Snoqualmie River Basin Fecal Coliform Bacteria, Dissolved Oxygen, Ammonia-Nitrogen, and pH Total Maximum Daily Load

Water Quality Effectiveness Monitoring Report

March 2008

Publication No. 08-03-005

WASHINGTON STATE DEPARTMENT OF ECOLOGY

Publication Information

This report is available on the Department of Ecology's website at
www.ecy.wa.gov/biblio/0803005.html

Data for this project are available at Ecology's Environmental Information Management (EIM) website at www.ecy.wa.gov/eim/index.htm. Search User Study ID, GONW0001.

Project Tracker Code (Environmental Assessment Program) is 06-025.

TMDL Study Code (Water Quality Program) is Snoq07MP.

For more information contact:

Publications Coordinator
Environmental Assessment Program
P.O. Box 47600
Olympia, WA 98504-7600

E-mail: jlet461@ecy.wa.gov
Phone: (360) 407-6764

Washington State Department of Ecology - www.ecy.wa.gov/

- Headquarters, Olympia 360-407-6000
- Northwest Regional Office, Bellevue 425-649-7000
- Southwest Regional Office, Olympia 360-407-6300
- Central Regional Office, Yakima 509-575-2490
- Eastern Regional Office, Spokane 509-329-3400

Cover photo: The Snoqualmie River at Fall City. This river is an important recreational resource and salmon fishery.

Snoqualmie River Basin Fecal Coliform Bacteria, Dissolved Oxygen, Ammonia-Nitrogen, and pH Total Maximum Daily Load

Water Quality Effectiveness Monitoring Report

by

Debby Sargeant
Environmental Assessment Program
Washington State Department of Ecology
Olympia, Washington

and

Ralph Svrjcek
Water Quality Program
Northwest Regional Office
Washington State Department of Ecology
Bellevue, Washington

March 2008

Waterbody Numbers:
WA-07-1060, -1062, -1064, -1066, -1068, -1070, -1100, -1101,
-1102, -1104, -1106, -1108, -1110, -1130, -1140, -1150

This page is purposely left blank

Table of Contents

Page

List of Appendices

List of Figures

Page

List of Tables

This page is purposely left blank

Abstract

The Washington State Department of Ecology (Ecology) is required under Section 303(d) of the federal Clean Water Act to develop and implement Total Maximum Daily Loads (TMDLs; water cleanup plans) for impaired waters in the state. Ecology is also required to evaluate the effectiveness of the water cleanup plan in achieving the needed improvement in water quality.

During 2003-05, Ecology conducted this study to determine the effectiveness of cleanup efforts in the Snoqualmie River watershed. The study analyzes the effectiveness of 1994-2004 TMDL implementation activities in protecting and restoring water quality.

Water quality in the Snoqualmie River has improved, but more effort is needed to ensure that Washington State water quality standards and TMDL targets are met. Dissolved oxygen levels in the mainstem Snoqualmie have generally remained the same. More study is needed to determine if dissolved oxygen TMDL targets are met. Bacteria levels in the mainstem and most of the tributaries have improved. The mainstem Snoqualmie River nearly meets standards for fecal coliform, but many tributaries do not meet fecal coliform standards. Higher nutrient levels and low dissolved oxygen levels in some of the tributaries may be associated with high bacterial inputs.

Ecology sampled wastewater from three wastewater treatment plants (WWTPs) for this 2003-05 study, but the amount of data collected was insufficient to determine compliance. Review of monitoring data submitted as part of WWTP National Pollutant Discharge Elimination System permits revealed compliance with the target control recommendations in the TMDL. Higher bacteria and nutrient levels were measured downstream of the City of North Bend and its WWTP.

This report recommends that local governments continue existing pollution-control actions in the Snoqualmie watershed. The study also shows that additional pollution controls are needed through on-site sewage system surveys, agricultural practice surveys, and stormwater pollution-control activities.

Acknowledgements

The authors of this report would like to thank the following people for their contribution to this study:

- Numerous staff from the King Conservation District and King County who supplied information on implementation activities.
- Janne Kaje and Kollin Higgins from the King County Water and Land Resources Division for review of the document and suggestions for improvements.
- Washington State Department of Ecology staff:
    - David Batts for his invaluable help with the history of this project and technical assistance.
    - David Batts, Cindy Callahan, Dave Garland, Bill Ward, Jim Garner, Chad Wiseman, and Casey Clishe for help with sampling.
    - Joe Joy, Jim Garner, and Bill Ward for technical assistance.
    - George Onwumere, Joe Joy, and Dave Garland for review of the document and suggestions for improvements.
    - Joan LeTourneau, Cindy Cook, and Gayla Lord for formatting and editing the final report.

This project was funded, in part, by King County.

Executive Summary

The Snoqualmie River is an important recreational resource and salmon fishery. The river also provides hydropower at Snoqualmie Falls, Twin Falls, and Weeks Falls, as well as aesthetic values throughout its diverse watershed.

Due to concerns about water quality, the Washington State Department of Ecology (Ecology) conducted a study of the Snoqualmie River and tributaries during 1989-91. In 1994 Ecology made recommendations on how to protect and improve water quality in the river in the report, *Snoqualmie River Total Maximum Daily Load (TMDL) Study* (Joy, 1994).

Early studies showed that the Snoqualmie River and some tributaries were polluted because of high levels of fecal coliform bacteria and nutrients. The risk of becoming ill from swimming and wading was too high in many areas because of the high bacteria levels. High levels of nutrients are a problem because they can cause excessive plant growth which in turn can lead to low oxygen levels in the water. Ecology was also concerned that future growth and the related increase in discharges from wastewater treatment plants would lower dissolved oxygen levels at several locations in the Snoqualmie River. The river could become unhealthy for fish if action was not taken.

Since 1994, many actions have been taken to improve water quality in the Snoqualmie basin. To check on progress, Ecology conducted an *Effectiveness Monitoring Study* on the river and tributaries in 2003-2005. The purpose of this study was to (1) determine how much water quality had improved, and (2) assess which areas could use more resources and funds to improve water quality. This report presents the results of the *Effectiveness Monitoring Study* and provides a picture of water quality in the watershed from North Bend downstream to Monroe. The good news is that water quality has been protected in many areas and is getting better in others.

Overall Water Quality is Being Protected or Getting Better

This 2003-05 Snoqualmie River *Effectiveness Monitoring Study* was more extensive than the original 1989-91 *TMDL Study* (Joy, 1994). The 2003-05 study shows that water is the same or getting better where clear comparisons could be made. During the study, dissolved oxygen levels in the Snoqualmie River met TMDL targets at several sensitive points (large pools of slow moving water). Definitive conclusions about dissolved oxygen in the river could not be made because the only way to determine if dissolved oxygen levels have actually improved is to rerun the original TMDL model or monitor water quality under projected worse-case conditions. Neither of these actions or conditions occurred as part of this 2003-05 study.

