Apr-04 | 5 | 7.13 |
| 17-Dec-96 | 1 | 27.56 | 24-May-99 | 20 | 4.36 | 6-Feb-01 | 13 | 22.77 | 17-May-04 | 20 | 2.38 |
| 22-Dec-96 | 19 | 30.89 | 1-Jun-99 | 22 | 3.06 | 13-Feb-01 | 12 | 8.77 | 22-Jun-04 | 105 | 1.24 |
| 7-Jan-97 | 25 | 77.51 | 9-Jun-99 | 21 | 3.39 | 20-Feb-01 | 19 | 57.18 | 15-Jul-04 | 30 | 1.49 |
| 14-Jan-97 | 7 | 19.44 | 21-Jun-99 | 510 | 3.34 | 27-Feb-01 | 3 | 10.35 | 24-Aug-04 | 90 | 1.01 |
| 21-Jan-97 | 27 | 59.43 | 20-Jul-99 | 31 | 1.31 | 6-Mar-01 | 3 | 12.26 | 22-Sep-04 | 85 | 1.18 |
| 28-Jan-97 | 13 | 30.67 | 28-Jul-99 | 48 | 1.13 | 12-Mar-01 | 4 | 7.28 | 19-Oct-04 | 90 | 5.04 |
| 4-Feb-97 | 7 | 26.88 | 24-Aug-99 | 30 | 0.84 | 20-Mar-01 | 2 | 12.7 | 9-Nov-04 | 10 | |
| 11-Feb-97 | 8 | 17.96 | 7-Sep-99 | 26 | 0.66 | 27-Mar-01 | 270 | 15.57 | 13-Dec-04 | 20 | 34.32 |
| 18-Feb-97 | 8 | 35.41 | 21-Sep-99 | 310 | 0.76 | 3-Apr-01 | 8 | 13.37 | 10-Jan-05 | 1 | 15.43 |
| 25-Feb-97 | 13 | 23.71 | 27-Sep-99 | 125 | 0.7 | 9-Apr-01 | 6 | 6.86 | 15-Feb-05 | 15 | 7.39 |
| 4-Mar-97 | 2 | 52.97 | 6-Oct-99 | 63 | 0.69 | 17-Apr-01 | 130 | 6.88 | 14-Mar-05 | 25 | 3.41 |
| 11-Mar-97 | 11 | 40.66 | 12-Oct-99 | 74 | 0.93 | 24-Apr-01 | 11 | 5.37 | 12-Apr-05 | 75 | 25.46 |
| 18-Mar-97 | 54 | 66.68 | 19-Oct-99 | 33 | 0.96 | 1-May-01 | 660 | 16.02 | 9-May-05 | 10 | 1.65 |
| 25-Mar-97 | 4 | 27.67 | 26-Oct-99 | 100 | 1.06 | 8-May-01 | 8 | 5.08 | 10-May-05 | 100 | 23.9 |
| 1-Apr-97 | 1 | 18.42 | 2-Nov-99 | 41 | 1.72 | 15-May-01 | 130 | 5.42 | 7-Jun-05 | 25 | 4.63 |
| 8-Apr-97 | 1 | 12.06 | 9-Nov-99 | 150 | 14.33 | 22-May-01 | 29 | 3.14 | 11-Jul-05 | 270 | 1.85 |
| 15-Apr-97 | 2 | 12.24 | 16-Nov-99 | 32 | 18 | 29-May-01 | 230 | 2.28 | | | |
| 4-Sep-97 | 60 | 1.33 | 22-Nov-99 | 31 | 42.99 | 5-Jun-01 | 24 | 2.02 | | | |
| 11-Nov-97 | 5 | 10.5 | 30-Nov-99 | 29 | 45.52 | 11-Jun-01 | 1100 | 5.96 | | | |
| 18-Nov-97 | 35 | 16.23 | 7-Dec-99 | 12 | 46.62 | 19-Jun-01 | 120 | 1.66 | | | |
| 24-Nov-97 | 22 | 41.31 | 14-Dec-99 | 28 | 100.13 | 17-Jul-01 | 210 | 0.8 | | | |
| 2-Dec-97 | 10 | 32.03 | 21-Dec-99 | 14 | 35.17 | 24-Jul-01 | 70 | 0.59 | | | |
| 9-Dec-97 | 15 | 13.5 | 28-Dec-99 | 12 | 13.92 | 14-Aug-01 | 160 | 0.22 | | | |
| 16-Dec-97 | 230 | 104.99 | 4-Jan-00 | 72 | 49.43 | 22-Aug-01 | 1200 | 1.84 | | | |
| 22-Dec-97 | 6 | 31.21 | | | | 28-Aug-01 | 155 | 0.98 | | | |
| 29-Dec-97 | 20 | 18.76 | | | | 4-Sep-01 | 100 | 0.45 | | | |
| 6-Jan-98 | 130 | 58.33 | | | | 18-Sep-01 | 210 | 0.56 | | | |
| 12-Jan-98 | 5 | 20.97 | | | | 2-Oct-01 | 200 | 0.37 | | | |

Table A-3. Burns Creek (FC= cfu/100 mL; Q=cfs), 1995-2002: Ecology (Nov-April), Thurston County (May-Oct).

| Date | FC | Q |
|---|---|---|
| 3-Jan-95 | 45 | 0.05 |
| 10-Jan-95 | 120 | 0.41 |
| 17-Jan-95 | 400 | 0.15 |
| 24-Jan-95 | 180 | 0.14 |
| 31-Jan-95 | 200 | 2.34 |
| 7-Feb-95 | 220 | 0.06 |
| 14-Feb-95 | 78 | 0.05 |
| 21-Feb-95 | 60 | 0.19 |
| 28-Feb-95 | 220 | 0.04 |
| 7-Mar-95 | 200 | 0.07 |
| 14-Mar-95 | 240 | 1.24 |
| 21-Mar-95 | 110 | 0.78 |
| 28-Mar-95 | 53 | 0.15 |
| 4-Apr-95 | 1200 | 0.1 |
| 11-Apr-95 | 220 | 0.11 |
| 18-Apr-95 | 51 | 0.09 |
| 28-Apr-95 | | 0.1 |
| 14-Nov-95 | 320 | 0.36 |
| 20-Nov-95 | 89 | 0.09 |
| 28-Nov-95 | 260 | 0.8 |
| 5-Dec-95 | 130 | 0.35 |
| 12-Dec-95 | 320 | 1.16 |
| 19-Dec-95 | 46 | 0.5 |
| 26-Dec-95 | 56 | 0.11 |
| 2-Jan-96 | 87 | 0.28 |
| 9-Jan-96 | 88 | 0.62 |
| 16-Jan-96 | 53 | 0.55 |
| 23-Jan-96 | 32 | 0.89 |
| 30-Jan-96 | 34 | 0.21 |
| 6-Feb-96 | 1400 | 8.89 |
| 13-Feb-96 | 29 | 0.5 |
| 20-Feb-96 | 33 | 0.53 |
| 27-Feb-96 | 28 | 0.28 |
| 5-Mar-96 | 35 | 0.28 |
| 12-Mar-96 | 57 | 0.28 |
| 19-Mar-96 | 22 | 0.11 |
| 26-Mar-96 | 12 | 0.08 |
| 2-Apr-96 | 25 | 0.07 |
| 9-Apr-96 | 620 | 0.08 |
| 16-Apr-96 | 1200 | 0.24 |
| 12-Nov-96 | 330 | 0.07 |
| 19-Nov-96 | 1400 | 0.39 |
| 25-Nov-96 | 71 | 0.22 |
| 3-Dec-96 | 92 | 0.32 |
| 10-Dec-96 | 180 | 0.89 |
| 17-Dec-96 | 31 | 0.24 |
| 22-Dec-96 | 81 | 0.41 |
| 7-Jan-97 | 40 | 1.16 |
| 14-Jan-97 | 16 | 0.27 |
| 21-Jan-97 | 69 | 0.62 |
| 28-Jan-97 | 130 | 0.39 |
| 4-Feb-97 | 6 | 0.28 |
| 11-Feb-97 | 17 | 0.3 |
| 18-Feb-97 | 36 | 0.32 |
| 25-Feb-97 | 22 | 0.16 |
| 4-Mar-97 | 14 | 0.38 |
| 11-Mar-97 | 75 | 0.33 |
| 18-Mar-97 | 140 | 1.42 |
| 25-Mar-97 | 8 | 0.28 |
| 1-Apr-97 | 32 | 0.14 |
| 8-Apr-97 | 270 | 0.09 |
| 15-Apr-97 | 650 | 0.13 |
| 11-Nov-97 | 160 | 0.13 |
| 18-Nov-97 | 970 | 0.13 |
| 24-Nov-97 | 360 | 0.39 |
| 2-Dec-97 | 92 | 0.2 |

| Date | FC | Q |
|---|---|---|
| 9-Dec-97 | 73 | 0.08 |
| 16-Dec-97 | 2700 | 3.86 |
| 22-Dec-97 | 91 | 0.21 |
| 29-Dec-97 | 120 | 0.19 |
| 6-Jan-98 | 880 | 1.86 |
| 12-Jan-98 | 43 | 0.2 |
| 20-Jan-98 | 80 | 0.52 |
| 27-Jan-98 | 84 | 0.6 |
| 3-Feb-98 | 60 | 0.25 |
| 10-Feb-98 | 110 | 0.42 |
| 17-Feb-98 | 100 | 0.28 |
| 24-Feb-98 | 29 | 0.28 |
| 3-Mar-98 | 59 | 0.28 |
| 10-Mar-98 | 44 | 0.52 |
| 17-Mar-98 | 64 | 0.11 |
| 24-Mar-98 | 330 | 0.35 |
| 31-Mar-98 | 120 | 0.18 |
| 7-Apr-98 | 14 | 0.08 |
| 14-Apr-98 | 29 | 0.1 |
| 13-Oct-98 | | 0.03 |
| 20-Oct-98 | | 0.01 |
| 27-Oct-98 | | 0.0004 |
| 3-Nov-98 | | 0.0013 |
| 11-Nov-98 | 2000 | 0.02 |
| 17-Nov-98 | 1800 | 0.04 |
| 23-Nov-98 | 700 | 0.57 |
| 1-Dec-98 | 2000 | 1.56 |
| 8-Dec-98 | 200 | 0.41 |
| 15-Dec-98 | 310 | 0.42 |
| 22-Dec-98 | 140 | 0.15 |
| 29-Dec-98 | 590 | 4.58 |
| 4-Jan-99 | 140 | 0.25 |
| 11-Jan-99 | 170 | 0.2 |
| 19-Jan-99 | 360 | 2.15 |
| 26-Jan-99 | 160 | 0.35 |
| 2-Feb-99 | 92 | 2.57 |
| 9-Feb-99 | 46 | 0.67 |
| 16-Feb-99 | 130 | 0.9 |
| 23-Feb-99 | 940 | 2.02 |
| 2-Mar-99 | 60 | 0.76 |
| 9-Mar-99 | 2100 | 0.38 |
| 17-Mar-99 | 150 | 0.24 |
| 23-Mar-99 | 84 | 0.19 |
| 30-Mar-99 | 110 | 0.67 |
| 6-Apr-99 | 280 | 0.09 |
| 13-Apr-99 | 450 | 0.11 |
| 19-Apr-99 | 4500 | 0.1 |
| 27-Apr-99 | 2800 | 0.07 |
| 5-May-99 | 1200 | 0.03 |
| 11-May-99 | 1400 | 0.08 |
| 18-May-99 | 3700 | 0.04 |
| 24-May-99 | 1200 | 0.01 |
| 1-Jun-99 | 600 | 0.0016 |
| 9-Jun-99 | 5500 | 0.01 |
| 21-Jun-99 | | 0.0009 |
| 26-Oct-99 | | 0.0016 |
| 2-Nov-99 | | 0.0027 |
| 9-Nov-99 | 9400 | 0.47 |
| 16-Nov-99 | 830 | 0.04 |
| 22-Nov-99 | 900 | 0.16 |
| 30-Nov-99 | 610 | 0.51 |
| 7-Dec-99 | 240 | 0.27 |
| 14-Dec-99 | 528 | 2.14 |
| 21-Dec-99 | 250 | 0.35 |
| 28-Dec-99 | 490 | 0.09 |
| 4-Jan-00 | 410 | 0.65 |

| Date | FC | Q |
|---|---|---|
| 11-Jan-00 | 84 | 0.49 |
| 18-Jan-00 | 54 | 0.36 |
| 25-Jan-00 | 210 | 0.18 |
| 1-Feb-00 | 3200 | 3.42 |
| 8-Feb-00 | 650 | 0.59 |
| 15-Feb-00 | 54 | 0.17 |
| 22-Feb-00 | 110 | 0.31 |
| 29-Feb-00 | 220 | 1.3 |
| 7-Mar-00 | 20 | 0.19 |
| 14-Mar-00 | 76 | 0.35 |
| 21-Mar-00 | 21 | 0.2 |
| 28-Mar-00 | 71 | 0.1 |
| 4-Apr-00 | 440 | 0.05 |
| 11-Apr-00 | 2400 | 0.05 |
| 18-Apr-00 | 490 | 0.03 |
| 25-Apr-00 | 3000 | 0.05 |
| 2-May-00 | 1800 | 0.03 |
| 9-May-00 | 93000 | 0.39 |
| 16-May-00 | 550 | 0.04 |
| 23-May-00 | 583 | 0.03 |
| 30-May-00 | 6799 | 0.08 |
| 6-Jun-00 | 53000 | 0.05 |
| 20-Jun-00 | 583 | 0.01 |
| 11-Jul-00 | 6 | 0 |
| 15-Aug-00 | | 0.001 |
| 6-Sep-00 | | 0.01 |
| 17-Oct-00 | 1746 | 0.01 |
| 31-Oct-00 | 1580 | 0.01 |
| 7-Nov-00 | 384 | 0.03 |
| 14-Nov-00 | 120 | 0.01 |
| 20-Nov-00 | 77 | 0.01 |
| 28-Nov-00 | 500 | 0.04 |
| 5-Dec-00 | 6200 | 0.02 |
| 12-Dec-00 | 1000 | 0.02 |
| 19-Dec-00 | 230 | 0.05 |
| 26-Dec-00 | 190 | 0.07 |
| 2-Jan-01 | 242 | 0.07 |
| 9-Jan-01 | 160 | 0.06 |
| 16-Jan-01 | 190 | 0.03 |
| 23-Jan-01 | 420 | 0.12 |
| 30-Jan-01 | 630 | 0.42 |
| 6-Feb-01 | 31 | 0.16 |
| 13-Feb-01 | 130 | 0.05 |
| 20-Feb-01 | 120 | 0.21 |
| 27-Feb-01 | 74 | 0.05 |
| 6-Mar-01 | 84 | 0.06 |
| 12-Mar-01 | 850 | 0.04 |
| 20-Mar-01 | 100 | 0.11 |
| 27-Mar-01 | 10000 | 1.01 |
| 3-Apr-01 | 250 | 0.13 |
| 9-Apr-01 | 84 | 0.03 |
| 17-Apr-01 | 660 | 0.03 |
| 24-Apr-01 | 420 | 0.08 |
| 1-May-01 | 3200 | 0.2 |
| 8-May-01 | 188 | |
| 15-May-01 | 2657 | |
| 22-May-01 | 242 | |
| 29-May-01 | 280 | 0.01 |
| 5-Jun-01 | 1663 | 0.01 |
| 11-Jun-01 | 33000 | 0.05 |
| 19-Jun-01 | 132 | 0.01 |
| 17-Jul-01 | | 0.0043 |
| 22-Aug-01 | 1995 | 0.04 |
| 23-Oct-01 | 13000 | 0.18 |
| 30-Oct-01 | 2100 | 0.1 |

| Date | FC | Q |
|---|---|---|
| 6-Nov-01 | 354 | 0.03 |
| 13-Nov-01 | 1166 | 0.03 |
| 19-Nov-01 | 4314 | 0.52 |
| 27-Nov-01 | 57 | 0.15 |
| 4-Dec-01 | 82 | 0.87 |
| 11-Dec-01 | 350 | 0.6 |
| 18-Dec-01 | 420 | 1.86 |
| 26-Dec-01 | 29 | 0.18 |
| 2-Jan-02 | 64 | 0.54 |
| 8-Jan-02 | 84 | 1.4 |
| 15-Jan-02 | 44 | 0.24 |
| 22-Jan-02 | 61 | 0.29 |
| 29-Jan-02 | 19 | 0.41 |
| 5-Feb-02 | 20 | 0.38 |
| 12-Feb-02 | 120 | 0.14 |
| 19-Feb-02 | 1000 | 0.43 |
| 26-Feb-02 | 35 | 0.32 |
| 5-Mar-02 | 45 | 0.14 |
| 11-Mar-02 | 1400 | 3.77 |
| 20-Mar-02 | 40 | 0.71 |
| 27-Mar-02 | 10 | 0.12 |
| 2-Apr-02 | 11 | 0.08 |
| 9-Apr-02 | 290 | 0.17 |
| 16-Apr-02 | 480 | 0.39 |
| 24-Apr-02 | 55 | 0.14 |
| 30-Apr-02 | 88 | 0.12 |
| 8-May-02 | 140 | 0.1 |
| 14-May-02 | 110 | 0.06 |
| 21-May-02 | 71 | 0.06 |
| 28-May-02 | 1300 | 0.08 |
| 4-Jun-02 | 250 | 0.02 |
| 11-Jun-02 | 51 | 0.01 |

Table A-4. Pierre Creek (FC= cfu/100 mL; Q=cfs), 1993-2002: Ecology (Nov-April), Thurston County (May-Oct).