Fecal coliform bacteria levels have improved in the Snoqualmie River and in many of the tributaries but need more improvement to reach Washington State standards. Bacteria levels in the main river have improved so that it is safer for swimming and other water contact recreation.

Ecology modified the effluent limit requirements for biochemical oxygen demand and ammonia at the North Bend, Snoqualmie, and Duvall wastewater treatment plants (WWTPs) as a result of the original Snoqualmie TMDL. Ecology also evaluated permit limit compliance and a limited number of wastewater samples from the WWTPs. No remedial actions are recommended for the WWTPs at this time. Ecology recommends further study of water quality downstream of the North Bend WWTP due to the elevated nutrient levels at the South Fork river mile (RM) 2.0 site.

While water quality has generally improved in the Snoqualmie watershed, there are some areas that need additional work to meet water quality standards. Water temperatures were high in many locations. Ecology is following up this *Effectiveness Monitoring Study* with a temperature TMDL to help evaluate the problem and develop solutions. For bacteria, many streams have good water quality except when it rains. This indicates that problems occur when stormwater picks up pollution as the stormwater travels over land and flows to surface water. Table ES-1 provides a summary of major water quality cleanup activities and monitoring needed in the Snoqualmie basin. A brief overview of water quality by subbasin is provided below.

Upper Snoqualmie River Watershed

Water from the North and Middle Forks is too warm but meets other water quality criteria. Actions to decrease water temperatures in these areas should proceed immediately.

South Fork water temperatures are acceptable. But a 14% reduction in bacteria levels is needed at RM 2.0 (Snoqualmie Trail crossing) during the critical period (August through October). In addition, higher phosphorus levels at this site (RM 2.0) should be investigated.

Kimball Creek does not meet Washington State standards for bacteria, temperature, or dissolved oxygen. Fecal coliform bacteria levels need to be reduced by 77% to meet standards. To improve water quality in Kimball Creek, Ecology recommends a survey of on-site sewage treatment systems, illicit discharge detection and correction, improvement of riparian vegetation, and implementation of small farm best management practices.

Lower Snoqualmie River Watershed

The quality of water going over Snoqualmie Falls into the Lower Snoqualmie watershed was good throughout the 2003-05 *Effectiveness Monitoring Study*. The next major tributary downstream of the falls, Tokul Creek, had generally good water quality with the exception high nitrogen and pH levels. Ecology recommends that additional monitoring be conducted to investigate any possible effects of the Tokul Creek hatchery activities.

Ecology determined that the Raging River met the TMDL target for bacteria, but pH and temperature were higher than (exceeded) criteria. Ecology places a high priority on additional study of the physical and biological characteristics of the Raging River because of the river's importance to the local fishery. Although Ecology is currently preparing a temperature TMDL for the Snoqualmie River, actions to reduce water temperatures in the Raging River should begin immediately.

A special diagnostic study (Sept. 2003-Sept. 2005) of the Snoqualmie River in the Fall City area revealed higher fecal coliform, nitrite-nitrate nitrogen, and chloride levels just upstream of the Fall City area on the left river bank (as seen traveling downstream from Snoqualmie Falls). Ecology recommends additional study of land uses, evaluation of potential pollution sources, and water quality monitoring of this upstream area and the Raging River.

Patterson Creek water quality was poor during the dry critical period (August – October) with violations of fecal coliform, dissolved oxygen, and temperature criteria. The highest bacteria levels were observed in association with storm events. A 64% reduction in fecal coliform bacteria levels is needed during the critical period. To improve water quality in Patterson Creek, Ecology recommends examination of compliance with livestock ordinances, on-site sewage treatment systems, and stormwater conveyances.

Griffin Creek had good water quality during the wet season (November through April) but high bacteria levels during storm events. Although mean bacteria levels in Griffin Creek have improved since the original 1989-91 *TMDL Study*, a 43% reduction in fecal coliform bacteria levels is needed during the critical period. Ecology recommends continued work with Griffin Creek property owners to control stormwater runoff. Because of the small size of the developable area and relative lack of growth pressure, Griffin Creek is a lower priority for focused water cleanup projects.

The Tolt River showed good water quality for bacteria, pH, and dissolved oxygen levels. Ecology recommends continued attention to stormwater management in the Tolt River watershed to prevent water quality problems in the future.

Harris Creek had good water quality during the wet season but showed higher bacteria levels during storm events. A 10% reduction in fecal coliform bacteria levels is needed during the August-October critical period. Ecology recommends continued work with Harris Creek property owners to control stormwater runoff. Because of the large size of the developable area, growth pressures, and potential changes in property ownership, Ecology considers Harris Creek an important area for continued water cleanup efforts.

Ames Creek bacteria levels showed improvement since the original 1989-91 *TMDL Study* (Joy, 1994). However water quality remains poor, and an 86% reduction in fecal coliform levels is needed during the August-October critical period. Ecology recommends continued work with Ames Creek property owners to control both dry-weather and wet-weather pollution discharges. Because of the consistently elevated bacteria levels and poor overall water quality, Ames Creek is a higher priority for focused water cleanup projects.

In Tuck Creek, water quality has deteriorated since the 1989-91 *TMDL Study*. The current 2003-05 *Effectiveness Monitoring Study* detected problems with bacteria, ammonia-nitrogen, dissolved oxygen, and pH levels. A 39% reduction in fecal coliform bacteria levels is needed during the critical period. Because of persistent elevated bacteria levels and poor overall water quality, Tuck Creek is a good candidate for focused water cleanup projects.

Cherry Creek bacteria levels have improved since the 1989-91 *TMDL Study*. Wet season water quality is good, but water quality during the August-October critical period remains poor. During the critical period, dissolved oxygen, pH, and temperature levels did not meet standards. In addition, a 63% reduction in fecal coliform levels is needed during the critical period. Ecology recommends continued work with Cherry Creek property owners to control critical period pollution discharges. Cherry Creek is a higher priority stream for focused water cleanup projects because of the consistently elevated bacteria levels and poor overall water quality.

Table ES-1. Summary of major water quality cleanup activities and monitoring needed in the Snoqualmie River basin.