| Date | FC | Q | Date | FC | Q | Date | FC | Q | Date | FC | Q |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5-Jan-93 | 32 | 0.172 | 12-Dec-95 | 170 | 1.56 | 22-Dec-98 | 47 | 0.07 | 28-Nov-00 | 180 | 0.04 |
| 12-Jan-93 | 32 | 0.040 | 19-Dec-95 | 160 | 0.422 | 29-Dec-98 | 150 | 5.92 | 5-Dec-00 | 50 | 0.0227 |
| 19-Jan-93 | 2000 | 2.81 | 26-Dec-95 | 240 | 0.102 | 4-Jan-99 | 48 | 0.185 | 12-Dec-00 | 23 | 0.016 |
| 26-Jan-93 | 49 | 0.78 | 2-Jan-96 | 210 | 0.176 | 11-Jan-99 | 85 | 0.053 | 19-Dec-00 | 60 | 0.098 |
| 2-Feb-93 | 20 | 0.095 | 9-Jan-96 | 240 | 0.395 | 19-Jan-99 | 48 | 1.986 | 26-Dec-00 | 73 | 0.136 |
| 9-Feb-93 | 16 | 0.067 | 16-Jan-96 | 230 | 0.511 | 26-Jan-99 | 110 | 0.327 | 2-Jan-01 | 33 | 0.086 |
| 16-Feb-93 | 20 | 0.095 | 23-Jan-96 | 100 | 0.850 | 2-Feb-99 | 57 | 3.527 | 9-Jan-01 | 36 | 0.124 |
| 23-Feb-93 | 12 | 0.031 | 30-Jan-96 | 230 | 0.142 | 9-Feb-99 | 53 | 0.64 | 16-Jan-01 | 36 | 0.067 |
| 2-Mar-93 | 18 | 0.034 | 6-Feb-96 | 450 | 13.0731 | 16-Feb-99 | 80 | 1.281 | 23-Jan-01 | 35 | 0.221 |
| 9-Mar-93 | 6 | 0.084 | 13-Feb-96 | 120 | 0.243 | 23-Feb-99 | 120 | 1.681 | 30-Jan-01 | 160 | 0.574 |
| 16-Mar-93 | 22 | 0.078 | 20-Feb-96 | 110 | 0.52 | 2-Mar-99 | 120 | 0.633 | 6-Feb-01 | 57 | 0.265 |
| 23-Mar-93 | 130 | 0.922 | 27-Feb-96 | 84 | 0.190 | 9-Mar-99 | 63 | 0.191 | 13-Feb-01 | 47 | 0.073 |
| 30-Mar-93 | 19 | 0.053 | 5-Mar-96 | 88 | 0.400 | 17-Mar-99 | 150 | 0.168 | 20-Feb-01 | 45 | 0.208 |
| 6-Apr-93 | 12 | 0.080 | 12-Mar-96 | 150 | 0.382 | 23-Mar-99 | 92 | 0.131 | 27-Feb-01 | 29 | 0.070 |
| 13-Apr-93 | 14 | 0.208 | 19-Mar-96 | 52 | 0.089 | 30-Mar-99 | 96 | 0.717 | 6-Mar-01 | 27 | 0.097 |
| 20-Jul-93 | 1350 | 0.07 | 26-Mar-96 | 23 | 0.063 | 6-Apr-99 | 20 | 0.075 | 12-Mar-01 | 34 | 0.056 |
| 9-Aug-93 | 65 | 0.001 | 2-Apr-96 | 28 | 0.094 | 13-Apr-99 | 40 | 0.081 | 20-Mar-01 | 25 | 0.180 |
| 16-Nov-93 | | 0 | 9-Apr-96 | 22 | 0.040 | 19-Apr-99 | 910 | 0.063 | 27-Mar-01 | 580 | 0.425 |
| 22-Nov-93 | | 0 | 16-Apr-96 | 120 | 0.390 | 27-Apr-99 | 430 | 0.069 | 3-Apr-01 | 8 | 0.158 |
| 30-Nov-93 | 3000 | 0.005 | 12-Nov-96 | 630 | 0.092 | 5-May-99 | 43 | 0.015 | 9-Apr-01 | 17 | 0.035 |
| 7-Dec-93 | 1700 | 0.656 | 19-Nov-96 | 930 | 0.570 | 11-May-99 | 640 | 0.057 | 17-Apr-01 | 44 | 0.049 |
| 14-Dec-93 | 160 | 0.33 | 25-Nov-96 | 450 | 0.551 | 18-May-99 | 180 | 0.070 | 24-Apr-01 | 39 | 0.0137 |
| 21-Dec-93 | 31 | 0.035 | 3-Dec-96 | 280 | 0.512 | 24-May-99 | 210 | 0.019 | 1-May-01 | 600 | 0.3434 |
| 28-Dec-93 | 28 | 0.011 | 10-Dec-96 | 270 | 1.481 | 1-Jun-99 | 160 | 0.001 | 8-May-01 | 1200 | |
| 4-Jan-94 | 150 | 2.28 | 17-Dec-96 | 55 | 0.178 | 9-Jun-99 | 450 | 0.0086 | 15-May-01 | 150 | 0.0080 |
| 11-Jan-94 | 63 | 0.210 | 22-Dec-96 | 200 | 0.566 | 21-Jun-99 | 26 | 0.00036 | 22-May-01 | 25 | |
| 18-Jan-94 | 37 | 0.0545 | 7-Jan-97 | 120 | 1.171 | 20-Jul-99 | 5 | 0.00042 | 29-May-01 | 2300 | 0.0004 |
| 23-Jan-94 | 130 | 0.268 | 14-Jan-97 | 660 | 0.191 | 24-Aug-99 | | 0.0 | 5-Jun-01 | 1400 | 0.0010 |
| 25-Jan-94 | 68 | 0.268 | 21-Jan-97 | 120 | 0.751 | 7-Sep-99 | | 0.0 | 11-Jun-01 | 7300 | 0.0164 |
| 1-Feb-94 | 140 | 0.046 | 28-Jan-97 | 160 | 0.519 | 21-Sep-99 | | 0.0 | 19-Jun-01 | 46 | 0 |
| 8-Feb-94 | 210 | 0.015 | 4-Feb-97 | 69 | 0.185 | 6-Oct-99 | | 0.00 | 17-Jul-01 | | 0.0002 |
| 14-Feb-94 | 80 | 0.411 | 11-Feb-97 | 96 | 0.347 | 12-Oct-99 | | 0.00 | 14-Aug-01 | | 0 |
| 15-Feb-94 | 120 | 3.13 | 18-Feb-97 | 100 | 0.319 | 19-Oct-99 | | 0.00 | 22-Aug-01 | 9700 | 0.0004 |
| 22-Feb-94 | 110 | 32.93 | 25-Feb-97 | 120 | 0.126 | 26-Oct-99 | | 0.0 | 4-Sep-01 | | |
| 1-Mar-94 | 140 | 0.495 | 4-Mar-97 | 36 | 0.481 | 2-Nov-99 | | 0.0012 | 2-Oct-01 | | 0.0004 |
| 2-Mar-94 | 76 | 1.488 | 11-Mar-97 | 65 | 0.370 | 9-Nov-99 | 2400 | 0.3847 | 16-Oct-01 | | 0.0004 |
| 8-Mar-94 | 80 | 0.065 | 18-Mar-97 | 61 | 1.897 | 16-Nov-99 | 140 | 0.0698 | 23-Oct-01 | 9300 | 0.0164 |
| 15-Mar-94 | 200 | 0.0496 | 25-Mar-97 | 69 | 0.122 | 22-Nov-99 | 71 | 0.3029 | 30-Oct-01 | 920 | 0.0329 |
| 21-Mar-94 | 63 | 0.5883 | 1-Apr-97 | 35 | 0.133 | 30-Nov-99 | 92 | 0.6046 | 6-Nov-01 | 62 | 0.0249 |
| 22-Mar-94 | 31 | 0.401 | 8-Apr-97 | 24 | 0.05 | 7-Dec-99 | 69 | 0.307 | 13-Nov-01 | 380 | 0.0035 |
| 29-Mar-94 | 17 | 0.015 | 15-Apr-97 | 88 | 0.14 | 14-Dec-99 | 140 | 2.43 | 19-Nov-01 | 520 | 0.3608 |
| 5-Apr-94 | 13 | 0.011 | 11-Nov-97 | 71 | 0.08 | 21-Dec-99 | 34 | 0.211 | 27-Nov-01 | 54 | 0.1068 |
| 6-Apr-94 | 690 | 0.0513 | 18-Nov-97 | 120 | 0.186 | 28-Dec-99 | 45 | 0.07 | 4-Dec-01 | 59 | 0.6313 |
| 12-Apr-94 | 19 | 0.020 | 24-Nov-97 | 78 | 0.539 | 4-Jan-00 | 89 | 1.09 | 11-Dec-01 | 220 | 0.207 |
| 19-Apr-94 | 7 | 0.008 | 2-Dec-97 | 40 | 0.267 | 11-Jan-00 | 41 | 0.58 | 18-Dec-01 | 88 | 1.9586 |
| 4-May-94 | | 0.02 | 9-Dec-97 | 25 | 0.065 | 18-Jan-00 | 37 | 0.425 | 26-Dec-01 | 16 | 0.0836 |
| 29-Aug-94 | 1110 | | 16-Dec-97 | 330 | 9.43 | 25-Jan-00 | 29 | 0.21 | 2-Jan-02 | 60 | 0.3608 |
| 15-Nov-94 | 1000 | 0.43 | 22-Dec-97 | 63 | 0.23 | 1-Feb-00 | 340 | 4.04 | 8-Jan-02 | 33 | 1.61 |
| 21-Nov-94 | 470 | 0.43 | 29-Dec-97 | 49 | 0.19 | 8-Feb-00 | 69 | 0.71 | 15-Jan-02 | 14 | 0.1440 |
| 29-Nov-94 | 2400 | 3.27 | 6-Jan-98 | 92 | 3.01 | 15-Feb-00 | 17 | 0.26 | 22-Jan-02 | 35 | 0.3667 |
| 6-Dec-94 | 830 | 0.43 | 12-Jan-98 | 27 | 0.11 | 22-Feb-00 | 81 | 0.392 | 29-Jan-02 | 10 | 0.1872 |
| 13-Dec-94 | 180 | 0.18 | 20-Jan-98 | 28 | 0.39 | 29-Feb-00 | 89 | 1.832 | 5-Feb-02 | 13 | 0.1963 |
| 19-Dec-94 | 590 | 4.41 | 27-Jan-98 | 39 | 0.389 | 7-Mar-00 | 11 | 0.146 | 12-Feb-02 | 20 | 0.2175 |
| 20-Dec-94 | 590 | 4.83 | 3-Feb-98 | 52 | 0.20 | 14-Mar-00 | 55 | 0.3614 | 19-Feb-02 | 25 | 0.4693 |
| 27-Dec-94 | 460 | 6.44 | 10-Feb-98 | 56 | 0.46 | 21-Mar-00 | 13 | 0.1623 | 26-Feb-02 | 9 | 0.2266 |
| 3-Jan-95 | 440 | 0.15 | 17-Feb-98 | 33 | 0.18 | 28-Mar-00 | 51 | 0.0698 | 5-Mar-02 | 28 | 0.0870 |
| 10-Jan-95 | 1100 | 0.62 | 24-Feb-98 | 27 | 0.21 | 4-Apr-00 | 200 | 0.010 | 11-Mar-02 | 290 | 6.1864 |
| 17-Jan-95 | 310 | 0.37 | 3-Mar-98 | 23 | 0.47 | 11-Apr-00 | 59 | 0.0481 | 20-Mar-02 | 17 | 1.0354 |
| 24-Jan-95 | 390 | 0.10 | 10-Mar-98 | 110 | 0.63 | 18-Apr-00 | 11 | 0.0279 | 27-Mar-02 | 92 | 0.0775 |
| 31-Jan-95 | 270 | 4.00 | 17-Mar-98 | 53 | 0.048 | 25-Apr-00 | 350 | 0.054 | 2-Apr-02 | 13 | 0.0308 |
| 7-Feb-95 | 1200 | 0.19 | 24-Mar-98 | 150 | 0.489 | 2-May-00 | 120 | 0.033 | 9-Apr-02 | 120 | 0.0571 |
| 14-Feb-95 | 550 | 0.15 | 31-Mar-98 | 27 | 0.117 | 9-May-00 | 19000 | 0.1363 | 16-Apr-02 | 73 | 0.45 |
| 21-Feb-95 | 680 | 0.43 | 7-Apr-98 | 140 | 0.028 | 16-May-00 | 40 | 0.034 | 24-Apr-02 | 2600 | 0.0419 |
| 28-Feb-95 | 730 | 0.06 | 14-Apr-98 | 20 | 0.05 | 23-May-00 | 26 | 0.0127 | 30-Apr-02 | 210 | 0.03 |
| 7-Mar-95 | 1400 | 0.04 | 2-Oct-98 | | 0.0 | 30-May-00 | 62 | 0.0167 | 8-May-02 | 140 | 0.02 |
| 14-Mar-95 | 230 | 1.89 | 7-Oct-98 | | 0.0 | 6-Jun-00 | 1700 | 0.0459 | 14-May-02 | 130 | 0.00 |
| 21-Mar-95 | 270 | 1.31 | 13-Oct-98 | | 0.0045 | 20-Jun-00 | 69 | 0.0078 | 21-May-02 | 91 | 0.00 |
| 28-Mar-95 | 390 | 0.09 | 20-Oct-98 | | 0.0000 | 11-Jul-00 | 16 | 0.00 | 28-May-02 | 550 | 0.01 |
| 4-Apr-95 | 150 | 0.05 | 27-Oct-98 | | 0 | 15-Aug-00 | | | 4-Jun-02 | 49 | 0.0109 |
| 11-Apr-95 | 66 | 0.0876 | 3-Nov-98 | | 0.0 | 6-Sep-00 | | 0.0011 | 11-Jun-02 | 11 | 0.0088 |
| 18-Apr-95 | 14 | 0.04 | 11-Nov-98 | | 0.0003 | 3-Oct-00 | | 0.0 | | | |
| 28-Apr-95 | | 0.0728 | 17-Nov-98 | 200 | 0.0271 | 10-Oct-00 | | 0.0 | | | |
| 14-Nov-95 | 310 | 0.54 | 23-Nov-98 | 250 | 0.8301 | 17-Oct-00 | | 0.0026 | | | |
| 20-Nov-95 | 80 | 0.08 | 1-Dec-98 | 210 | 2.2882 | 31-Oct-00 | | | | | |
| 28-Nov-95 | 210 | 1.07 | 8-Dec-98 | 69 | 0.5928 | 7-Nov-00 | | 0.0089 | | | |
| 5-Dec-95 | 100 | 0.255 | 15-Dec-98 | 53 | 0.40 | 14-Nov-00 | | 0.0089 | | | |

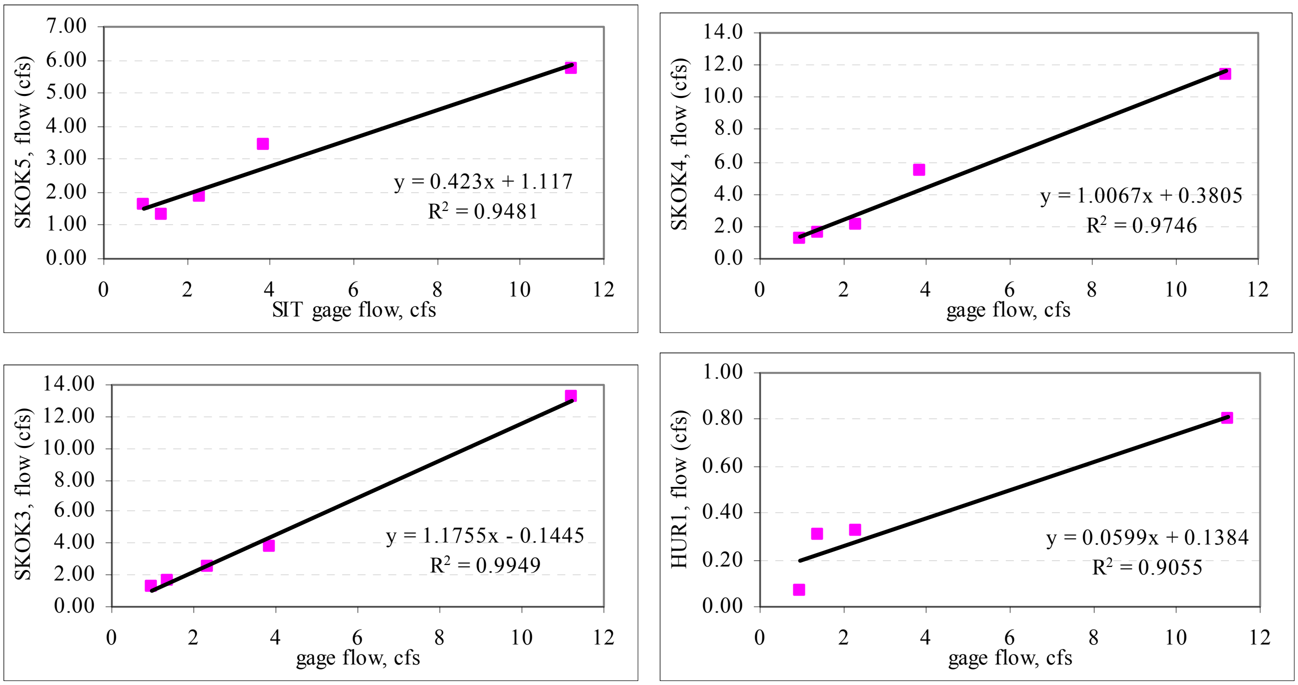
Table A-5. McLane Creek (FC= cfu/100 mL; Q=cfs), 1995-2003: Ecology (Nov-April), Thurston County (May-Oct).

| Date | FC | Q | Date | FC | Q | Date | FC | Q | Date | FC | Q | Date | FC | Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3-Jan-95 | 20 | 51.91 | 9-Dec-97 | 16 | 34.16 | 30-Nov-99 | 27 | 96.87 | 11-Jun-01 | 2000 | 23.84 | 23-Jul-01 | 180 | 3.49 |
| 10-Jan-95 | 23 | 56.37 | 16-Dec-97 | 430 | 342.65 | 7-Dec-99 | 45 | 125.45 | 19-Jun-01 | 240 | 6.27 | 14-Aug-01 | 220 | 1.40 |
| 17-Jan-95 | 100 | 67.63 | 22-Dec-97 | 15 | 74.29 | 14-Dec-99 | 48 | 234.73 | 17-Jul-01 | 220 | 2.62 | 22-Aug-01 | 3800 | 11.05 |
| 24-Jan-95 | 10 | 43.97 | 29-Dec-97 | 34 | 65.66 | 21-Dec-99 | 14 | 100.38 | 23-Jul-01 | 180 | 3.49 | 28-Aug-01 | 565 | 3.3 |
| 31-Jan-95 | 92 | 339.08 | 6-Jan-98 | 240 | 228.73 | 28-Dec-99 | 100 | 37.87 | 14-Aug-01 | 220 | 1.40 | 4-Sep-01 | 260 | 2.54 |
| 7-Feb-95 | 13 | 43.60 | 12-Jan-98 | 96 | 61.91 | 4-Jan-00 | 64 | 216.10 | 22-Aug-01 | 3800 | 11.05 | 18-Sep-01 | 210 | 1.57 |
| 14-Feb-95 | 51 | 17.23 | 20-Jan-98 | 28 | 131.49 | 11-Jan-00 | 23 | 111.64 | 28-Aug-01 | 565 | 3.3 | 2-Oct-01 | 74 | 2.23 |
| 21-Feb-95 | 40 | 204.17 | 27-Jan-98 | 19 | 139.60 | 18-Jan-00 | 13 | 109.28 | 4-Sep-01 | 260 | 2.54 | 16-Oct-01 | 110 | |
| 28-Feb-95 | 16 | 44.72 | 3-Feb-98 | 13 | 43.76 | 25-Jan-00 | 15 | 67.34 | 18-Sep-01 | 210 | 1.57 | 23-Oct-01 | 760 | 16.20 |
| 7-Mar-95 | 8 | 35.81 | 10-Feb-98 | 20 | 51.68 | 1-Feb-00 | 260 | 345.21 | 2-Oct-01 | 74 | 2.23 | 30-Oct-01 | 350 | 10.41 |
| 14-Mar-95 | 100 | 194.49 | 17-Feb-98 | 19 | 67.16 | 8-Feb-00 | 57 | 91.14 | 16-Oct-01 | 110 | | 6-Nov-01 | 530 | 12.21 |
| 21-Mar-95 | 35 | 153.65 | 24-Feb-98 | 13 | 72.67 | 15-Feb-00 | 28 | 48.65 | 23-Oct-01 | 760 | 16.20 | 13-Nov-01 | 580 | 10.93 |
| 28-Mar-95 | 20 | 48.08 | 3-Mar-98 | 25 | 87.53 | 22-Feb-00 | 18 | 36.85 | 30-Oct-01 | 350 | 10.41 | 19-Nov-01 | 530 | 76.25 |
| 4-Apr-95 | 160 | 32.96 | 10-Mar-98 | 31 | 133.55 | 29-Feb-00 | 210 | 125.09 | 6-Nov-01 | 530 | 12.21 | 27-Nov-01 | 250 | 53.57 |
| 11-Apr-95 | 49 | 31.81 | 17-Mar-98 | 8 | 48.74 | 7-Mar-00 | 6 | 62.17 | 13-Nov-01 | 580 | 10.93 | 4-Dec-01 | 3 | 148.45 |
| 18-Apr-95 | 24 | 35.14 | 24-Mar-98 | 190 | 84.75 | 14-Mar-00 | 22 | 64.76 | 19-Nov-01 | 530 | 76.25 | 11-Dec-01 | 270 | 124.63 |
| 28-Apr-95 | | 23.01 | 31-Mar-98 | 21 | 45.78 | 21-Mar-00 | 8 | 78.60 | 27-Nov-01 | 250 | 53.57 | 18-Dec-01 | 49 | 236.89 |
| 31-Aug-95 | 137 | 2.6 | 7-Apr-98 | 34 | 28.68 | 28-Mar-00 | 6 | 37.42 | 4-Dec-01 | 3 | 148.45 | 26-Dec-01 | 85 | 42.37 |
| 25-Sep-95 | 610 | 2.73 | 14-Apr-98 | 9 | 25.03 | 4-Apr-00 | 63 | 23.67 | 11-Dec-01 | 270 | 124.63 | 2-Jan-02 | 35 | 40.58 |
| 14-Nov-95 | 27 | 120.70 | 27-Jul-99 | 745 | 3.99 | 11-Apr-00 | 13 | 19.08 | 18-Dec-01 | 49 | 236.89 | 8-Jan-02 | 17 | 309.10 |
| 20-Nov-95 | 21 | 51.87 | 22-Sep-99 | 110 | 2.27 | 18-Apr-00 | 53 | 16.02 | 26-Dec-01 | 85 | 42.37 | 15-Jan-02 | 120 | 55.92 |
| 28-Nov-95 | 76 | 194.46 | 2-Oct-98 | | 2.40 | 25-Apr-00 | 120 | 22.72 | 2-Jan-02 | 35 | 40.58 | 22-Jan-02 | 53 | 59.92 |
| 5-Dec-95 | 19 | 103.46 | 7-Oct-98 | 130 | 3.06 | 2-May-00 | 120 | 21.09 | 8-Jan-02 | 17 | 309.10 | 29-Jan-02 | 48 | 80.75 |
| 12-Dec-95 | 22 | 160.23 | 13-Oct-98 | 840 | 10.87 | 9-May-00 | 2800 | 10.10 | 15-Jan-02 | 120 | 55.92 | 5-Feb-02 | 26 | 76.84 |
| 19-Dec-95 | 56 | 82.55 | 20-Oct-98 | 49 | 2.75 | 16-May-00 | 400 | 15.66 | 22-Jan-02 | 53 | 59.92 | 12-Feb-02 | 28 | 63.90 |
| 26-Dec-95 | 57 | 36.85 | 27-Oct-98 | 84 | 2.49 | 23-May-00 | 54 | 12.68 | 29-Jan-02 | 48 | 80.75 | 19-Feb-02 | 21 | 43.88 |
| 2-Jan-96 | 17 | 67.26 | 3-Nov-98 | 110 | 2.73 | 30-May-00 | 120 | 12.21 | 5-Feb-02 | 26 | 76.84 | 26-Feb-02 | 18 | 68.94 |
| 9-Jan-96 | 14 | 126.31 | 11-Nov-98 | 92 | 3.28 | 6-Jun-00 | 980 | 13.22 | 12-Feb-02 | 28 | 63.90 | 5-Mar-02 | 5 | 35.03 |
| 16-Jan-96 | 23 | 147.46 | 17-Nov-98 | 63 | 29.96 | 20-Jun-00 | 200 | 16.48 | 19-Feb-02 | 21 | 43.88 | 11-Mar-02 | 480 | 171.78 |
| 23-Jan-96 | 44 | 191.89 | 23-Nov-98 | 61 | 153.79 | 11-Jul-00 | 160 | 6.13 | 26-Feb-02 | 18 | 68.94 | 20-Mar-02 | 40 | 127.84 |
| 30-Jan-96 | 10 | 52.60 | 1-Dec-98 | 85 | 117.81 | 27-Jul-00 | 160 | 3.9 | 5-Mar-02 | 5 | 35.03 | 27-Mar-02 | 11 | 44.58 |
| 6-Feb-96 | 160 | 360.90 | 8-Dec-98 | 110 | 122.43 | 15-Aug-00 | 250 | 3.20 | 11-Mar-02 | 480 | 171.78 | 2-Apr-02 | 13 | 29.87 |
| 13-Feb-96 | 2 | 79.57 | 15-Dec-98 | 77 | 141.73 | 22-Aug-00 | 790 | 3.26 | 20-Mar-02 | 40 | 127.84 | 9-Apr-02 | 21 | 27.29 |
| 20-Feb-96 | 33 | 84.92 | 22-Dec-98 | 150 | 35.35 | 6-Sep-00 | 400 | 3.28 | 27-Mar-02 | 11 | 44.58 | 16-Apr-02 | 29 | 106.81 |
| 27-Feb-96 | 8 | 68.68 | 29-Dec-98 | 92 | 524.48 | 20-Sep-00 | 250 | 2.58 | 2-Apr-02 | 13 | 29.87 | 24-Apr-02 | 40 | 36.30 |
| 5-Mar-96 | 18 | 52.61 | 4-Jan-99 | 130 | 64.89 | 3-Oct-00 | 260 | 3.15 | 9-Apr-02 | 21 | 27.29 | 30-Apr-02 | 39 | 26.47 |
| 12-Mar-96 | 19 | 60.28 | 11-Jan-99 | 170 | 38.57 | 10-Oct-00 | 610 | 7.58 | 16-Apr-02 | 29 | 106.81 | 8-May-02 | 15 | 18.06 |
| 19-Mar-96 | 8 | 36.58 | 19-Jan-99 | 85 | 206.28 | 17-Oct-00 | 320 | 4.47 | 24-Apr-02 | 40 | 36.30 | 14-May-02 | 49 | 11.78 |
| 26-Mar-96 | 14 | 25.81 | 26-Jan-99 | 100 | 80.82 | 24-Oct-00 | 160 | 5.22 | 30-Apr-02 | 39 | 26.47 | 21-May-02 | 100 | 12.83 |
| 2-Apr-96 | 28 | 28.12 | 2-Feb-99 | 81 | 277.12 | 31-Oct-00 | 160 | 5.22 | 8-May-02 | 15 | 18.06 | 28-May-02 | 84 | 12.39 |
| 9-Apr-96 | 22 | 17.59 | 9-Feb-99 | 32 | 189.20 | 7-Nov-00 | 150 | 7.64 | 14-May-02 | 49 | 11.78 | 4-Jun-02 | 47 | 9.51 |
| 16-Apr-96 | 410 | 53.14 | 16-Feb-99 | 740 | 151.91 | 14-Nov-00 | 88 | 5.11 | 21-May-02 | 100 | 12.83 | 11-Jun-02 | 120 | 7.70 |
| 4-Sep-96 | 180 | 2.8 | 23-Feb-99 | 12 | 184.06 | 20-Nov-00 | 110 | 4.43 | 28-May-02 | 84 | 12.39 | 29-Jul-02 | 210 | 3.39 |
| 4-Sep-97 | 60 | 3.75 | 2-Mar-99 | 60 | 200.13 | 28-Nov-00 | 160 | 24.10 | 4-Jun-02 | 47 | 9.51 | 28-Aug-02 | 40 | 2.83 |
| 12-Nov-96 | 37 | 26.94 | 9-Mar-99 | 140 | 73.80 | 5-Dec-00 | 240 | 16.28 | 11-Jun-02 | 120 | 7.70 | 17-Dec-02 | 7 | |
| 19-Nov-96 | 92 | 55.58 | 17-Mar-99 | 85 | 64.65 | 12-Dec-00 | 130 | 9.49 | 29-Jul-02 | 210 | 3.39 | 28-Jan-03 | 5 | |
| 25-Nov-96 | 77 | 111.92 | 23-Mar-99 | 80 | 41.44 | 19-Dec-00 | 100 | 36.97 | 28-Aug-02 | 40 | 2.83 | 19-Feb-03 | 5 | 48.48 |
| 3-Dec-96 | 19 | 113.75 | 30-Mar-99 | 76 | 114.05 | 26-Dec-00 | 92 | 39.45 | 17-Dec-02 | 7 | | 17-Mar-03 | 5 | 102.06 |
| 10-Dec-96 | 65 | 127.11 | 6-Apr-99 | 28 | 36.70 | 2-Jan-01 | 63 | 30.59 | 28-Jan-03 | 5 | | 21-Jul-03 | 110 | 3.66 |
| 17-Dec-96 | 29 | 65.86 | 13-Apr-99 | 51 | 27.87 | 9-Jan-01 | 350 | 32.33 | 19-Feb-03 | 5 | 48.48 | 12-Aug-03 | 745 | 4.02 |
| 22-Dec-96 | 36 | 75.06 | 19-Apr-99 | 110 | 22.22 | 16-Jan-01 | 160 | 18.70 | 17-Mar-03 | 5 | 102.06 | 16-Dec-03 | 25 | 87.7 |
| 7-Jan-97 | 38 | 183.07 | 27-Apr-99 | 120 | 19.83 | 23-Jan-01 | 120 | 32.89 | 21-Jul-03 | 110 | 3.66 | 22-Jan-04 | 10 | 44.4 |
| 14-Jan-97 | 24 | 49.39 | 5-May-99 | 280 | 18.77 | 30-Jan-01 | 77 | 47.35 | 12-Aug-03 | 745 | 4.02 | 17-Feb-04 | 15 | 61.6 |
| 21-Jan-97 | 30 | 110.08 | 11-May-99 | 470 | 19.40 | 6-Feb-01 | 21 | 49.48 | 27-Feb-01 | 7 | 23.08 | 15-Mar-04 | 15 | 30.8 |
| 28-Jan-97 | 66 | 89.53 | 18-May-99 | 220 | 25.19 | 13-Feb-01 | 5 | 24.83 | 6-Mar-01 | 13 | 21.85 | 19-Apr-04 | 50 | 20.98 |
| 4-Feb-97 | 31 | 64.55 | 24-May-99 | 200 | 14.42 | 20-Feb-01 | 15 | 35.45 | 12-Mar-01 | 7 | 16.27 | 17-May-04 | 110 | 7.7 |
| 11-Feb-97 | 14 | 40.72 | 1-Jun-99 | 170 | 9.84 | 27-Feb-01 | 7 | 23.08 | 20-Mar-01 | 27 | 40.29 | 22-Jun-04 | 120 | 5.37 |
| 18-Feb-97 | 13 | 82.73 | 9-Jun-99 | 1300 | 7.23 | 6-Mar-01 | 13 | 21.85 | 27-Mar-01 | 22 | 29.20 | 15-Jul-04 | 140 | 3.08 |
| 25-Feb-97 | 4 | 58.84 | 21-Jun-99 | 5000 | 6.84 | 12-Mar-01 | 7 | 16.27 | 3-Apr-01 | 9 | 27.49 | 24-Aug-04 | 150 | 3.53 |
| 4-Mar-97 | 4 | 105.46 | 20-Jul-99 | 670 | 4.17 | 20-Mar-01 | 27 | 40.29 | 9-Apr-01 | 8 | 21.08 | 22-Sep-04 | 225 | 4.85 |
| 11-Mar-97 | 4 | 113.65 | 24-Aug-99 | 780 | 2.73 | 27-Mar-01 | 22 | 29.20 | 17-Apr-01 | 27 | 18.44 | 19-Oct-04 | 225 | 24.31 |
| 18-Mar-97 | 28 | 137.48 | 7-Sep-99 | 120 | 2.12 | 3-Apr-01 | 9 | 27.49 | 24-Apr-01 | 30 | 19.41 | 9-Nov-04 | 25 | |
| 25-Mar-97 | 1 | 77.76 | 21-Sep-99 | 250 | 1.77 | 9-Apr-01 | 8 | 21.08 | 1-May-01 | 100 | 40 | 13-Dec-04 | 10 | |
| 1-Apr-97 | 5 | 50.15 | 6-Oct-99 | 130 | 2.17 | 17-Apr-01 | 27 | 18.44 | 8-May-01 | 52 | 15.49 | 10-Jan-05 | 30 | 36.24 |
| 8-Apr-97 | 13 | 27.22 | 12-Oct-99 | 96 | 3.16 | 24-Apr-01 | 30 | 19.41 | 15-May-01 | 330 | 24.19 | 15-Feb-05 | 65 | 22.52 |
| 15-Apr-97 | 19 | 42.13 | 19-Oct-99 | 200 | 2.65 | 1-May-01 | 100 | 40 | 22-May-01 | 40 | 14.79 | 14-Mar-05 | 30 | 10.92 |
| 26-Aug-98 | 17000 | 4.01 | 26-Oct-99 | 54 | 3.05 | 8-May-01 | 52 | 15.49 | 29-May-01 | 90 | 8.95 | 12-Apr-05 | 45 | 57.17 |
| 11-Nov-97 | 160 | 32.99 | 2-Nov-99 | 45 | 7.01 | 15-May-01 | 330 | 24.19 | 5-Jun-01 | 150 | 9.12 | 10-May-05 | 100 | 53.84 |
| 18-Nov-97 | 88 | 43.39 | 9-Nov-99 | 120 | 14.66 | 22-May-01 | 40 | 14.79 | 11-Jun-01 | 2000 | 23.84 | 7-Jun-05 | 120 | 18.55 |
| 24-Nov-97 | 27 | 111.30 | 16-Nov-99 | 32 | 37.22 | 29-May-01 | 90 | 8.95 | 19-Jun-01 | 240 | 6.27 | 12-Jul-05 | 195 | 11.58 |
| 2-Dec-97 | 9 | 76.97 | 22-Nov-99 | 48 | 114.24 | 5-Jun-01 | 150 | 9.12 | 17-Jul-01 | 220 | 2.62 | | | |

Table A-6. Perry Creek (FC= cfu/100 mL; Q=cfs), 1995-2003: Ecology (Nov-April), Thurston County (May-Oct).