Subbasin location	Best Management Practices						Monitoring		
	Improve riparian shading*	Illicit discharge detection & elimination	Investigate agricultural practices	Prevent future stormwater impacts	Survey on-site sewage systems	Reduce phosphorus discharges	More study	Long-term	Periodic
Upper Snoqualmie basin									
Middle Fork	X								X
North Fork	X								X
South Fork at RM 2.0									X
North Bend WWTP						X			
South Fork at RM 1.5		X	X	X			X	X	
Snoqualmie RM 42.3				X				X**	
Kimball Creek	X	X	X	X	X		X	X	
Lower Snoqualmie basin									
Snoqualmie RM 40.7							X		X
Tokul Creek							X		X
Raging River	X						X	X	
Snoqualmie RM 35.3		X	X	X			X	X	
Patterson Creek	X	X	X	X	X		X	X	
Griffin Creek			X		X				X
Snoqualmie RM 25.2			X						X
Tolt River				X					X
Harris Creek			X	X	X			X	
Ames Creek		X	X	X	X		X	X	
Tuck Creek	X	X	X	X	X		X	X	
Cherry Creek	X	X	X	X	X		X	X	
Snoqualmie RM 2.7	X	X	X	X	X			X**	

* Due to downstream temperature problems, investigation of additional shading opportunities is recommended for all tributaries.
** Currently performed by the Washington State Department of Ecology (Ecology).
RM - river mile
WWTP - wastewater treatment plant

Why is Ecology Checking Water Quality in the Snoqualmie River Watershed?

The Washington State Department of Ecology (Ecology) is concerned about the quality of water in the Snoqualmie River watershed. In the early 1990s, Ecology conducted a technical study of the Snoqualmie River and tributaries and made recommendations on how to protect and improve water quality in the river (Joy, 1994). This type of study is called a Total Maximum Daily Load (TMDL) study.

The early studies showed that the Snoqualmie River and some of its tributaries were polluted because of high levels of bacteria (fecal coliform) and nutrients. High levels of nutrients are a problem because they can cause excessive plant growth which in turn can lead to low oxygen levels in the water. During the original 1989-91 *TMDL Study* (Joy, 1994), the river was frequently unhealthy for people and could become a problem for fish if action was not taken.

Since the 1990s many actions have been taken to improve water quality in the Snoqualmie watershed. To check on progress toward making the watershed safer for people and fish, Ecology conducted a water quality study on the river and its tributaries in 2003-2005. The purpose of the study was to see how much water quality had improved and determine which areas could use more resources and funds to make the water cleaner.

This report describes our current understanding of the pollution problems in the Snoqualmie River basin. The report provides a picture of water quality in the watershed from the city of North Bend downstream to the Snoqualmie River's confluence with the Skykomish River. The good news is that water quality has improved in many areas, but more work needs to be done. This report recommends additional studies and pollution cleanup work that will help these waterbodies meet water quality standards.

In the following pages, we will discuss the following:

- What is *effectiveness monitoring*?
- Why is it important to have good water quality in the Snoqualmie River?
- What pollution sources can affect the Snoqualmie River?
- Is the watershed getting cleaner?

Because this report analyzes a large amount of scientific data, the discussion of current water quality and pollution trends is fairly technical. Ecology has attempted to write the report in a way that will help all readers learn more about the river's water quality. Appendix A includes a glossary of terms and acronyms. Appendix B discusses potential pollution sources and actions taken to reduce pollution. Readers needing more information or explanation are encouraged to call the Ecology Water Quality Specialist for the Snoqualmie Watershed at 425-649-7000.

What is Ecology's Water Cleanup Process?

Washington State's Water Quality Assessment

The federal Clean Water Act established a process to identify and clean up the nation's polluted waters. Under the Clean Water Act, every state and many tribes have their own water quality standards designed to protect, restore, and preserve water quality. Water quality standards consist of designated uses for protection, such as cold water biota and drinking water supply, and criteria, usually numeric criteria, to achieve those uses.

Every two years, states are required to prepare a list of waterbodies – lakes, rivers, streams or marine waters – that do not meet water quality standards. This list is called the 303(d) list. To develop the list for Washington State, Ecology compiles its own water quality data along with data submitted by local, state, and federal governments, tribes, industries, and citizen monitoring groups. All data are reviewed to ensure that they were collected using appropriate scientific methods before they are used to develop the water quality assessment.

The 303(d) list identifies polluted waters. In Washington State, we include the 303(d) list in our Water Quality Assessment process. Our list tells a more complete story about the condition of Washington's waters. This list divides waterbodies into one of five categories:

- Category 1 – Meets tested standards for clean water.
- Category 2 – Waters of concern.
- Category 3 – No data available.
- Category 4 – Polluted waters that do not require a TMDL since the problems are being solved in one of three ways:
  - 4a – Has a TMDL approved and it is being implemented.
  - 4b – Has a pollution control project in place that should solve the problem.
  - 4c – Is impaired by a non-pollutant such as low water flow, dams, culverts.
- Category 5 – Polluted waters that require a Total Maximum Daily Load – on the 303d list.

A Total Maximum Daily Load (TMDL) Limits Water Pollution

The goal of a TMDL is to ensure that Category 5 impaired waters will eventually meet water quality standards, or TMDL targets, that protect beneficial uses. Beneficial uses are activities like fishing, shellfish harvesting, and swimming among other things. A TMDL includes a written, quantitative assessment of water quality problems and of the pollutant sources that cause the problem. The TMDL determines the amount of a given pollutant that can be discharged to the waterbody and still meet standards (the loading capacity) and allocates that load among the various sources.

If the pollutant comes from a discrete source (referred to as a point source) such as a municipal or industrial facility's discharge pipe, that facility's share of the loading capacity is called a *wasteload allocation*. If it comes from diffuse sources such as general urban, residential, or farm runoff (referred to as nonpoint sources), the cumulative share is called a *load allocation.*

The TMDL must also consider seasonal variations and include a margin of safety that takes into account any lack of knowledge about the causes of the water quality problem or its loading capacity. A reserve capacity for future loads from growth pressures is sometimes included as well. The sum of the wasteload and load allocations, the margin of safety, and any reserve capacity must be equal to or less than the loading capacity.

Ecology follows a three-step TMDL process

Washington State now follows a three-step process for documenting the problems and solutions for polluted waterbodies (see Figure 1). In early TMDLs such as the Snoqualmie TMDL, we did not use the same names for our reports but they addressed the same needs. Currently, Ecology typically prepares separate reports for each step of the process. Those steps are discussed below. We completed Steps 1-3 for the Snoqualmie TMDL.

After significant pollution control activities are completed, Ecology conducts an *Effectiveness Monitoring Study*. This study evaluates water quality and reexamines what cleanup activities are still needed.