| Date | FC | Q | Date | FC | Q | Date | FC | Q | Date | FC | Q |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3-Jan-95 | 4 | 23.27 | 29-Dec-97 | 16 | 23.84 | 14-Dec-99 | 33 | 150.19 | 17-Jul-01 | 23 | 1.27 |
| 10-Jan-95 | 47 | 30.14 | 6-Jan-98 | 56 | 178.67 | 21-Dec-99 | 11 | 45.52 | 23-Jul-01 | 35 | 1.65 |
| 17-Jan-95 | 19 | 32.31 | 12-Jan-98 | 3 | 25.29 | 28-Dec-99 | 13 | 14.22 | 14-Aug-01 | 17 | 0.48 |
| 24-Jan-95 | 4 | 22.67 | 20-Jan-98 | 7 | 62.13 | 4-Jan-00 | 29 | 74.69 | 22-Aug-01 | 1800 | 7.33 |
| 31-Jan-95 | 27 | 148.26 | 27-Jan-98 | 3 | 76.34 | 11-Jan-00 | 16 | 52.82 | 28-Aug-01 | 65 | 1.47 |
| 7-Feb-95 | 11 | 19.13 | 3-Feb-98 | 15 | 25.08 | 18-Jan-00 | 5 | 78.62 | 4-Sep-01 | 70 | 1 |
| 14-Feb-95 | 32 | 11.88 | 10-Feb-98 | 24 | 24.45 | 25-Jan-00 | 50 | 31.43 | 18-Sep-01 | 18 | 1 |
| 21-Feb-95 | 2 | 96.75 | 17-Feb-98 | 3 | 31.07 | 1-Feb-00 | 88 | 117.56 | 2-Oct-01 | 22 | 0.87 |
| 28-Feb-95 | 1 | 20.07 | 24-Feb-98 | 4 | 43.80 | 8-Feb-00 | 15 | 38.77 | 16-Oct-01 | 46 | 2.8046 |
| 7-Mar-95 | 5 | 14.72 | 3-Mar-98 | 10 | 30.95 | 15-Feb-00 | 15 | 20.70 | 23-Oct-01 | 250 | 4.19 |
| 14-Mar-95 | 200 | 124.95 | 10-Mar-98 | 14 | 47.22 | 22-Feb-00 | 1 | 18.93 | 30-Oct-01 | 120 | 3.84 |
| 21-Mar-95 | 29 | 97.51 | 17-Mar-98 | 3 | 22.23 | 29-Feb-00 | 10 | 66.69 | 6-Nov-01 | 20 | 3.99 |
| 28-Mar-95 | 9 | 21.74 | 24-Mar-98 | 35 | 43.62 | 7-Mar-00 | 3 | 39.11 | 13-Nov-01 | 100 | 3.65 |
| 4-Apr-95 | 5 | 13.28 | 31-Mar-98 | 2 | 23.74 | 14-Mar-00 | 7 | 33.17 | 19-Nov-01 | 660 | 12.41 |
| 11-Apr-95 | 29 | 17.81 | 7-Apr-98 | 8 | 13.32 | 21-Mar-00 | 1 | 42.60 | 27-Nov-01 | 43 | 28.23 |
| 18-Apr-95 | 13 | 15.81 | 14-Apr-98 | 3 | 7.11 | 28-Mar-00 | 1 | 16.34 | 4-Dec-01 | 55 | 66.25 |
| 28-Apr-95 | | 11.53 | 26-Aug-98 | 20 | 0.25 | 4-Apr-00 | 5 | 8.77 | 11-Dec-01 | 2100 | 48.31 |
| 31-Aug-95 | 5 | 0.46 | 2-Oct-98 | | 0.570 | 11-Apr-00 | 1 | 6.14 | 18-Dec-01 | 34 | 150.99 |
| 25-Sep-95 | 370 | 0.62 | 7-Oct-98 | 18 | 1.427 | 18-Apr-00 | 1 | 6.12 | 26-Dec-01 | 260 | 17.59 |
| 14-Nov-95 | 31 | 42.83 | 13-Oct-98 | 420 | 5.31 | 25-Apr-00 | 33 | 8.40 | 2-Jan-02 | 34 | 24.00 |
| 20-Nov-95 | 11 | 20.33 | 20-Oct-98 | 31 | 0.483 | 2-May-00 | 38 | 8.58 | 8-Jan-02 | 28 | 204.75 |
| 28-Nov-95 | 59 | 97.67 | 27-Oct-98 | 15 | 0.572 | 9-May-00 | 23 | 9.79 | 15-Jan-02 | 20 | 26.5080 |
| 5-Dec-95 | 6 | 63.36 | 3-Nov-98 | 8 | 0.502 | 16-May-00 | 11 | 6.08 | 22-Jan-02 | 2 | 28.10 |
| 12-Dec-95 | 44 | 112.27 | 11-Nov-98 | 12 | 1.059 | 23-May-00 | 1 | 3.4030 | 29-Jan-02 | 8 | 39.93 |
| 19-Dec-95 | 61 | 50.22 | 17-Nov-98 | 12 | 11.77 | 30-May-00 | 13 | 0.98 | 5-Feb-02 | 4 | 32.59 |
| 26-Dec-95 | 33 | 14.77 | 23-Nov-98 | 38 | 85.28 | 6-Jun-00 | 130 | 2.54 | 12-Feb-02 | 7 | 27.79 |
| 2-Jan-96 | 6 | 39.60 | 1-Dec-98 | 86 | 114.56 | 20-Jun-00 | 12 | 7.11 | 19-Feb-02 | 37 | 18.73 |
| 9-Jan-96 | 33 | 70.54 | 8-Dec-98 | 44 | 56.82 | 11-Jul-00 | 18 | 1.55 | 26-Feb-02 | 2 | 37.04 |
| 16-Jan-96 | 6 | 58.42 | 15-Dec-98 | 55 | 77.45 | 27-Jul-00 | 20 | 1.52 | 5-Mar-02 | 5 | 15.41 |
| 23-Jan-96 | 15 | 95.96 | 22-Dec-98 | 17 | 35.94 | 15-Aug-00 | 41 | 0.96 | 11-Mar-02 | 390 | 107.45 |
| 30-Jan-96 | 4 | 22.90 | 29-Dec-98 | 47 | 474.86 | 22-Aug-00 | 70 | 0.48 | 20-Mar-02 | 9 | 57.59 |
| 6-Feb-96 | 73 | 160.84 | 4-Jan-99 | 18 | 28.93 | 6-Sep-00 | 25 | 0.75 | 27-Mar-02 | 9 | 20.74 |
| 13-Feb-96 | 9 | 37.35 | 11-Jan-99 | 19 | 16.34 | 20-Sep-00 | 21 | 0.79 | 2-Apr-02 | 1 | 11.28 |
| 20-Feb-96 | 110 | 62.78 | 19-Jan-99 | 17 | 189.85 | 3-Oct-00 | 20 | 0.65 | 9-Apr-02 | 35 | 8.4712 |
| 27-Feb-96 | 2 | 35.64 | 26-Jan-99 | 3 | 35.65 | 10-Oct-00 | 110 | 2.52 | 16-Apr-02 | 40 | 53.60 |
| 5-Mar-96 | 11 | 21.68 | 2-Feb-99 | 84 | 287.92 | 17-Oct-00 | 14 | 2.40 | 24-Apr-02 | 13 | 15.78 |
| 12-Mar-96 | 2 | 29.83 | 9-Feb-99 | 4 | 78.03 | 24-Oct-00 | 5 | 1.67 | 30-Apr-02 | 15 | 10.82 |
| 19-Mar-96 | 4 | 16.04 | 16-Feb-99 | 35 | 66.47 | 31-Oct-00 | 22 | 1.76 | 8-May-02 | 39 | 7.57 |
| 26-Mar-96 | 1 | 10.78 | 23-Feb-99 | 7 | 147.28 | 7-Nov-00 | 27 | 2.52 | 14-May-02 | 25 | 6.44 |
| 2-Apr-96 | 5 | 10.03 | 2-Mar-99 | 9 | 106.35 | 14-Nov-00 | 24 | 1.74 | 21-May-02 | 12 | 4.69 |
| 9-Apr-96 | 2 | 6.05 | 9-Mar-99 | 4 | 32.91 | 20-Nov-00 | 19 | 1.41 | 28-May-02 | 10 | 4.62 |
| 16-Apr-96 | 120 | 22.72 | 17-Mar-99 | 6 | 36.89 | 28-Nov-00 | 16 | 9.57 | 4-Jun-02 | 31 | 3.41 |
| 4-Sep-96 | 10 | 0.82 | 23-Mar-99 | 1 | 15.98 | 5-Dec-00 | 130 | 7.35 | 11-Jun-02 | 8 | 2.85 |
| 12-Nov-96 | 10 | 10.51 | 30-Mar-99 | 11 | 85.18 | 12-Dec-00 | 130 | 5.68 | 29-Jul-02 | 33 | 0.55 |
| 19-Nov-96 | 25 | 18.11 | 6-Apr-99 | 1 | 19.13 | 19-Dec-00 | 84 | 17.45 | 28-Aug-02 | 175 | 0.29 |
| 25-Nov-96 | 36 | 56.45 | 13-Apr-99 | 1 | 15.39 | 26-Dec-00 | 3 | 26.33 | 17-Dec-02 | 30 | 58.34 |
| 3-Dec-96 | 17 | 60.82 | 19-Apr-99 | 6 | 8.16 | 2-Jan-01 | 14 | 15.20 | 28-Jan-03 | 1 | 86.57 |
| 10-Dec-96 | 18 | 81.34 | 27-Apr-99 | 1 | 6.97 | 9-Jan-01 | 64 | 17.78 | 19-Feb-03 | 15 | 22.77 |
| 17-Dec-96 | 4 | 33.69 | 5-May-99 | 5 | 5.14 | 16-Jan-01 | 5 | 10.10 | 17-Mar-03 | 35 | 65.62 |
| 22-Dec-96 | 32 | 31.55 | 11-May-99 | 11 | 6.88 | 23-Jan-01 | 5 | 25.50 | 21-Jul-03 | 130 | 0.91 |
| 7-Jan-97 | 9 | 84.52 | 18-May-99 | 10 | 7.40 | 30-Jan-01 | 74 | 20.10 | 12-Aug-03 | 55 | 0.28 |
| 14-Jan-97 | 10 | 24.74 | 24-May-99 | 31 | 4.45 | 6-Feb-01 | 3 | 24.77 | 16-Dec-03 | 40 | |
| 21-Jan-97 | 6 | 61.92 | 1-Jun-99 | 1 | 3.515 | 13-Feb-01 | 1 | 13.95 | 22-Jan-04 | 5 | 21.2 |
| 28-Jan-97 | 7 | 39.41 | 9-Jun-99 | 24 | 3.17 | 20-Feb-01 | 8 | 17.50 | 17-Feb-04 | 10 | 40.8 |
| 4-Feb-97 | 4 | 37.59 | 21-Jun-99 | 13 | 2.55 | 27-Feb-01 | 1 | 14.03 | 15-Mar-04 | 5 | 13.3 |
| 11-Feb-97 | 2 | 18.92 | 20-Jul-99 | 11 | 1.21 | 6-Mar-01 | 4 | 16.37 | 19-Apr-04 | 25 | 7.56 |
| 18-Feb-97 | 10 | 42.22 | 28-Jul-99 | 60 | 1.26 | 12-Mar-01 | 7 | 9.25 | 17-May-04 | 30 | 3.48 |
| 25-Feb-97 | 8 | 32.28 | 24-Aug-99 | 45 | 0.788 | 20-Mar-01 | 11 | 18.38 | 22-Jun-04 | 20 | 1.75 |
| 4-Mar-97 | 7 | 62.86 | 7-Sep-99 | 210 | 0.538 | 27-Mar-01 | 7 | 11.93 | 15-Jul-04 | 85 | 0.92 |
| 11-Mar-97 | 5 | 49.88 | 21-Sep-99 | 37 | 0.499 | 3-Apr-01 | 4 | 16.43 | 24-Aug-04 | 60 | 1.04 |
| 18-Mar-97 | 30 | 103.88 | 22-Sep-99 | 70 | 0.74 | 9-Apr-01 | 2 | 10.26 | 22-Sep-04 | 15 | 1.19 |
| 25-Mar-97 | 1 | 29.78 | 6-Oct-99 | 11 | 0.47 | 17-Apr-01 | 12 | 10.55 | 19-Oct-04 | 80 | 14.09 |
| 1-Apr-97 | 1 | 19.42 | 12-Oct-99 | 6 | 0.76 | 24-Apr-01 | 4 | 8.65 | 9-Nov-04 | 50 | |
| 8-Apr-97 | 1 | 11.69 | 19-Oct-99 | 14 | 0.70 | 1-May-01 | 28 | 18 | 13-Dec-04 | 55 | |
| 15-Apr-97 | 1 | 15.01 | 26-Oct-99 | 19 | 0.72 | 8-May-01 | 4 | 8.53 | 10-Jan-05 | 10 | 22.9 |
| 4-Sep-97 | 1 | 1.14 | 2-Nov-99 | 6 | 3.33 | 15-May-01 | 70 | 10.60 | 15-Feb-05 | 25 | 9.58 |
| 11-Nov-97 | 34 | 14.03 | 9-Nov-99 | 29 | 8.94 | 22-May-01 | 41 | | 14-Mar-05 | 25 | 4.67 |
| 18-Nov-97 | 17 | 17.98 | 16-Nov-99 | 16 | 23.14 | 29-May-01 | 59 | 4.76 | 12-Apr-05 | 45 | 31.22 |
| 24-Nov-97 | 20 | 66.13 | 22-Nov-99 | 41 | 64.32 | 5-Jun-01 | 50 | 4.07 | 10-May-05 | 1300 | 22.22 |
| 2-Dec-97 | 8 | 44.34 | 30-Nov-99 | 13 | 21.94 | 11-Jun-01 | 250 | 9.67 | 7-Jun-05 | 45 | 7.26 |
| 9-Dec-97 | 6 | 17.06 | 7-Dec-99 | 29 | 78.81 | 19-Jun-01 | 68 | 2.79 | 11-Jul-05 | 230 | 3.08 |
| 16-Dec-97 | 220 | 192.15 | | | | | | | | | |
| 22-Dec-97 | 21 | 35.54 | | | | | | | | | |

# Appendix B. Relationship between Tribal Gage-flow and Flow at Other Stations in Skookum Creek




SIT – Squaxin Island Tribe

Figure B-1. Relationship between Tribal Gage-flow and Flow at Other Stations in Skookum Creek.

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# Appendix C. Rainfall and Fecal Coliform Concentrations

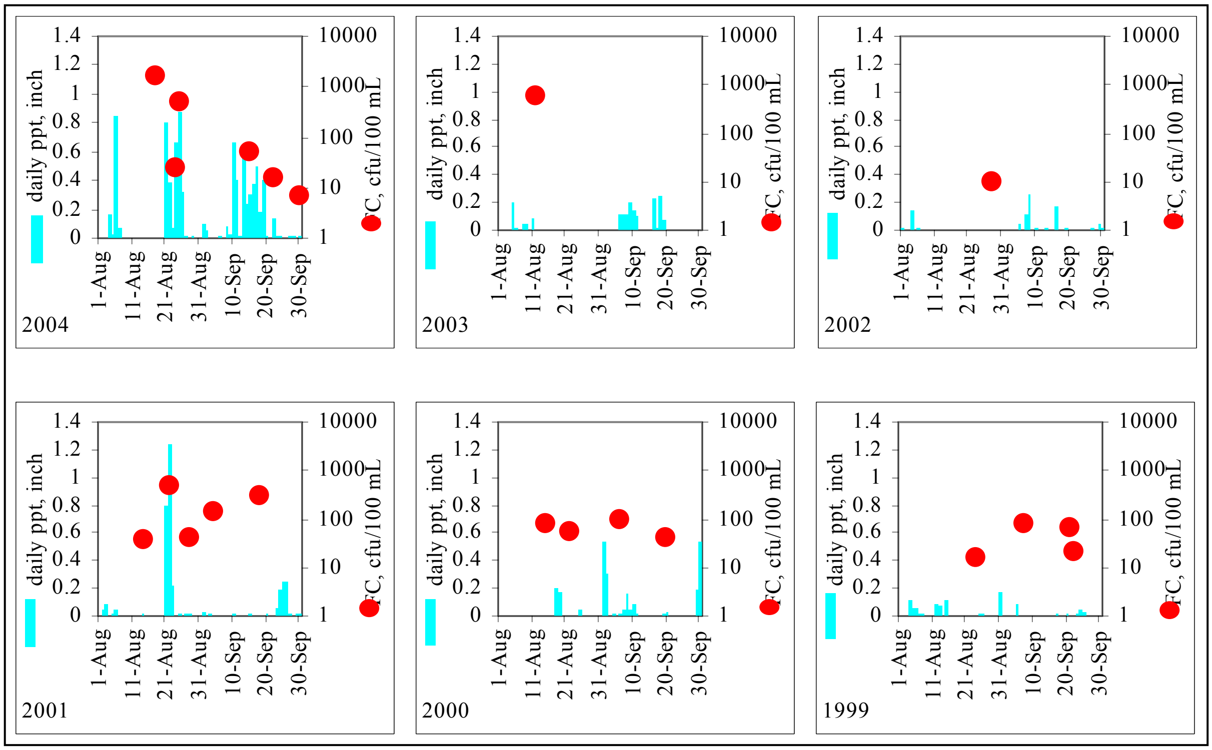


Figure C-1. FC concentrations in **Kennedy Creek** and rainfall at Olympia Airport (Aug-Sept, 1999-2004).

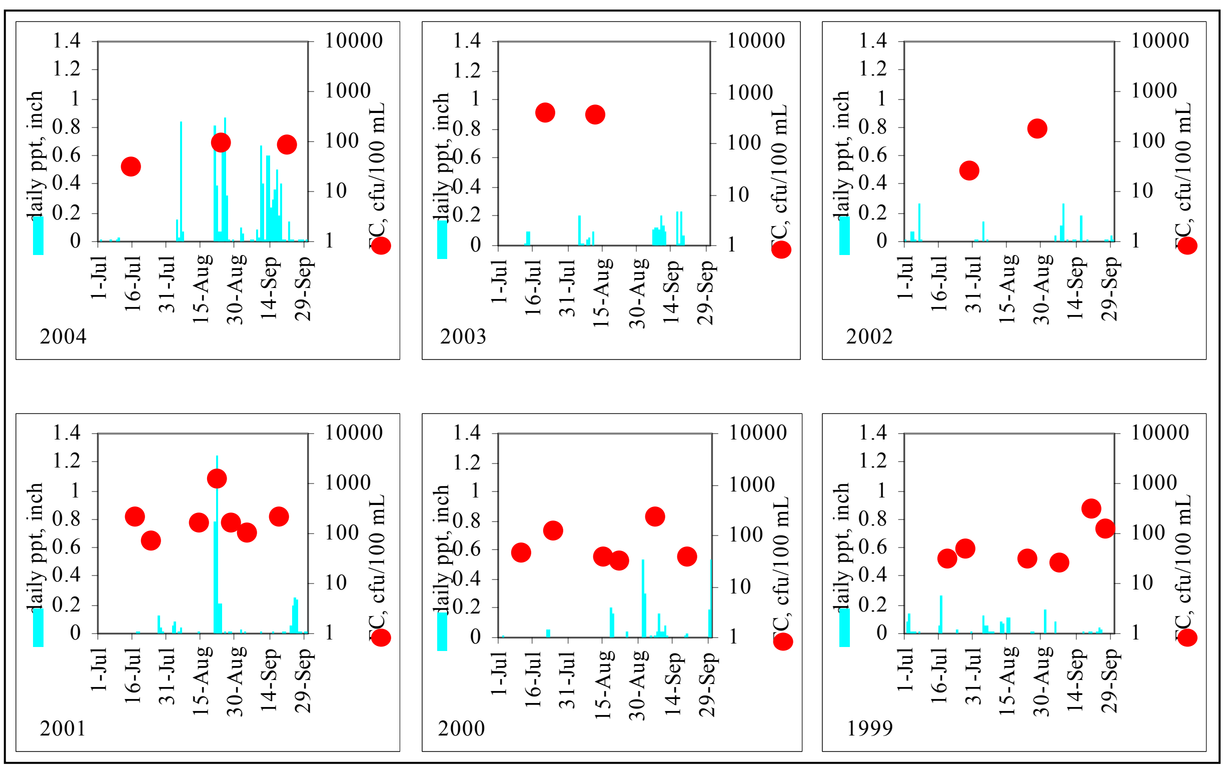


Figure C-2. FC concentrations in **Schneider Creek** and rainfall at Olympia Airport (Jul-Sept, 1999-2004).

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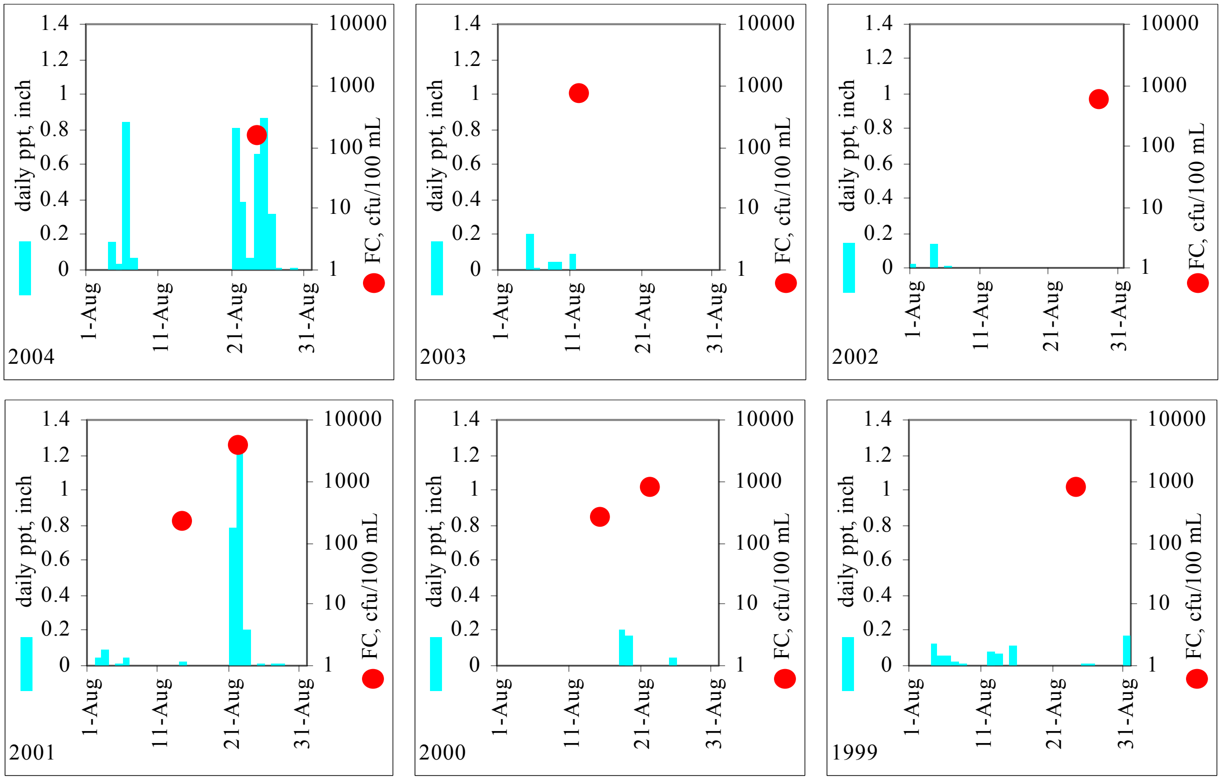

Figure C-3. FC concentrations in **McLane Creek** and rainfall at Olympia Airport (August, 1999-2004).

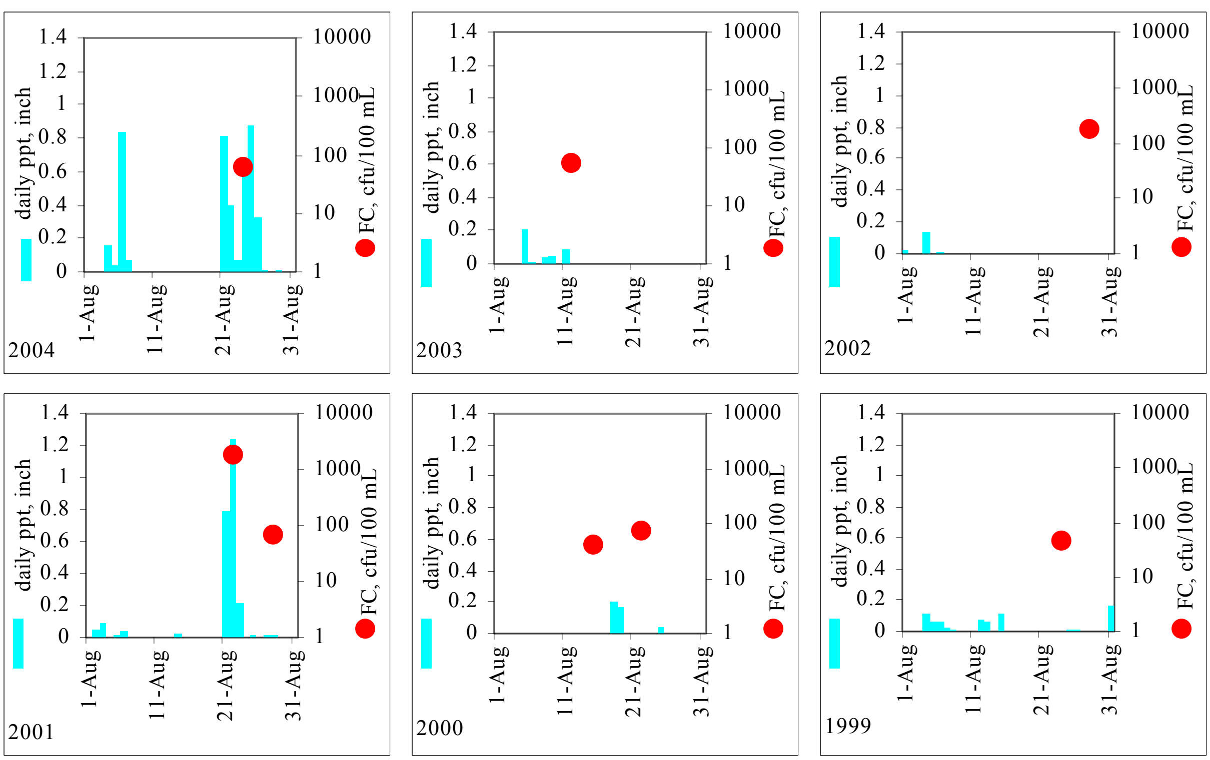

Figure C-4. FC concentrations in **Perry Creek** and rainfall at Olympia Airport (August, 1999-2004).

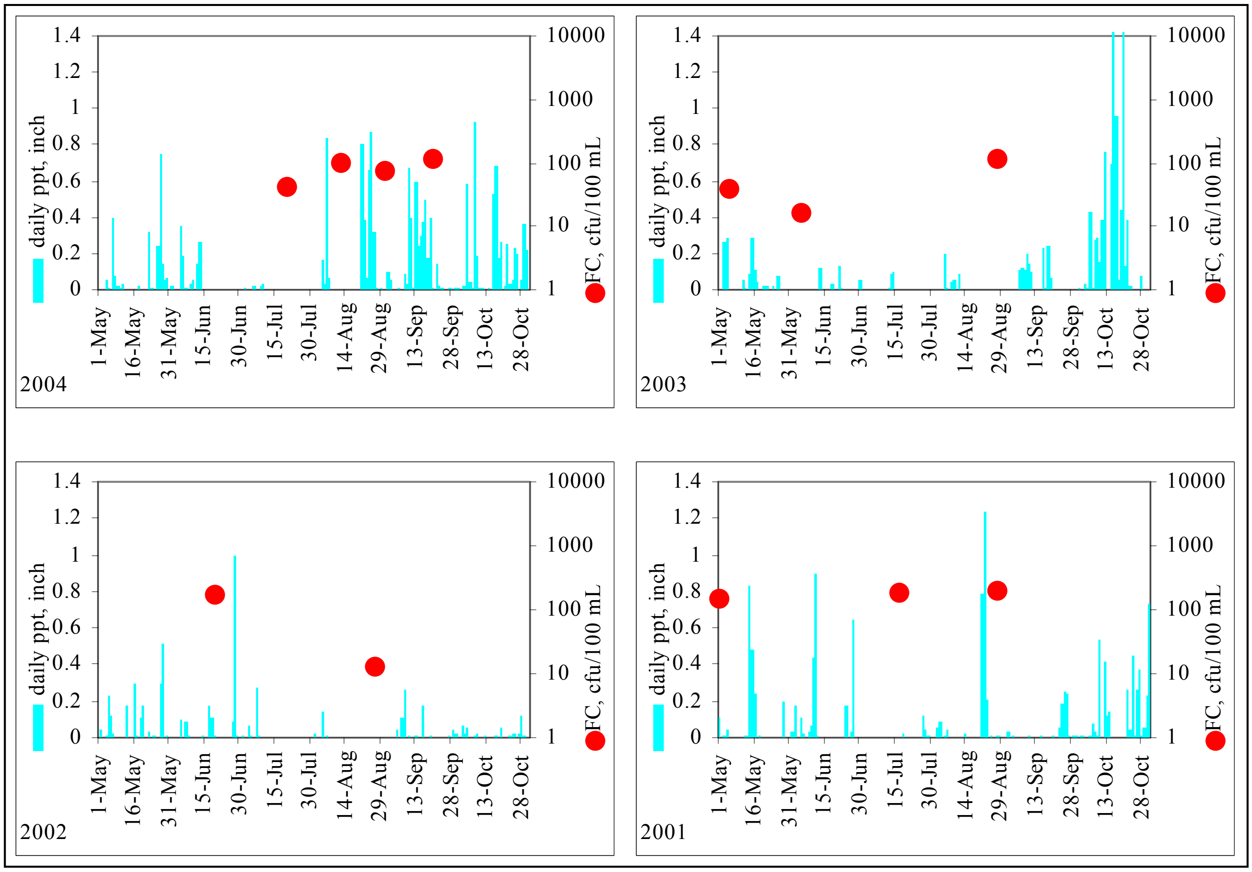


Figure C-5. FC concentrations in **Skookum Creek** and rainfall at Olympia Airport (August, 2001-2004).

# Appendix D.  Streamflows and Fecal Coliform Loads

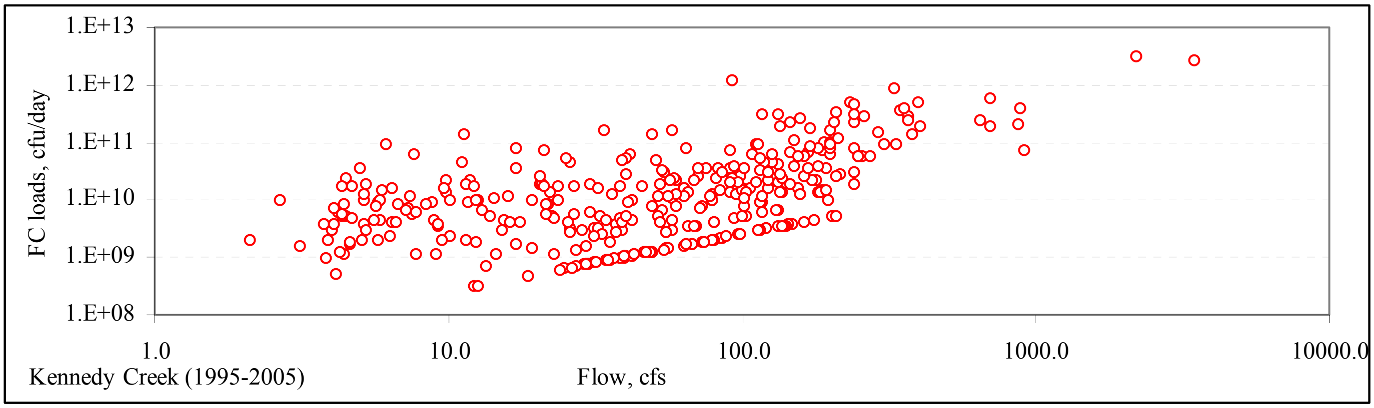


Figure D-1.  Instream flows and fecal coliform loads in **Kennedy Creek** (1995-2005).

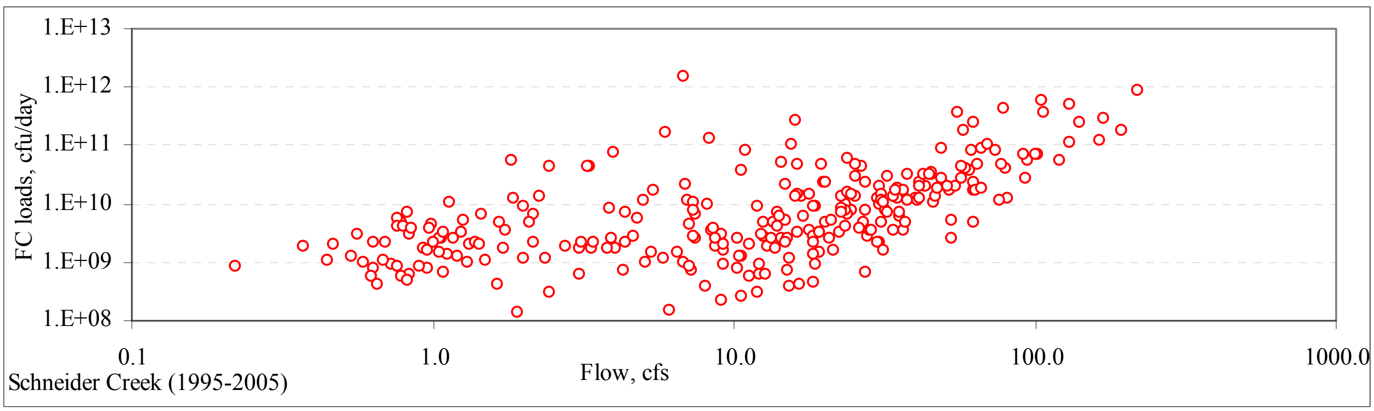


Figure D-2.  Instream flows and fecal coliform loads in **Schneider Creek** (1995-2005).

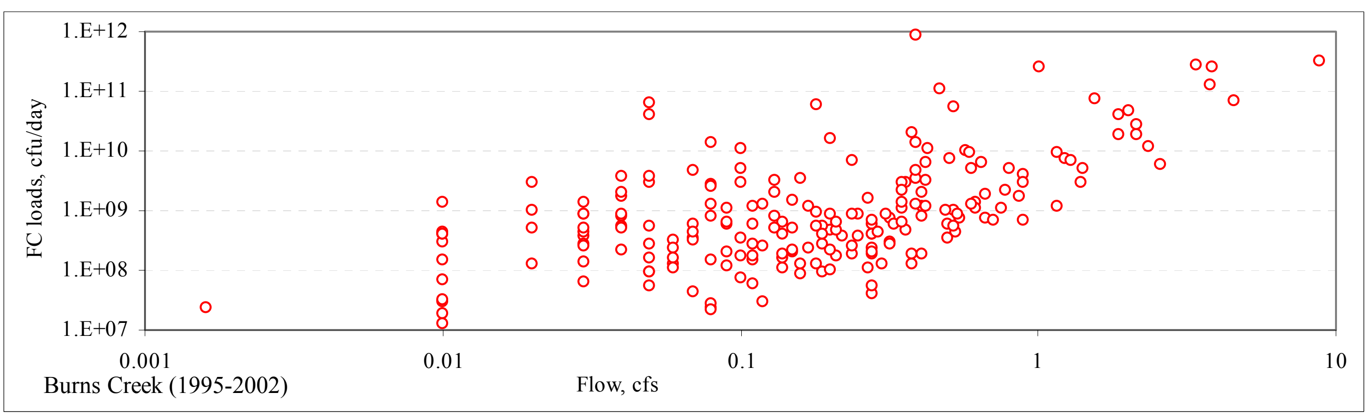


Figure D-3.  Instream flows and fecal coliform loads in **Burns Creek** (1995-2002).

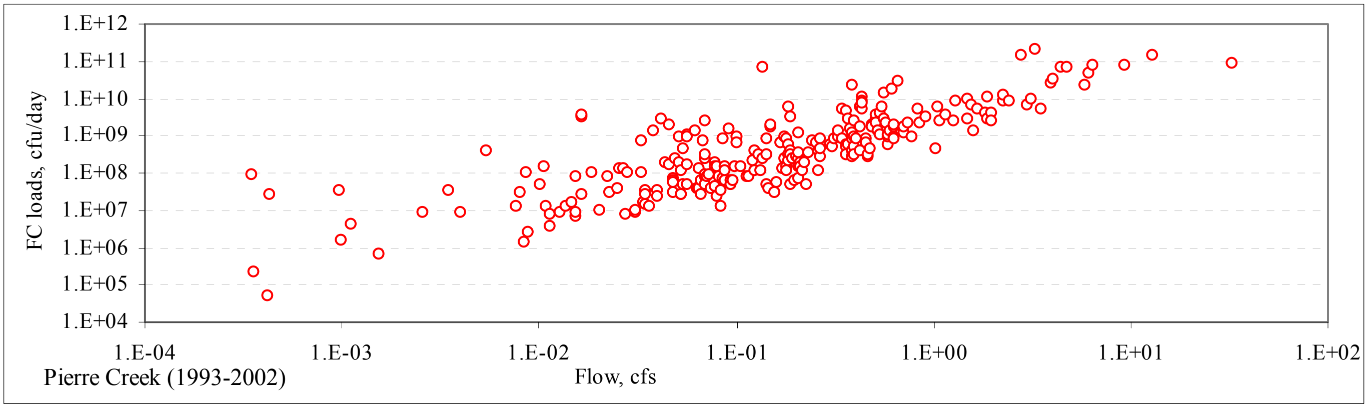


Figure D-4. Instream flows and fecal coliform loads in **Pierre Creek** (1995-2002).

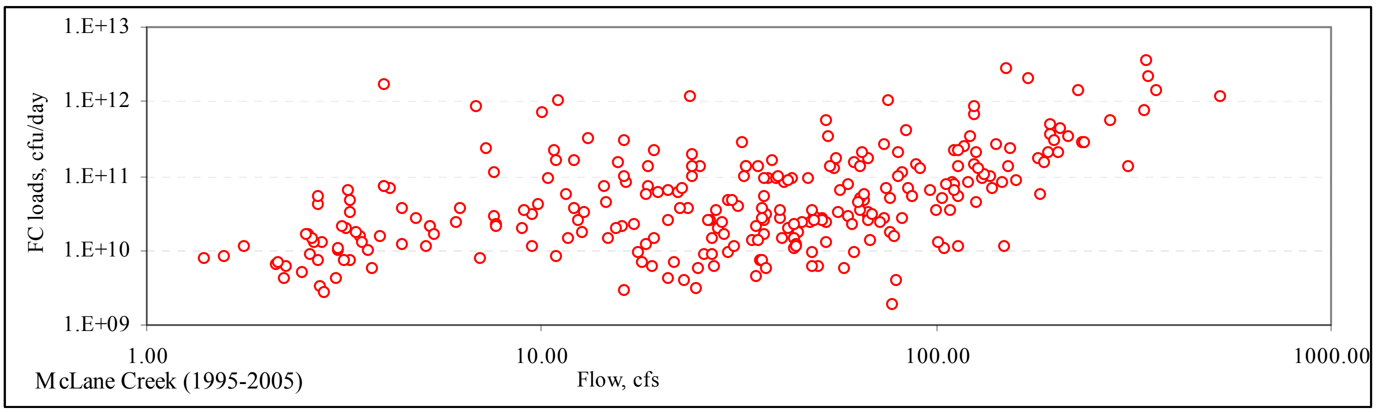


Figure D-5. Instream flows and fecal coliform loads in **McLane Creek** (1995-2005).