Step 1: The Water Quality Study

Ecology reviewed available water quality data and shared this information with local governments, environmental organizations, and others. This scientific review showed how dirty the water was in the early 1990s, and how clean it needed to be. The original study (Joy et al., 1991) is available on Ecology's website at www.ecy.wa.gov/biblio/91e30.html.

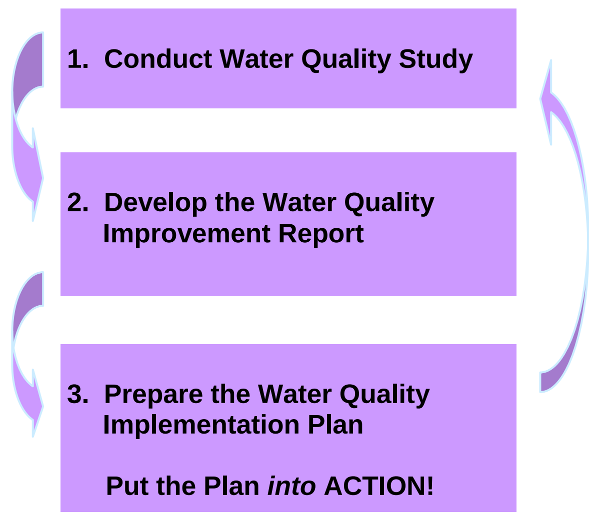

Figure 1. Ecology's Water Cleanup Process

Step 2: Water Quality Improvement Report

Ecology outlined the findings of the water quality study and set numeric goals for cleaning up the Snoqualmie River in 1994 (Joy, 1994). We received approval for our plan from the United States Environmental Protection Agency (EPA) 1996. To learn more about the federal TMDL program, visit the EPA website at www.epa.gov/owow/tmdl/intro.html. Ecology's Snoqualmie Water Quality Improvement Report can be found at www.ecy.wa.gov/biblio/9471.html.

Step 3: Water Quality Implementation Plan (Action Plan)

Ecology collaborated with local government, businesses, and the public to identify the actions needed to make the Snoqualmie River a safe place for people and fish. Earlier TMDLs such as the Snoqualmie River TMDL did not have a published Implementation Plan. Instead, Ecology put numeric effluent limitations in the Water Quality Improvement Plan (Joy, 1994) and prepared a separate Nonpoint Action Plan (Ecology, 1994).

Effectiveness Monitoring Measures Water Quality Improvement

As noted above, the *Effectiveness Monitoring Study* determines if the water quality standards and water quality targets set in the TMDL have been met. It also reevaluates what actions are still needed in the TMDL area to ensure local waters will meet water quality standards, be safe to swim in, and be a healthy place for fish and other aquatic life. Effectiveness monitoring is an important part of any restoration or implementation activity since it measures whether the water cleanup work has been successful and tells us what we need to do next.

The benefits of effectiveness monitoring and evaluation include:

- Optimization in planning/decision-making (i.e., program benefits).
- Watershed recovery status (i.e., how much restoration has been achieved, how much more effort is required).
- Adaptive management or technical feedback to refine restoration design and implementation.
- More efficient allocation of funding for future water cleanup activities.

Effectiveness monitoring addresses four fundamental questions:

1. Is the restoration or implementation work achieving the desired objectives or goals (significant improvement)?
2. How can restoration or implementation techniques be improved?
3. Is the water quality improvement sustainable?
4. How can the cost-effectiveness of the work be improved?

Ecology Studied Bacteria, Nutrients, pH, and Dissolved Oxygen

Ecology studies in the early 1990s revealed that most of the mainstem of the Snoqualmie River had good water quality during the low-flow conditions found during summer and early fall (Joy et al., 1991; Joy, 1994). However, some mainstem reaches and many of the tributary streams were either threatened or not meeting some state water quality standards. Water quality parameters in the Snoqualmie watershed that did not meet water quality standards included dissolved oxygen, fecal coliform bacteria, pH, and temperature. Ecology's early TMDL work studied all of these with the exception of temperature. For that reason, this report will focus on dissolved oxygen, fecal coliform, and nutrients. This report also discusses temperature because it affects dissolved oxygen levels.

A summary of previous TMDL findings is provided in Appendix C. The summary is discussed for comparative purposes, along with upper and lower basin water quality data, later in this report.

Good Water Quality in the Snoqualmie Watershed is Important for People and Fish

State law sets the standards for quality in Washington State waters (Washington Administrative Code (WAC) Chapter 173-201A). These are referred to as the water quality standards. The purpose of the standards is to establish the uses and activities (*beneficial uses*) that we should all expect from our local rivers, streams, lakes, and marine areas. The water quality standards are discussed in Appendix D. When surface waters do not meet state standards, the risk of injury or sickness to people and animals, including fish and other aquatic life, increases. Those risks are discussed below.

Health Risks for People

Bacteria targets for Washington waters are set to a low level to protect people who work and play in and on the water from waterborne illnesses. Fecal coliform is used as an "indicator bacteria" for the state's freshwaters (lakes, rivers, and streams). Fecal coliform in water "indicates" the presence of waste from humans and other warm-blooded animals. Waste from warm-blooded animals is likely to contain bacteria, viruses, and parasites that will cause illness in humans. Pathogens known to be present in fecal matter include *Escherichia coli* 0157, salmonella, cryptosporidium, giardia, and viruses such as hepatitis A. Keeping local waters at or below state bacteria standards should result in low rates of serious intestinal illness (gastroenteritis) in people.

The majority of the Snoqualmie River watershed has a "Primary Contact" designation in the Washington State Water Quality Standards WAC 173-201A). Primary contact use waters should support swimming and other recreational activities. Waters should be suitable for activities that involve direct contact with water to the point of complete submergence. To meet this standard, fecal coliform levels must not exceed a *geometric mean* value of 100 colonies/100 mL, with not more than 10% of all samples (or any single sample when less than ten sample points exist) exceeding 200 colonies/100 mL" (WAC 173-201A-200(2)(b), 2003 edition).[1] The estimated 90th percentile is often used in this report as a surrogate for the "not-more-than-10 percent" criterion[2]. Parts of the upper watershed have an even higher standard of "Extraordinary Primary Contact."

The water quality standard for fecal coliform bacteria limits the risk of illness to humans that work or play in water. Our state standards are designed to allow no more than seven illnesses out of every 1,000 people engaged in primary contact activities. Once the concentration of fecal coliform in the water exceeds one of the criteria, the chance of becoming ill increases above acceptable levels. Ecology studies have shown we have reached that point in the Snoqualmie watershed in a number of areas, and bacteria levels must now be reduced.

[1] The term "colonies" (sometimes referred to as *colony forming units* or cfu)) refers to the number of bacteria colonies that grow in a Petri dish after 100 milliliters (mL) of stream water is filtered and tested on the dish. To give you an idea of how much water that is, 100 mL is almost half a cup (0.42 cups to be more exact).