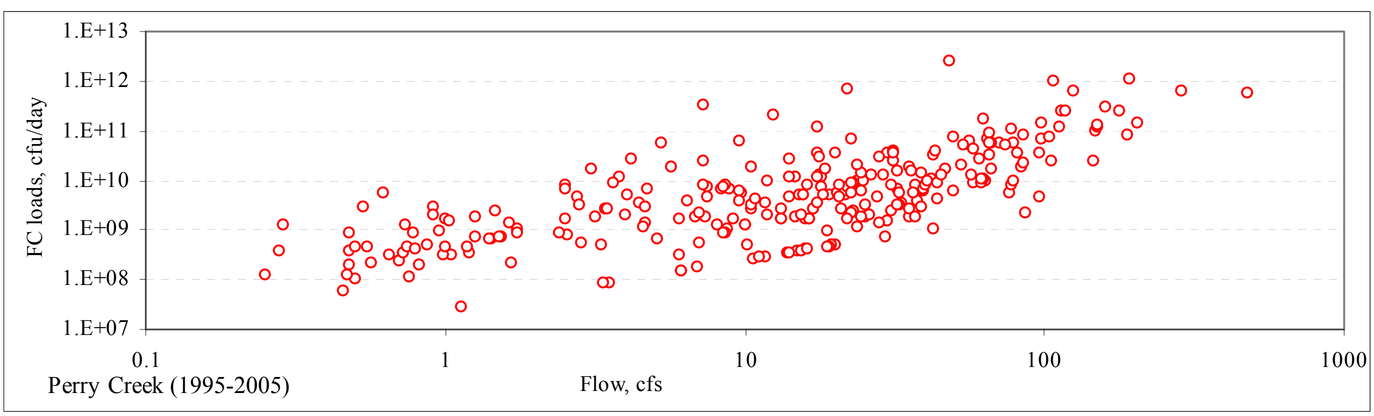


Figure D-6. Instream flows and fecal coliform loads in **Perry Creek** (1995-2005).

# Appendix E.  Streamflows and Fecal Coliform Concentrations During Critical Periods

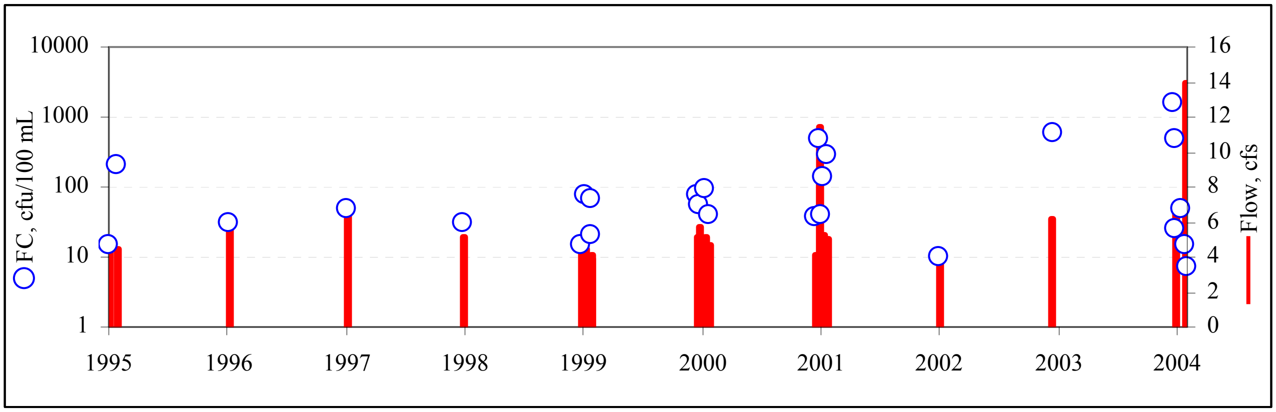


Figure E-1.  FC concentrations and streamflows for critical period in **Kennedy Creek** (Aug-Sept, 1995-2004).

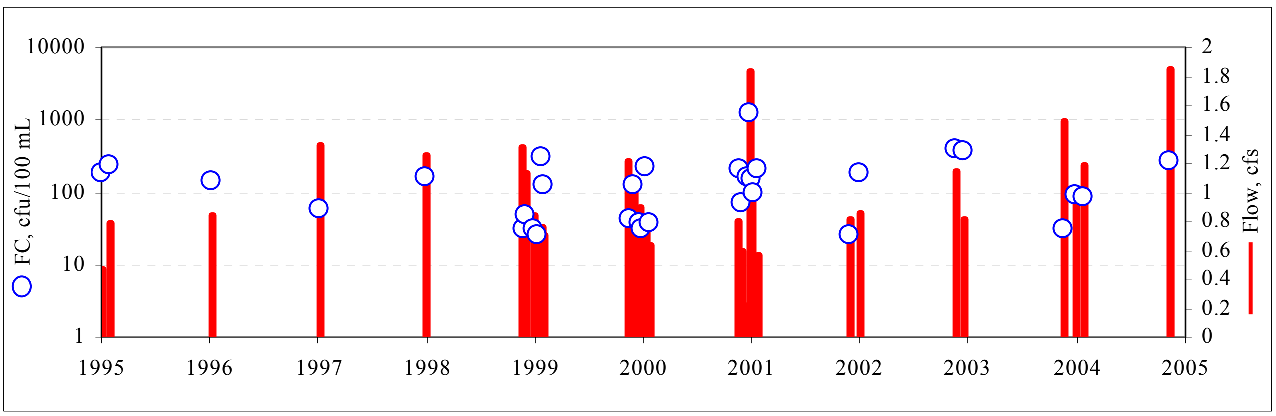


Figure E-2.  FC concentrations and streamflows for critical period in **Schneider Creek** (Jul-Sept, 1995-2005).

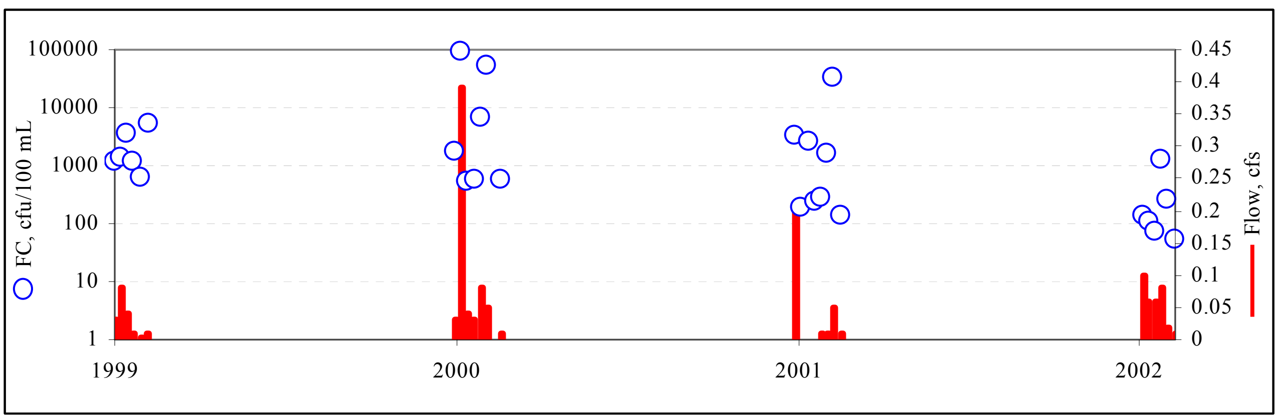


Figure E-3.  FC concentrations and streamflows for critical period in **Burns Creek** (May-June, 1999-2002).

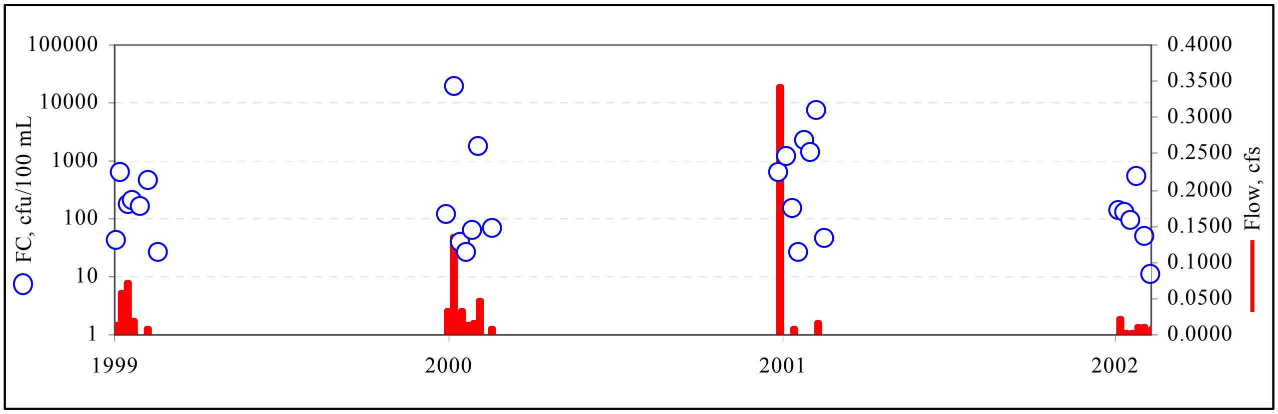


Figure E-4. FC concentrations and streamflows for critical period in **Pierre Creek** (May-June, 1999-2002).

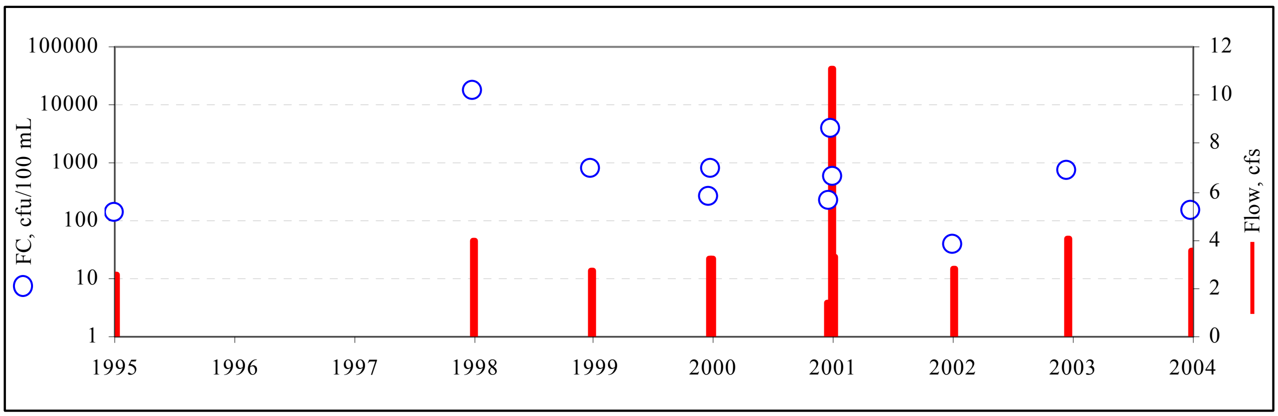


Figure E-5. FC concentrations and streamflows for critical period in **McLane Creek** (August, 1995-2004).

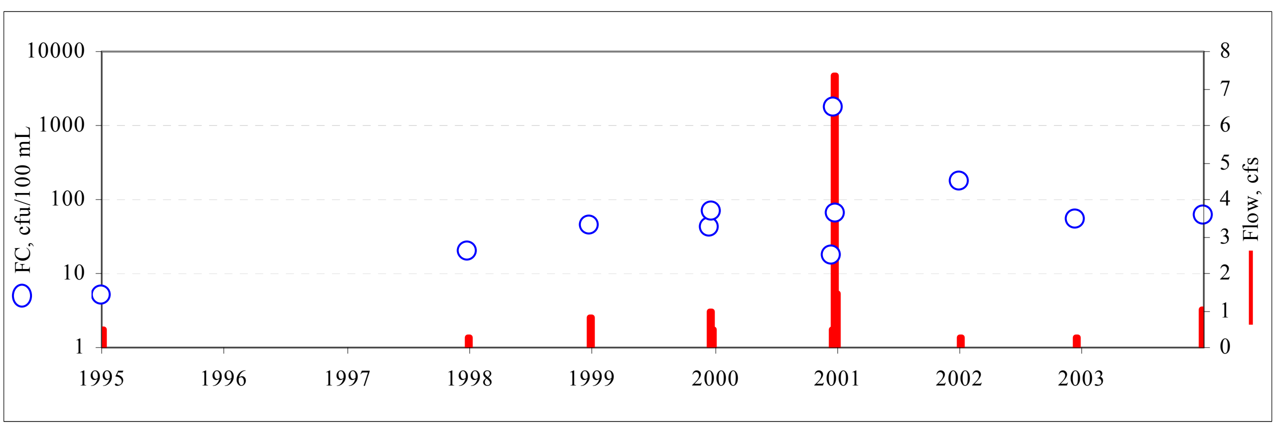


Figure E-6. FC concentrations and streamflows for critical period in **Perry Creek** (August, 1995-2004).

# Appendix F. Groundwater and Stream Temperature Profiles, and Hydraulic Gradients, at Skookum Creek Stations

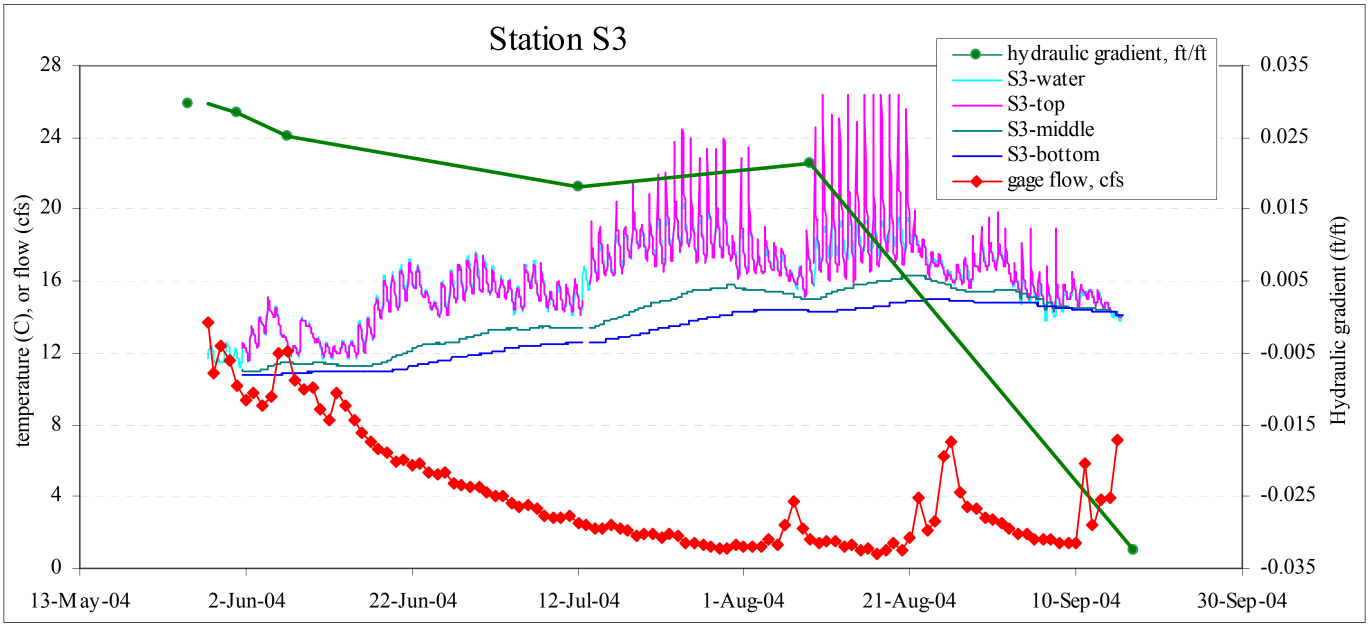


Figure F-1. Groundwater and stream temperature profiles, and hydraulic gradients, at Station S3.

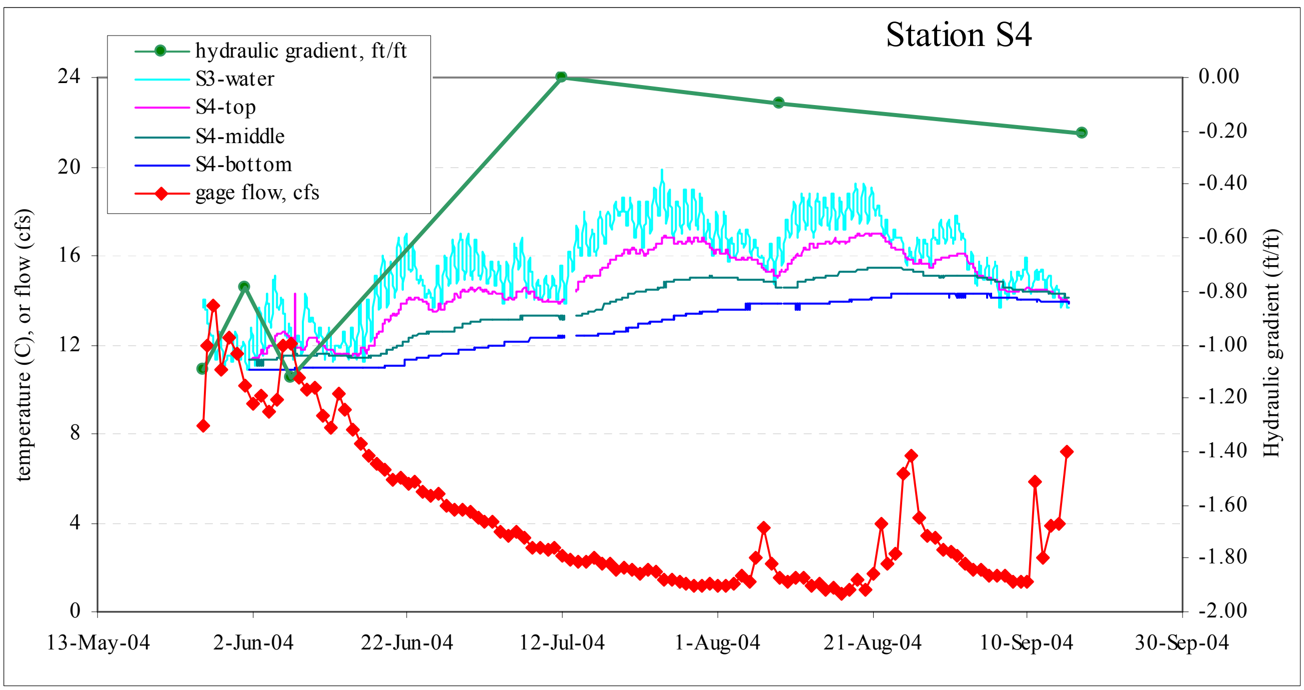


Figure F-2. Groundwater and stream temperature profiles, and hydraulic gradients, at Station S4.