[2] For compliance with not-more-than 10% criterion, 90th percentile levels determined using the log values of sample results (as done by the National Shellfish Sanitation Program (2003)) will be used as a screening tool. Where this conflicts with the Water Quality Standards, Ecology will use the state standard.

Health Risks for Animals

Clean water is important for keeping livestock and other animals healthy. Water constitutes 60 to 70% of the bodies of livestock. Animals that do not drink enough water may suffer stress or even dehydration. This in turn makes them more susceptible to diseases (Faries et al. 1998). Waters polluted with suspended solids, objectionable tastes, or unusual odors can cause animals to drink less than they should (Pfost et al., 2006).

Water needs for animals change depending on weather and the type of food consumed. While dry cows generally need 8 to 10 gallons of water daily, a cow in her last 3 months of pregnancy may drink up to 15 gallons/day. Those producing milk need about five times as much water as the volume of milk produced (Faries et al., 1998).

Sick animals do not gain weight quickly which can result in lower profits at auction. Among the many water-transmitted diseases that can affect livestock are leptospirosis (foot-rot), fusobacterium, cryptosporidium, and giardia (Fleming and Eng, 2004; Atwill, 2006). Fusobacterium is carried on the feet of animals, which contaminates any body of water they enter (Pfost et al., 2006). Cryptosporidium affects mainly younger animals; approximately 25% of calves with diarrhea between 5 days to 1 month old are infected with *Cryptosporidium parva* (Fleming and Eng, 2004). In some cases, giardia infections can reduce livestock weight gains by 20% (Yurchak and Buchanan, 1995).

Effects on Aquatic Life

Washington State Water Quality Standards are also meant to help protect all natural biota living in our local waters. The Snoqualmie River watershed supports many species of salmon, trout, whitefish, suckers, and other important fish species and supporting habitat. The watershed is home to the threatened chinook and other salmon species that use the waters throughout the year.

Other organisms that live in the watershed are no less important to salmon survival although they receive less attention. The wide range of plants, insects, and other living organisms that live in the watershed provide the underlying support for those fishery resources. Starting at the plant level with algae, then moving up to zooplankton and macroinvertebrates, each of these organisms are needed to feed fish from their development from fry to fingerlings to smolts. Good oxygen levels, low water temperatures, proper nutrient levels, and adequate streamflows are all important to the good health of the small creatures that live in the river and its tributary streams.

When a stream or river experiences pollution, native plants and bugs often fail to flourish and are replaced by non-native plants and bugs. Fish populations that have used those native species as food sources over their thousands of years in the stream often do not adjust to the new food sources and can suffer from a lack of nutrition. Poorly nourished fish do not compete as well and become more susceptible to predation. In extreme cases, young fish could die due to malnutrition. Inappropriate oxygen, nutrient, or temperature levels can cause this problem. In addition, young fish that experience excessively high temperatures during rearing are more susceptible to diseases and can suffer developmental problems that can reduce their ability to spawn successfully in the future (Meyers et al., 1998).

Study Area and Background Information

Snoqualmie River Basin

The Snoqualmie is a river system with generally good water quality and multiple aquatic resources, located within 15 miles (24 km) of the Seattle-Bellevue metropolitan area (Figure 2). The river and its tributaries are highly valued for their recreational, aesthetics, aquatic habitat, hydropower, and domestic water supply uses. The Snoqualmie River Valley has been undergoing rapid changes in land use with additional wasteload discharges proposed for the river (Joy, 1994). As a result, the Washington State Department of Ecology (Ecology) developed a TMDL for ammonia, biochemical oxygen demand (BOD), and fecal coliform for the basin. The TMDL was approved by the U.S. Environmental Protection Agency (EPA) Region 10 in 1996. The 303(d) listings addressed in the TMDL are described in Table 1.

Table 1. 303(d) Listings addressed in the *TMDL Study* (Joy, 1994).

Waterbody Segment	Waterbody Name	TMDL Parameters Addressed
ID-WA-07-1060	Snoqualmie River	Ammonia-nitrogen, fecal coliform, BOD
ID-WA-07-1062	Cherry Creek	Ammonia-nitrogen, fecal coliform, BOD
ID-WA-07-1066	Ames Creek	Ammonia-nitrogen, fecal coliform, BOD
ID-WA-07-1064	Tuck Creek	Ammonia-nitrogen, fecal coliform, BOD
ID-WA-07-1068	Harris Creek	Ammonia-nitrogen, fecal coliform, BOD
ID-WA-07-1070	Tolt River	Ammonia-nitrogen, fecal coliform, BOD
ID-WA-07-1100	Snoqualmie River	Ammonia-nitrogen, fecal coliform, BOD
ID-WA-07-1101	Griffin Creek	Ammonia-nitrogen, fecal coliform, BOD
ID-WA-07-1102	Patterson Creek	Ammonia-nitrogen, fecal coliform, BOD
ID-WA-07-1104	Raging River	Ammonia-nitrogen, fecal coliform, BOD
ID-WA-07-1106	Tokul Creek	Ammonia-nitrogen, fecal coliform, BOD
ID-WA-07-1108	Kimball Creek	Ammonia-nitrogen, fecal coliform, BOD
ID-WA-07-1110	Snoqualmie River	Ammonia-nitrogen, fecal coliform, BOD
ID-WA-07-1130	Snoqualmie River	Ammonia-nitrogen, fecal coliform, BOD
ID-WA-07-1140	Snoqualmie River	Ammonia-nitrogen, fecal coliform, BOD
ID-WA-07-1150	Snoqualmie River	Ammonia-nitrogen, fecal coliform, BOD

The Snoqualmie River system drains 700 square miles (mi^2), or 1813 square kilometers (km^2), in King and Snohomish Counties before meeting the Skykomish River to create the Snohomish River. Most of the Snoqualmie River basin is in King County. The study area includes the lower 44.5 miles (71.6 km) of the river from the South Fork Snoqualmie River and confluence of the two other main forks near North Bend (elevation 430 ft / 131 m), to the confluence with the Skykomish River at Monroe (elevation 15 ft / 4.6 m), as illustrated in Figures 2 and 3. Snoqualmie Falls, with a vertical height of 268 feet (81.7 m), is a predominant feature of the Snoqualmie River at river mile (RM) 40.4. The Tolt River, which drains a 101 mi^2 (262 km^2) basin, is a large tributary to the lower mainstem Snoqualmie (Joy, 1994). The Tolt provides 30% of the drinking water for the 1.3 million people in the Seattle area.