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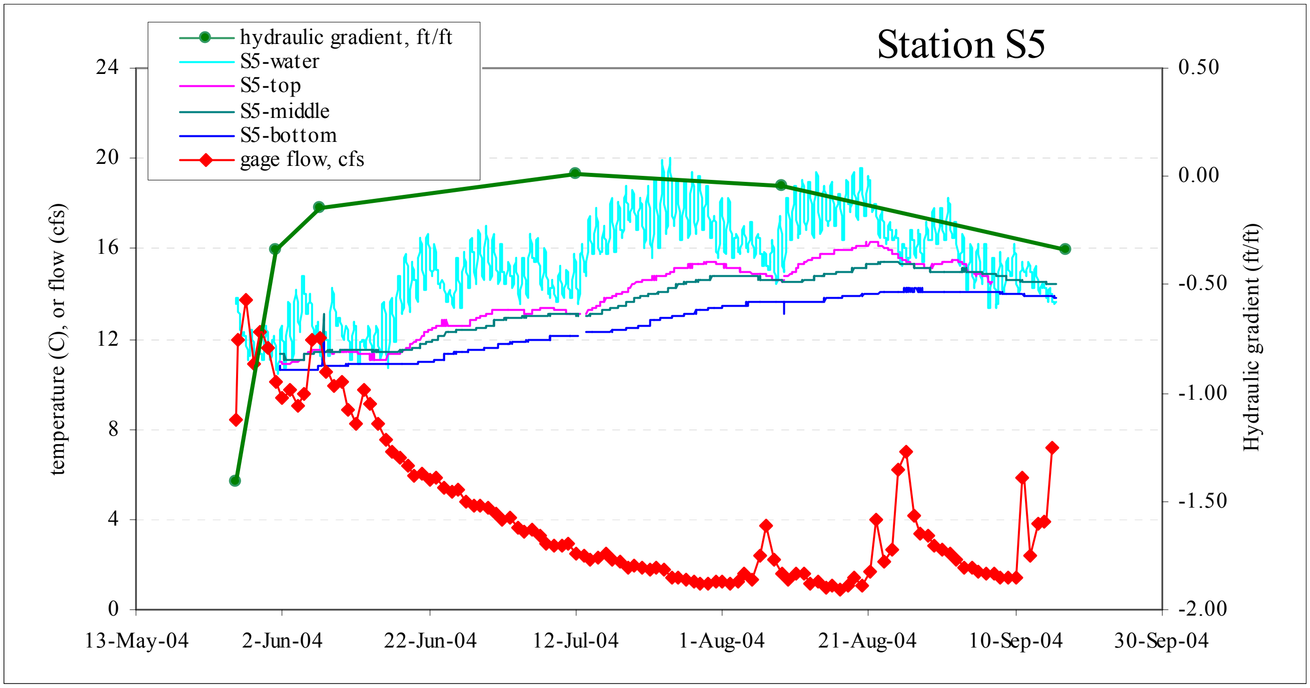


Figure F-3. Groundwater and stream temperature profiles, and hydraulic gradients, at Station S5.

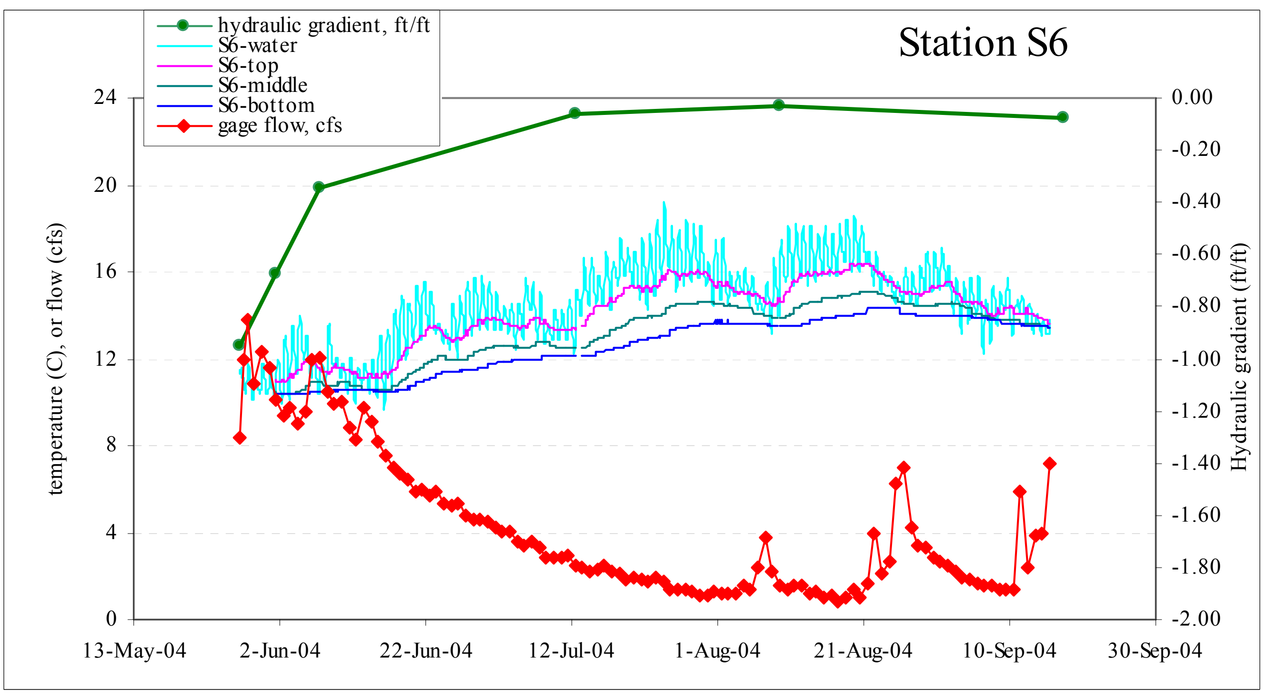


Figure F-4. Groundwater and stream temperature profiles, and hydraulic gradients, at Station S6.

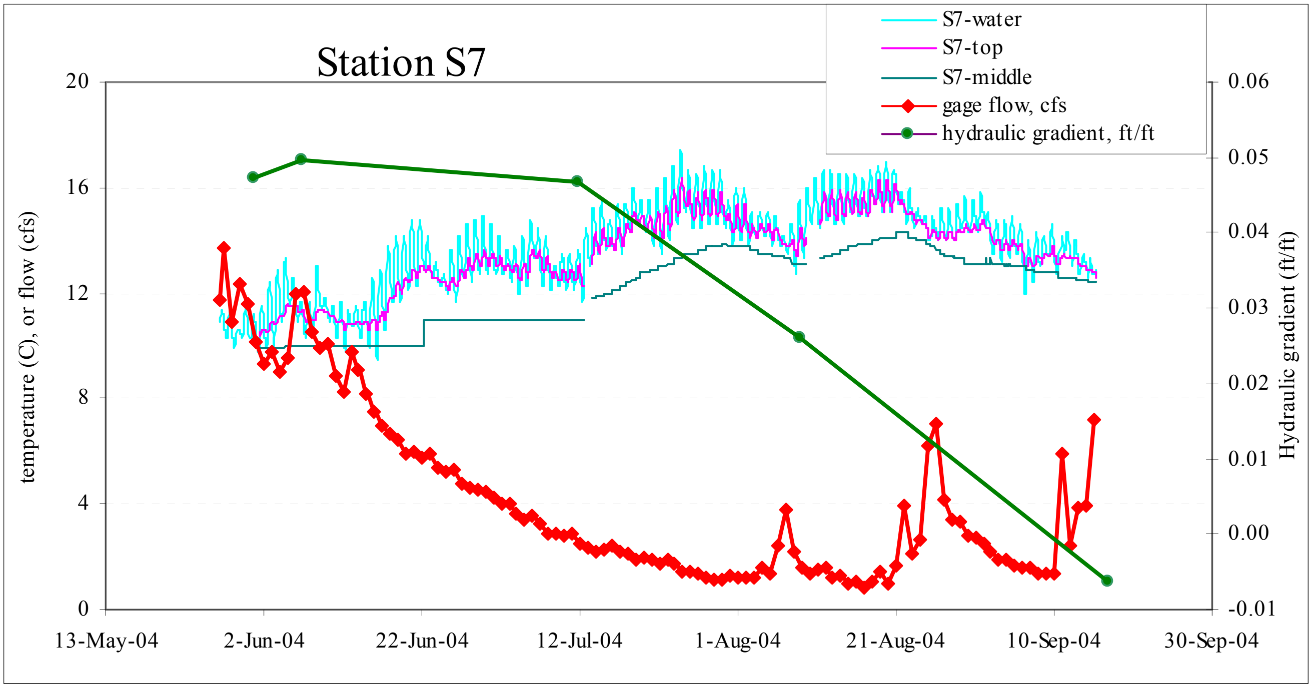


Figure F-5. Groundwater and stream temperature profiles, and hydraulic gradients, at Station S7.

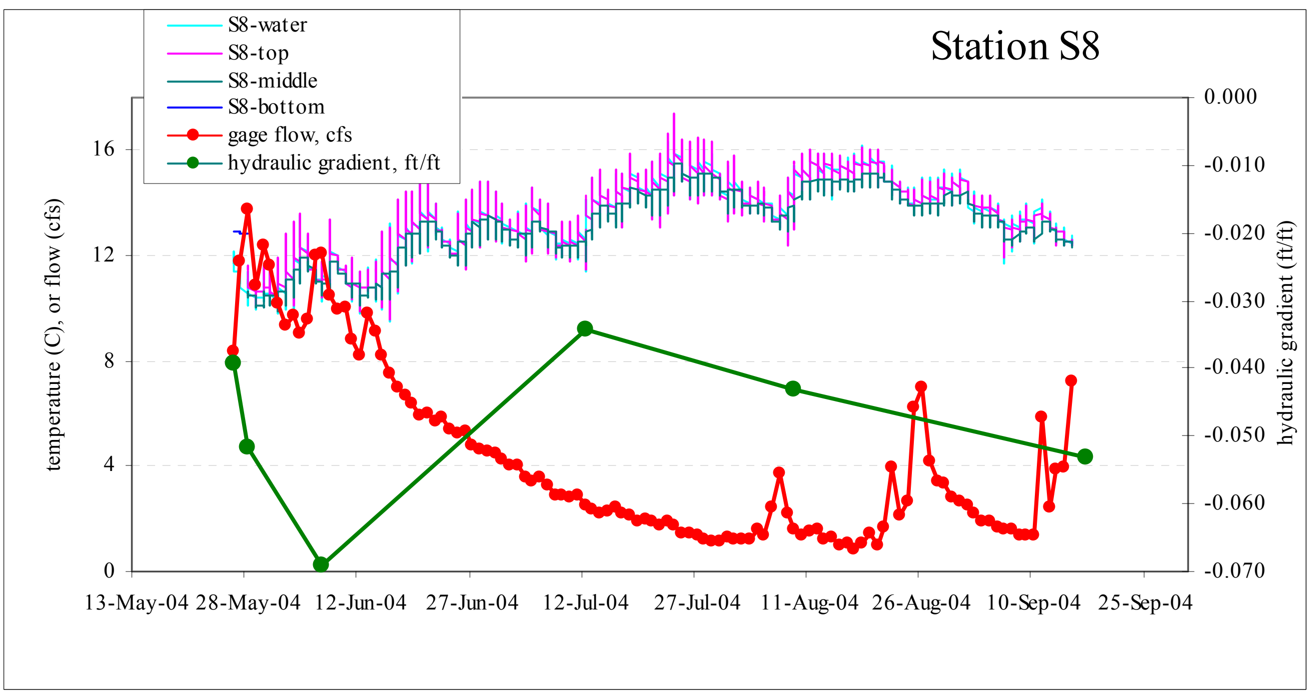


Figure F-6. Groundwater and stream temperature profiles, and hydraulic gradients, at Station S8.

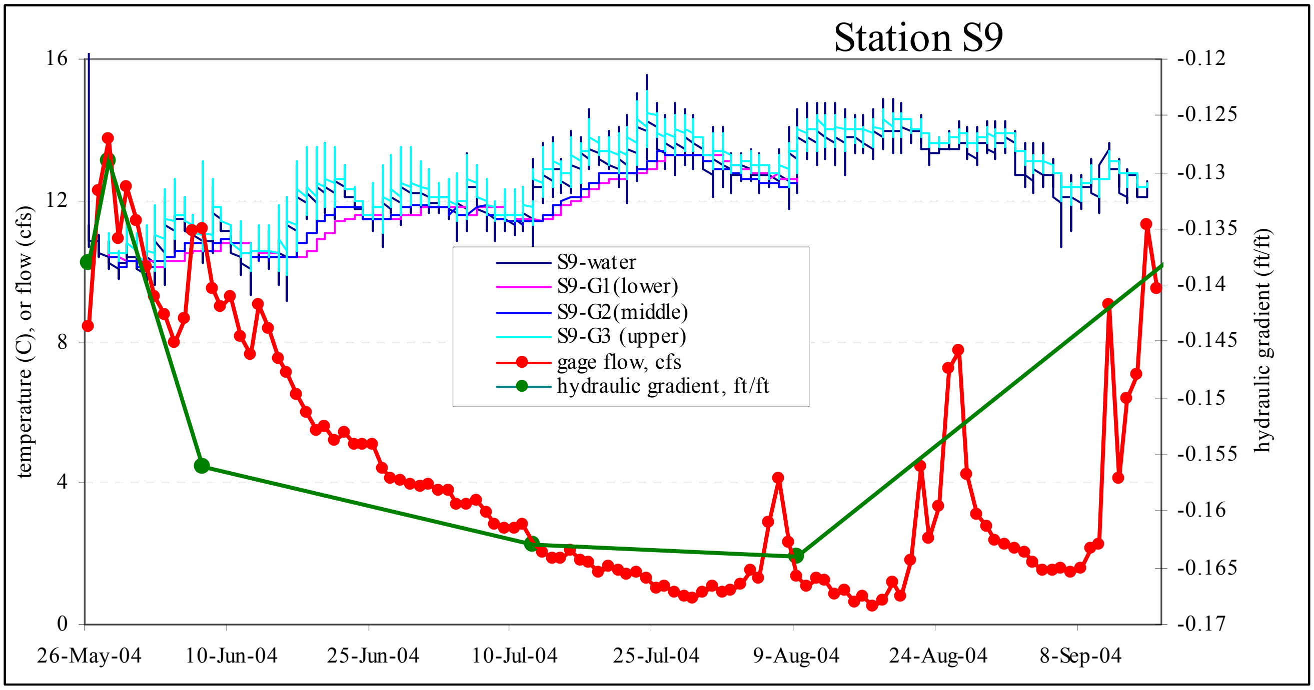


Figure F-7. Groundwater and stream temperature profiles, and hydraulic gradients, at Station S9.

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# Appendix G. Field Data on Riparian Vegetation

Table G-1. Riparian tree heights and types at selected locations along Skookum Creek (August 16, 2004).

| Station | location above mouth, Km | direction | type | height, ft (m) |
|---|---|---|---|---|
| S9 | 13.35 | upstream | alder | 81.9 (25) |
| | | downstream | alder | 90 (27) |
| | | | shrubs on both sides | 15 (5) |
| S8 | 11.55 | | no measurements taken | |
| S7 | 10.65 | upstream | dense vegetation visible upstream | -------- |
| | | downstream | alder | 70 (21) |
| S6 | 8.55 | downstream | cedar1 | 104.7 (32) |
| | | | cedar2 | 108.9 (33) |
| | | | cedar3 | 88.7 (27) |
| | | | alder | 78.4 (24) |
| S5 | 6.15 | 100 ft downstream | trees on both sides | could not be not measured |
| S4 | 4.65 | 100 ft upstream (above bridge) | grass | tall about 5 ft (1.5 m) shades the stream sides but not the mid-channel |
| | | downstream (below bridge) | trees on both sides | heights not measured |
| S3 | 2.95 | upstream | maple | 100.4 (31) |
| | | downstream | cedar | 110.7 (34) |

Table G-2. Riparian tree heights and types at selected locations along Skookum Creek (April 28, 2005).

| Station | km | type | height | density |
|---|---|---|---|---|
| S9 | 13.35 | large cedar, comparable deciduous, and understory shrubs | trees =120 ft, shrubs = 5-10 ft | medium density with mixed canopy openings |
| S8 | 11.55 | deciduous and conifers | about 94 ft | canopy medium to sparse |
| | | large conifers | 100 ft | |
| | | understory - ferns and salmon berry | | |
| S7 | 10.65 | deciduous | 60 ft | more deciduous than conifers |
| | | left bank grass | 2-3 ft | huge field >100 ft |
| Kamilche Valley | | pastures/cultivated, grass along stream up to 4 ft, 30 ft deciduous trees, smaller buffer (less than 50 ft) | | |
| S5 | 6.15 | deciduous trees | 30 ft | thick |
| | | shrubs along creek | 5-10 ft | |
| | | conifers further from creek | 80 - 100 ft | |
| | | conifers further from creek | 100 ft | |
| H1 | near Hurley Creek | large (1 acre +) meadows with 1-2 feet grass; large marsh | | |
| S4 | 4.65 | upstream grass along the creek | 3 ft + | both sides |
| | | upstream deciduous | 30 ft | sparse |
| | | downstream from bridge: small deciduous and some conifers | 50 -80 ft | dense |
| S3 | 2.95 | thick overstory, deciduous/conifer mix, understory, wildflowers/ferns/shrubs; left bank vegetation at least 50 feet, power lines, cleared brushy area on other side of power lines, 150 ft conifers; right bank thick vegetation to road, 80 ft conifers and deciduous, 100 ft vegetation throughout | | |

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# Appendix H. Public Involvement and Response to Public Comments

During development of the *Tributaries to Totten, Eld, and Little Skookum Inlets Water Quality Improvement Report,* Ecology worked with a technical advisory group (TAG) that included the Squaxin Island Tribe, local and state agencies with responsibility or jurisdiction, Taylor Shellfish, Green Diamond Resource Company, and a representative of the SW Puget Sound Watershed Council. Briefings were also given to the Kennedy/Goldsborough planning unit.