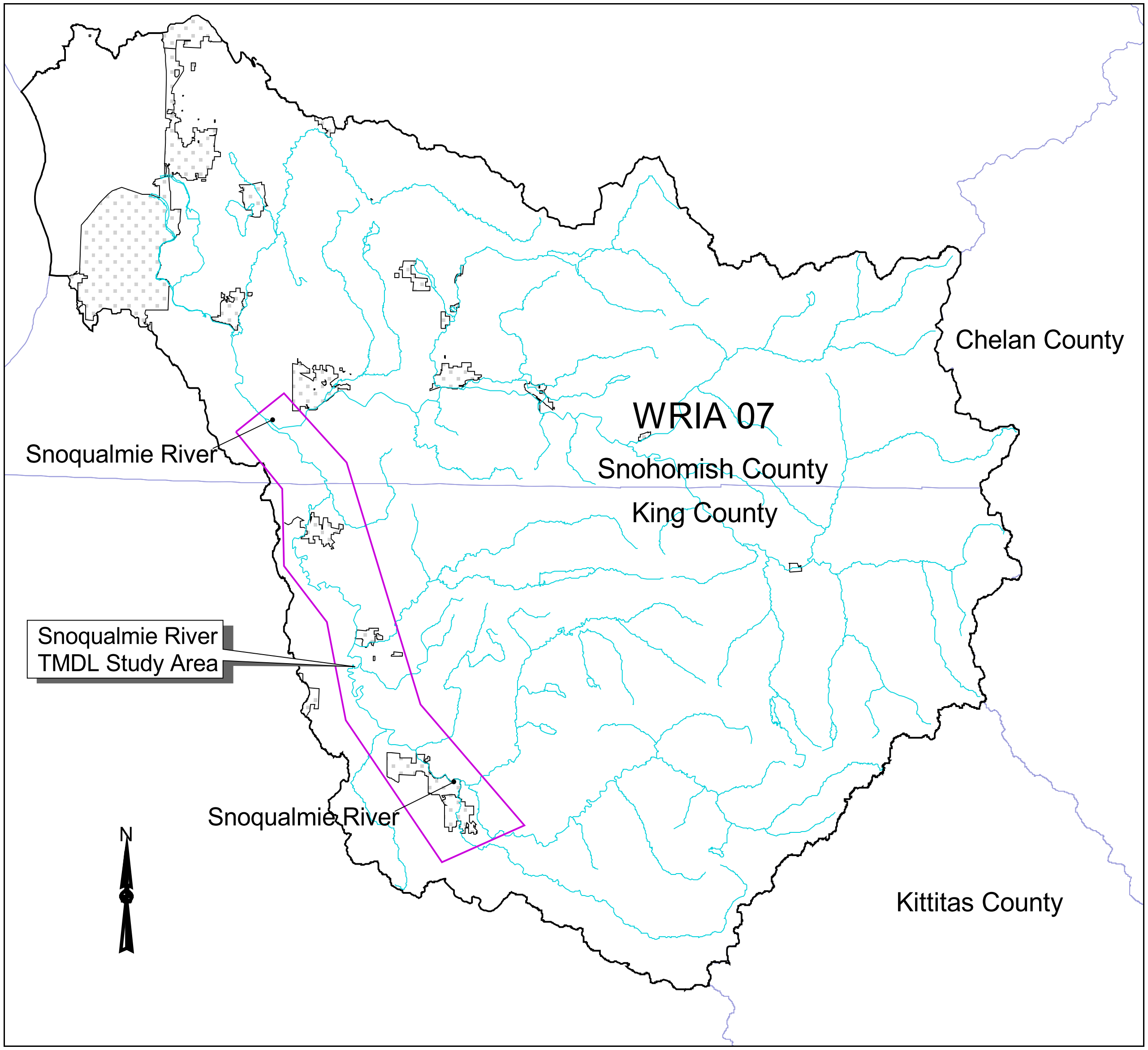

Figure 2. Snoqualmie River monitoring study area. (WRIA - Water Resource Inventory Area)

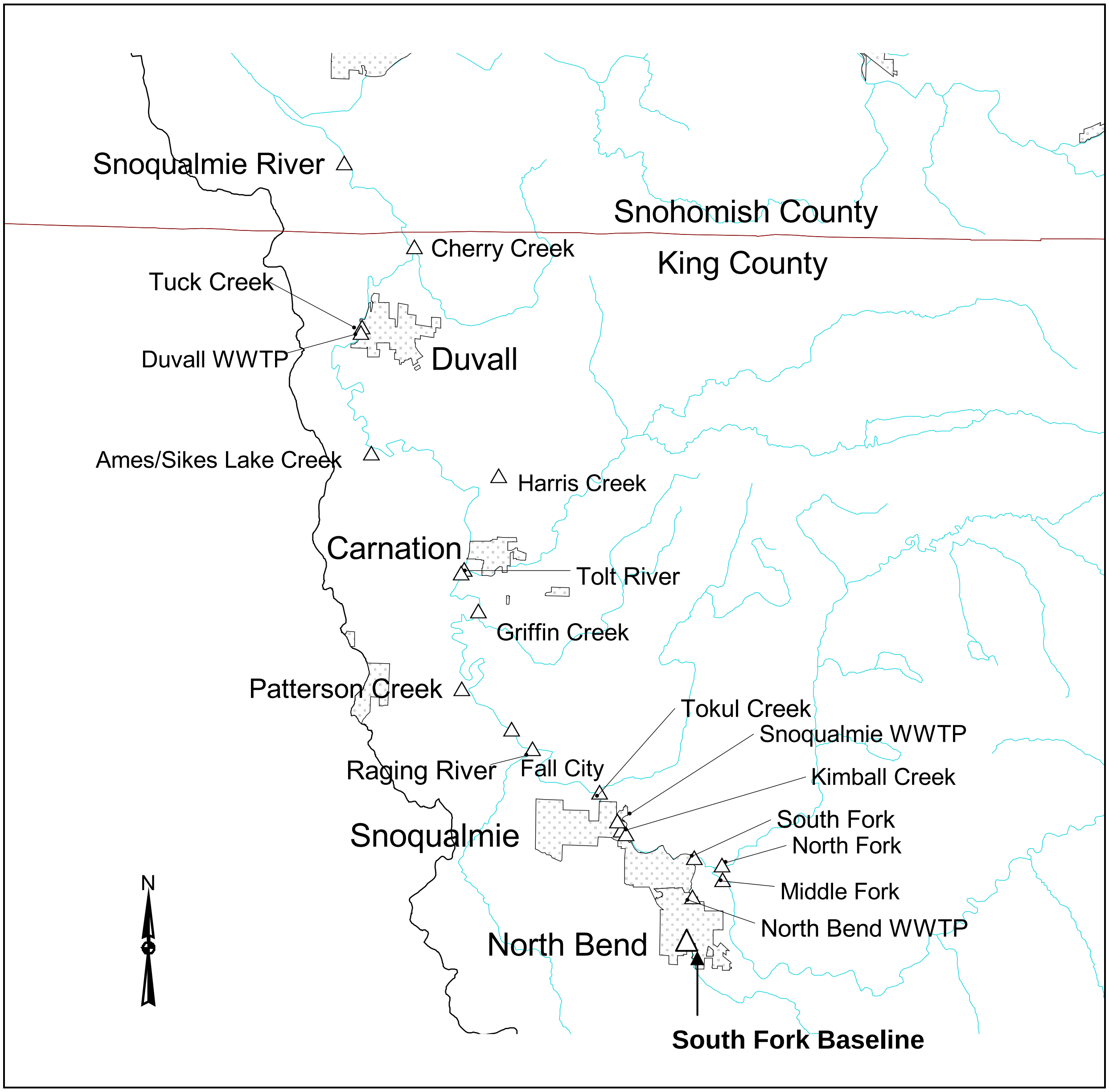

Figure 3. Snoqualmie River and tributary sampling locations. (WWTP - Wastewater Treatment Plant)

The upper Snoqualmie watershed above North Bend is mainly forested land under both private and U.S. Forest Service management. Residential and commercial land uses are concentrated in two areas in the upper portion of the study area: along the Interstate 90 corridor around the city of North Bend, and in the city of Snoqualmie located near Snoqualmie Falls.

The lower valley, which is located below Snoqualmie Falls, is characterized by several major population centers and mixed agriculture. The population centers are the cities of Duvall and Carnation and the unincorporated towns of Fall City and Preston. Agriculture includes dairies, berry fields, pastures, and row crop fields. In addition, golf courses, wildlife reserves, and other recreational facilities are present along the mid to lower end of the river. The slopes and upland sub-drainage areas of the lower valley have traditionally supported forestry and water supply uses, but are being converted to residential and commercial developments along the western borders of the lower basin and around several cities. Stormwater from a number of residential developments on the western plateaus discharges into the Snoqualmie River through drainage systems or by direct pipeline (Onwumere and Batts, 2004).

Sampling sites for the *Effectiveness Monitoring Study* are shown in Figure 3. All but one of the sampling sites used in the study are located on a stream reach that are either TMDL or 303(d) listed or both. The unlisted site is on the South Fork at river mile (RM) 2.8 and is considered a baseline station.

Appendix D summarizes water quality criteria and beneficial uses for the waterbody classifications in the Snoqualmie watershed. The Snoqualmie River and its tributaries are classified as *Primary Contact Recreation* waters from the mouth to the west border of Twin Falls State Park at river mile (RM) 9.1 on the South Fork. The entire Middle Fork and North Fork Snoqualmie Rivers, and South Fork Snoqualmie River above RM 9.1, are classified as *Extraordinary Primary Contact Recreation* waters. The South Fork Tolt River system is also *Extraordinary Primary Contact Recreation* waters, with a special condition on the South Fork of the Tolt River (a Seattle water supply) above RM 6.9 prohibiting any waste discharge.

Potential Pollution Sources Vary Throughout the Watershed

A number of pollution sources have the potential of degrading water quality in the Snoqualmie watershed. Several categories of pollution sources are described in Appendix B. Specific actions taken within subbasins of the watershed are discussed in the following sections in this report: *Water Quality in the Upper Snoqualmie River* and *Water Quality in the Upper Snoqualmie River.*

What Was Done to Improve Water Quality?

Ecology surveyed internal staff, local governments, and other agencies to determine key implementation activities that took place prior to, or during, the 2003-05 Snoqualmie TMDL *Effectiveness Monitoring Study*. Ecology, King County, King Conservation District, Public Health of Seattle-King County, and National Resources Conservation District (NRCS) activities comprise the majority of activities documented during the period prior to effectiveness monitoring, 1994 to 2004.

Each organization and its major program elements and accomplishments are discussed below. Individual projects may be discussed, along with water quality data by subbasin, later in this report. Some organizations discussed below have only become active in recent years; therefore, their activities have not contributed significantly to water quality changes observed in this study. However, Ecology considers their activities important to TMDL implementation in the future.

Washington State Department of Ecology

Ecology administers two programs that control pollution inputs to the Snoqualmie watershed

1. The National Pollutant Discharge Elimination System (NPDES) permits for wastewater treatment plants and other point source discharges.
2. The Dairy Nutrient Management Program (Chapter 90.64 Revised Code of Washington).

The activities for these programs are discussed below.

1. Management of Municipal Wastewater Treatment Plant Discharges

Municipal wastewater treatment plants (WWTPs) for the cities of North Bend, Snoqualmie, and Duvall currently discharge directly to the Snoqualmie River. Many changes have taken place at these WWTPs since the original TMDL technical work was performed in the early 1990s. These changes are discussed later in this report under *Water Quality in the Upper Snoqualmie River* and *Water Quality in the Lower Snoqualmie River*.

The 1994 Snoqualmie low-flow TMDL analyzed several scenarios for managing municipal wastewater discharges from existing and potential future sources (Joy, 1994). At the time of the TMDL's approval, four WWTPs were operating within the basin: North Bend, Snoqualmie, Echo Glen, and Duvall. Echo Glen discharges were not significant during dry weather conditions as wastewater infiltrated into the dry streambed during that time of the year. Wastewater from Echo Glen now flows to the Snoqualmie WWTP, eliminating all discharges from this site.

After EPA approved the Snoqualmie TMDL in 1996, Ecology started to include special effluent limitations in the NPDES permits to these treatment plants. Ecology reduced the amount of ammonia and biochemical oxygen demand (BOD) that could be discharged from these plants during the dry summer season. The reductions were designed to protect dissolved oxygen levels downstream of the plants. A summary of these permit limits is shown in Table 2. (The reader should refer to the NPDES permits for the correct limits for compliance purposes.)

Table 2. Wastewater treatment plant effluent limits summary.

For comparison, this table contains only selected limits that are specifically related to the TMDL. Some limits in the table are expressed in different units than those in the NPDES permits.