Ecology held a comment period on the draft report from February 13 to March 13, 2006. Notice was mailed to all streamside landowners on the seven creeks involved in the TMDL study, and display ads ran in The Olympian and the Shelton-Mason County Journal. Ecology mailed the draft document to 23 TAG members, posted it on the web, and placed printed copies in the Olympia and Shelton Timberline libraries for review.

The public notice offered for Ecology staff to meet with interested individuals or groups during the comment period. The Griffin Neighborhood Association requested a presentation. On March 8, Ecology staff attended the Association's annual meeting and provided information on the TMDL study and implementation plan, and had a discussion with the group.

Ecology received four public comments. Full text of the comments appears below, followed by Ecology's response, in italic font. Thanks to commentors for their interest and thoughtful comments.

## 1. Comment from Mark Musser

My name is Mark Musser. We received a copy of DOE's study on the Eld Inlet watershed, including McLane Creek. We do own property on the banks of McLane Creek at 3237 Musser Dr SW. We love our property and take very good care of it. This property is also undeveloped (no house on it), with only pastureland and timber on it. This five acre tract was previously part of our family farm for more than 65 years now. We do have some cattle who graze on this land from time to time throughout the year, but it is mostly used for making hay. We do have a fence which prevents cattle from going down into McLane Creek, and the streambanks are also well protected by much timber and well established undergrowth beneath the canopy, a veritable temperate jungle. Any runoff from the pastureland will be well filtered before it runs into McLane Creek.

However, with regard to your study, I find it most interesting that bacteria levels in McLane Creek are the highest when the runoff levels are the lowest in the summer. This seriously calls into question that livestock, pets and even septic systems can be considered among the primary sources of fecal coliform in McLane Creek. Our summers are very dry, the driest in the lower 48 outside California and the Southwest, and runoff from the pastures into McLane Creek at this time of year is virtually non-existent. How animal waste or even septic systems can runoff into McLane Creek in the summertime seems rare and highly unlikely. The low runoff and dry summers also leave McLane Creek very shallow indeed by August and September, a creek which can be easily jumped across at many points at this time of year. The stream also moves very slowly at this time of year. How it is that the highest fecal coliform shows up in McLane Creek at precisely the time of year when runoff is at its lowest seems to leave the property owner off the hook as the primary "polluter." Furthermore, how do you know that high coliform counts in McLane Creek are not normal in the summer, and that this has been going on for more than one hundred years? If you are looking for pre-forested undeveloped conditions as your basis for determining whether or not there is too much fecal coliform in the streams you have no way of making any comparisons for the simple reason that the data is non-existent in the past. My guess is that it fecal coliform levels were probably much worse in the 1940's and 50's with three dairies on McLane Creek, and cows were seldom kept out of the stream for any reason. Since runoff levels are extremely low in the summers, and since there are no more dairy farms on the McLane Creek (in our own field I have seen more elk than our own cows who do not pay any attention to fences and drink water in the creek), your only other alternative of blame would be septic systems failing underground that somehow travels down to the creek in mysterious subterranean ways which will be very difficult to prove from a strict scientific point of view without doing some literal digging around. Moreover, at this time of the year, thirsty trees will be sucking up any "leaking" subterranean waters from septic systems long before they ever reach the McLane Creek.

We think that the McLane Creek beaver pond (where the nature trail is upstream) may be worthy of investigation to see if beaver are contributing to the higher fecal coliform counts in the summer. With lower water levels in the summer, and therefore lower dilution, not to mention warmer weather and perhaps warmer waters too, beavers upstream may be responsible for higher fecal coliform counts which float downstream. This beaver pond is very large indeed with many beaver. There are a few more beaver ponds downstream from this one which also feed into McLane Creek as well, supposedly thick with beaver. We believe that before McLane Creek is labeled impaired with high fecal coliform counts, sampling should be made above and below the McLane Creek Nature Trail beaver pond(s) to find out if the beaver might indeed be the primary contributor of this "pollution."

We would also like to add that from our point of view, McLane Creek is most toxic with bacteria in the fall-winter salmon runs when rotting fish stink up the entire valley, attracting scores of seagulls which plaster many rooftops with their excrement (since the Thurston County Landfill has been closed down to regular garbage, the seagull population along McLane Creek in the winter has exploded), and also is a pet killer. Your focus on fecal coliform seems highly selective from our point of view, which actually shows a bias toward salmon and shellfish more than anything else, even though the rancid salmon run far outsmells any potential problem of a “leaking” septic drainfield.

I believe that we take very good care of our property, but I am greatly alarmed by DOE's increasing strict tentacles of influence over the use of private property. When I receive a letter from DOE suggesting to me that it is time to start picking up my own dog's poop in the field, this has all the earmarkings of a state agency out of control and is not a good harbinger of things to come. What else could possibly be left? Not even my dog's poop is considered private anymore. When state agencies begin regulating dog poop on private property, it goes without saying that it is time to shoot the dog, and sell the property to California developers who will pay good "cash money" for our prime piece of real estate (I receive such offers every month in the mail and DOE will largely be responsible for the corporate takeover that they are so allegedly against). Why should I keep such a piece of property? For what purpose? Just to get taxed for a piece of land that my own dog cannot even go poop on?

When I was younger and naive (I graduated from evergreen in 1989), I used to be an environmentalist, but that was when the environmental movement was still all involved in preserving national parks and wilderness areas, and stopping corporate pollution. However, since that has already been by and large been accomplished, the environmental movement had to move on to something else instead of sitting down and declaring victory. Where else to go? The invasion of private property of course, and so now everyday people who go to the bathroom on their own property are almost considered to be "polluters" too. While I can have some sympathy for the former, I cannot have any for the latter. The definitions of pollution have become way too broadly defined since the 1970s (bacteria and turbidity), which has greatly increased the power of the environmental movement over the use of private property, and is also leading us down a path of an environmental ethic that makes the Puritans look like overindulgent pushovers.

I am not looking forward to what “responsibilities” will find myself involved in a year’s time from DOE with regard to my property. Your constant offer in the letter for financial assistance greatly concerns me, and I have no confidence whatsoever that your upcoming solution for all of the so-called ills that McLane Creek allegedly has will have any great impact on the salmon and shellfish problem. The reason why the salmon have diminished in our state for the last several decades is for the simple reason that they have been overfished, not because of turbidity and bacteria in stream waters. As for the shellfish fecal coliform problem, one should not expect that with 4-5 million people living all around the Puget Sound basin that bacteria levels are not going to rise. What is worse is that the environmentalist cure to solve the fecal coliform problem will be worse than the disease it is trying to stop because it will increasingly come at the expense of the free use of private property, which is the foundation of our great country.

Sincerely but very disconcerted,

R. Mark Musser

***Response to Mark Musser***

*As you note, there are many questions to be answered about the bacteria counts in McLane Creek. The water quality study had only one sampling point near the mouth of McLane creek, and one near the mouth of Swift Creek (a major tributary, upstream of the sampling location on McLane Creek). Monitoring to get a more refined understanding of source areas will surely be needed as part of the implementation plan.*

*While the study found no statistical correlation between bacteria concentrations and summer rainfall events, the low flows of late summer mean that even relatively small sources of bacteria can create relatively strong concentrations. A couple of horses or cows with direct access to the creek might be enough to account for the concentrations measured. And, while on-site septic systems are much more likely to fail in the wet season, dry season failures can and do happen. “Straight pipes” (i.e., sewage that bypasses any treatment system and is piped straight into the creek) have been found in some situations. Party, play, camping and fishing areas have also* *been identified as sources in other cleanups. We will need to look into the potential for sources like these. The technical advisory group is also discussing these late summer high bacteria counts throughout the area, and proposing a study to evaluate the issue as resources allow.*

*State water quality standards for fecal coliform bacteria are based on protecting human health. Salmon are not directly affected by bacteria. The concern regarding shellfish from contaminated water is to protect the health of people who eat them. Fecal coliform bacteria are considered an indicator. The presence of fecal coliform bacteria means that sewage and/or manure are in the water, along with all the bacteria and viruses they may carry. People can be exposed through an open cut, or by inadvertently swallowing contaminated water. Health effects can range from an earache or rash to very serious things such as hepatitis. Over a certain concentration of bacteria, the potential health risk is considered unacceptable, and state and federal water quality law require that concentrations be reduced.*

*As more refined monitoring is conducted, we will have a better idea of what the source areas are, whether the beaver seem to be a big contribution, etc. The approach we propose to cleanup is to address these controllable sources of manure and sewage. If bacteria concentrations are still above water quality standards after these human-related sources have been eliminated, the state water quality standards allow us to then consider that " natural background" (such as from wildlife) is above the water quality standards.*

*Typically, natural causes such as wildlife are not controlled. Wildlife is usually only addressed as a source if their numbers are enhanced by human activity, for instance, a landfill.*

*Outreach and technical assistance are very effective tools for improving water quality.*

## 2. Comment from Bob Musser

My name is Bob Musser. I received a copy of DOE's study on the McLane Creek which stated that bacteria levels are too high. I have a LLC farm corporation on both sides of the McLane Creek at 3215 Musser Dr SW. I do have cows on this property on several different fields which we rotate, and I also have a larger field I use for growing hay. Most of the property I have along the creek is flat with very little runoff, but I still do have fences protecting the creek from the cows, and the banks along the creek are well vegetated with many trees.

I have lived on this section of McLane Creek since 1940. At that time, there were three dairies on the creek with at least 30 head, and the animals had free run of the creek. The creek was full of salmon every fall — some silver and kings — but the majority of them were chum salmon. In spite of the fact that there were three dairies on the creek, and that the Black Hills and all the surrounding area had recently been butchered on a scale that would be outlawed today (which also led to a deer population explosion as well — there use to be car jams full of hunters driving up to Capitol Peak during the deer hunting season), there were so many fish coming up the stream you could walk across from bank to bank without getting your feet wet (if you wanted to try). It was not until after 1960 that the salmon started disappearing. It was also in the 1960's that the state fisheries used logging equipment to clear out all the logjams on the creek, which made the creek flow faster and also made the banks erode more quickly. The faster speed of the water also surely affected the fish eggs being more easily carried away from what protected areas in the stream that were left. If this practice was statewide, which would not surprise me, then perhaps the tipping point for salmon depletion began right here?

Meanwhile, ITT Raynior was discharging chemical waste into Oakland Bay and the Olympia Oysters almost became extinct. ITT Raynior settled out of court not admitting any guilt and also agreed not to discharge any more chemicals into Oakland Bay as part of the settlement. At roughly the same time, LOTT started discharging treated waste water with chlorine into Eld Inlet, which is also very warm water. This practice continued for some time and has since started treating waste water with Black Lite, but chlorine is still being put into drinking water, which at some point still flows down into the sewer systems and finally into Puget Sound, and treated waste water is still very warm all the same.

In any event, chlorine kills microorganisms, and I even learned as a boy that it kills vegetation too. I am convinced that all of the chlorine that has been injected into Puget Sound (all the way from the Canadian border to Olympia) from treated waste water has greatly hampered the food chain in Puget Sound since the 1960's, far more than any other problem Puget Sound suffers from. The city of Olympia alone discharges 10 millions gallons of treated waste water at 68 degrees F into Eld Inlet with around .2 nitrates allowed. I am convinced that such city practices, as necessary as they may be, is perhaps more responsible for the degradation of Puget Sound than septic tanks and farm animals. We need waters which have nutrition in them, and contrary to popular ecological opinion, perhaps the septics and farms are actually a good balance to keep in check all of the cleansed city waste waters which are flowing into Puget Sound?

Could there also be a relationship between the warm treated waste water and red tides? In fact, with all that treated waste water flowing into Puget Sound, perhaps the bacteria levels may in fact be lower than they use to be, and any testing which has been done in the last 30-40 years may actually show less bacteria levels than what was common before then, and thus also throw off the testing figures of various creeks which flow into Puget Sound which show too much of a difference between a cleansed Puget Sound and the creeks which flow into the sound? Raw sewage used to go right into Puget Sound from many cities all the way through the 1950's, which did not seem to harm the salmon runs that much, and people ate the shellfish without worrying about getting sick. It was when waste water began to be treated all over Puget Sound that the salmon runs also started to decline as well (but in the last analysis, the real culprit for the depletion of the salmon runs is that they have been simply overfished). Perhaps Puget Sound has been cleansed too much by chlorine and treated waste water, and bacteria from septics and farms is not all that bad to have after all? I am not convinced that bacteria is a real problem that the DOE should be trying to resolve, and worse is that you virtually make me out to be "polluter" by definition simply because I do use our bathroom and septic system everyday, and we do have cows and pets who must relieve themselves too.

In other words, I think that the problems of Puget Sound are far more complex than simply blaming creeks full of bacteria, especially with so many people living on Puget Sound. There is also a long history involved which you seem to take into no consideration whatsoever, and then you go after the person who should be last on the list with regard to the reason why we have depleting salmon runs, and which will also have far reaching repercussions with regard to property rights issues. If various species of salmon are considered to be endangered, then why are we allowed to continue to fish them? No other endangered species are allowed to be "taken" in this way except salmon, and so instead of going after those who overfish the salmon, you go after property owners upstream who are "polluting" creeks with bacteria because of septics, pets and farm animals. This makes very little sense to me and feels more like a political agenda to control the use of my property, especially when you consider that bacteria is virtually everywhere anyway, perhaps one of the most prolific forms of microorganisms around. Talk to any doctor and he will tell you that bacteria is everywhere all over the place.

Keep in mind too that the McLane Creek is also a very short creek, flowing right out of the Black Hills with most of its watershed in undeveloped state-owned land upstream. There is only about 4-5 miles of stream banks where people actually live, and really not all that many people live on the creek anyway, maybe 20? How many letters did you send out for the McLane Creek watershed? If McLane Creek is polluted with too much bacteria, then so must be every other creek in Western Washington. This simply does not add up, especially when your highest bacteria readings on the McLane Creek are showing up in the summers when there is very little runoff, if any at all that time of year. This only reinforces my view that the environmental best available science is junk science.

Finally I would like to add that in the 1940's the State of Washington planted a beaver colony in the McLane creek watershed which has since flourished into several colonies, which eventually gave birth to the McLane Creek Nature Trail. Beavers are of course great at making wetlands, which of course draw in all kinds of other animals and microorganisms to the area, along with all of their bacteria creating germs that come along with them. It seems to me that you may want to look at the beaver first as the primary culprit for too much bacteria, together with all of the wetlands which they have made, which now flow into McLane Creek before assuming that people and their septics, pets and farm animals are the problem.

Sincerely,

Bob Musser
65 year resident on the McLane Creek

***Response to Bob Musser***

*The scope of this project is limited – the goal, with respect to fecal coliform bacteria, is to make these seven creeks healthy for kids (and others) to play or fish in. We also want to protect the downstream marine area. Bacteria concentrations above a certain level have increasing potential for health effects to those who consume shellfish. Commercial shellfish harvest is regulated by the Department of Health on the basis of fecal coliform bacteria concentrations. Harvest restrictions can create negative economic impacts for both growers and communities. (Please see the information regarding salmon and bacteria, wildlife, and human health in the previous response.)*

*Bacteria are just one small part of the health of Puget Sound and those of us who live around it. Fecal coliform bacteria indicate the presence of feces, and many of the bacteria and viruses associated with feces are disease vectors for humans.*

*As noted in the response above, the only sampling location on McLane Creek was near the mouth. More refined monitoring is needed to narrow down source areas, including potential contributions from the nature trail and areas along Swift Creek.*

## 3. Comment from Kareth Duval

I have read your notice regarding the quality and your concerns for the Perry Creek. I feel that this does not directly affect me although I do own property along the creek it is in forest land, there are no structures, septic tanks nor domestic animals on it. The area on my side of the creek has been undisturbed for the last 15 to 20 years except for the area where the Mud Bay Water Company collected spring water which they have now ceased to do.

There are areas along the creek where there is fairly dense housing and areas where there is little vegetation along the sides of the creek. I would hope that you would concentrate on those areas rather than on open land unless you are contemplating the necessity of a fence to keep the wildlife from their life-giving water supply.

***Response to Kareth Duval***

*While the detailed water quality improvement plan has yet to be developed, we know it will include a plan for more refined water quality monitoring to learn more about source areas. It's likely that areas of dense housing and/or poor streamside vegetation, as you suggest, will be towards the top of the priority list, as they have a higher potential to pollute. As mentioned in the response to the first commenter, we usually manage natural sources like wildlife only if human activities are enhancing their populations.*

## 4. Comment from Gayle Broadbent Ferris

I recently watched a presentation titled ' TMDL's: A study of water quality and pollution sources of Totten and Eld inlets'. This was presented by Christine Hempleman and Anise Ahmed, at the Griffin Neighborhood Association annual meeting on March 8, 2006.
The presentation was very effective and impressive. The information given was interesting, clearly and concisely presented, the study process and the results clearly explained. Perhaps most important of all, the presenters and presentation gave the listeners ideas and impetus on what they could do to help save, enhance or restore the extremely valuable resource—our clean water, fresh and marine. I think this is so valuable because it will take the efforts of the entire community to act and to protect the water quality. As I follow very closely the land use practices of Thurston County, and examine the regulations applied to development—and when I say 'follow closely' I mean very closely—obsession is not a bad thing in this case, I think—when I follow this, I see that individual use exemptions, and reasonable use permits, and variances, and improperly installed and inadequately maintained septic systems and lawn care habits, when I see how farmers frequently implement their plans—(I'm on the Agricultural Advisory Board for Thurston County) I see that these are the things that are polluting our water, the little cumulative impacts that are killing it. Educating a community is the way to stop these little deadly acts.

I strongly support the intent and efforts behind this study and the actual study and project presently underway. I look forward to following the entire process, up unto the successful outcome. I urge you to give every support to this valuable project.

***Response to Gayle Broadbent Ferris***

*Thank you for the positive feedback. Land use and agriculture will be among the topics discussed during development of the water quality improvement plan. As you suggest, we anticipate outreach and technical assistance to be the primary methods of encouraging people to do a little better with practices on their land, in order to help reduce bacteria concentrations.*