Wastewater Treatment Plant	**Year-round or Wet Weather Limits** (November thru July, lbs/day)			**Dry Season Limits** (August thru October, lbs/day)		
Duvall WWTP						
Date Permit Issued	Weekly Average Maximum		Daily Maximum	Weekly Maximum	Daily Maximum	Calculated Daily Maximum limit[1]
	BOD_5	$CBOD_5$	Ammonia	$CBOD_5$	Ammonia	$CBOD_5$ + Ammonia
10/9/1992	338	---	60	---	---	---
3/10/2000	---	300	60	172	12.5	
4/11/2002	---	300	60	---	---	203.5
6/19/2006	---	438	---	---	---	171.8

[1] Equivalent $CBOD_5$ loading is defined as follows: $CBOD_5$ lbs/day + (2.5 * NH_3-N lbs/day) where $CBOD_5$ and total ammonia (as NH_3-N) are measurements from the same daily composite sample.

Snoqualmie WWTP						
Date Permit Issued	Weekly Average Maximum		Daily Maximum			
	BOD_5	$CBOD_5$	Ammonia	BOD_5	$CBOD_5$	Ammonia
12/15/1994	87	---	29	---	---	---
12/20/2002	807	---	n/a	225.2	---	75

[1]Dry season limits are derived from daily maximum concentration limits in the permit and the maximum daily flow of 1.8 MGD.

North Bend WWTP						
Date Permit Issued	Weekly Average Maximum		Daily Maximum	Weekly Average Maximum		Daily Maximum
	BOD_5	$CBOD_5$	Ammonia	BOD_5	$CBOD_5$	Ammonia
11/15/1994	150	---	93.4	---	---	---
12/19/1999	---	354	---	---	307	20.25
4/7/2006		801				

[1]Wasteload allocations for North Bend WWTP are 175 lbs/day $CBOD_5$ and 81.5 lbs/day ammonia based on the original TMDL. Using the QUAL2E model, this distribution was changed to 307.5 and 20.25 lbs/day for CBOD5 and ammonia, respectively. This allocation is more suited for the present configuration of the North Bend plant.

The City of Carnation has begun constructing a new WWTP to serve its growing wastewater needs. Carnation will be converting from the use of individual on-site septic systems to community use of membrane bioreactor technology and constructed wetlands to meet the TMDL allocations. The new WWTP is expected to begin operating in 2008 or 2009.

2. Dairy Nutrient Management Program

In 1997 Ecology began a systematic dairy inspection program. All dairies were inspected and required to develop and implement Dairy Nutrient Management Plans by December 31, 2003. All dairy inspections are now performed by the Washington State Department of Agriculture.

In 1998, Class A dairies became regulated by the Dairy Nutrient Management Act, RCW 90.64. Each dairy was required to develop and implement a Dairy Nutrient Management Plan (DNMP). The DNMP describes how to manage nutrient-rich byproducts of the dairy operation. All DNMPs were to be implemented by December 31, 2003.

Both financial and technical assistance is available to dairies and other commercial animal husbandry organizations through the National Resource Conservation Service, the King Conservation District, and King County's Agricultural Assistance Program.

Ecology administered the Dairy Nutrient Management Act until July 1, 2003, when those duties were transferred to the Washington State Department of Agriculture.

Nine dairies were in operation during the 2003-05 *Effectiveness Monitoring Study*. This number is down from approximately 25 dairies at the time the original TMDL data was collected (Ecology Database; Nelson, 2004) (Figure 4). Most dairies were located along the mainstem of the Snoqualmie River.

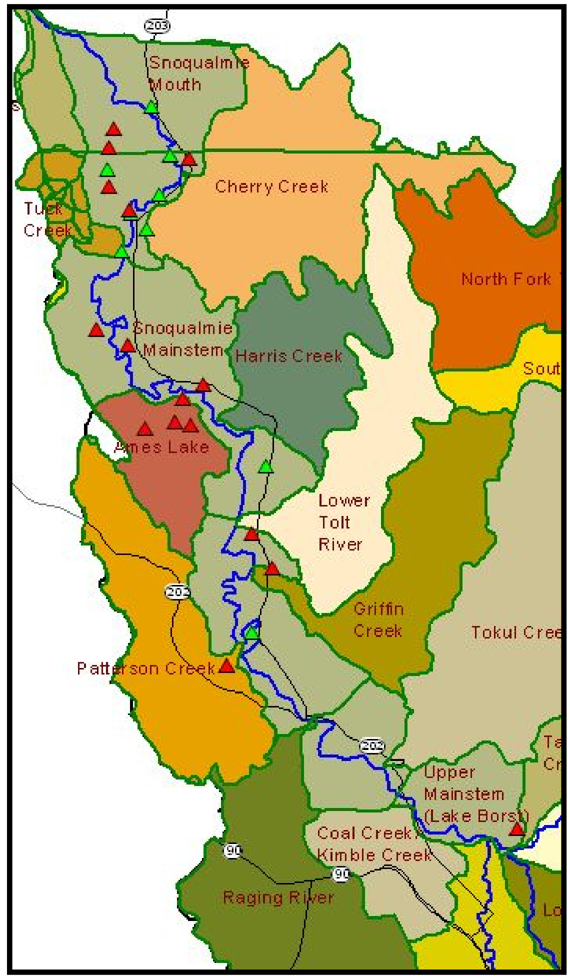

Figure 4. Dairies in the Snoqualmie River basin. Dairies active during the 2003-05 study are shown with green triangles. Currently inactive dairies believed to be in operation at the time TMDL data were collected are shown with red triangles.

Ecology staff inspected all active facilities from approximately 1998 to 2003. As a result of these inspections, 23 formal and informal enforcement actions were taken against 10 dairies (Hovde, 2001). Nine of those 10 facilities had some type of water quality concern. Ecology issued two dairy NPDES permits as a result of ongoing or potential water quality problems at those locations. One dairy in the Duvall area had failed to develop and implement a farm plan during the *Effectiveness Monitoring Study* and was receiving monthly fines of $100.

A dairy in the Tuck Creek subbasin went out of business near the end of the 2003-05 *Effectiveness Monitoring Study* and is now home to an organic herb and vegetable facility.

Washington State Department of Agriculture

Ecology administered the Dairy Nutrient Management Act until July 1, 2003. At that time, he Washington State Department of Agriculture (WSDA) took over the inspection responsibilities for that program with enforcement authority retained by Ecology. The act requires dairy farmers to implement approved dairy nutrient management plans. WSDA has responsibility for inspecting dairies for compliance with state and federal water quality laws.

The WSDA is committed to inspecting all dairies in the Snoqualmie watershed on an 18-24 month interval. If a problem is noted at the facility, follow-up inspections will be made and enforcement actions initiated as needed. WSDA will also routinely inspect any non-dairy operations covered under the NPDES CAFO permit and coordinate with Ecology on any compliance actions on such facilities. WSDA will coordinate with Ecology on responding to water quality complaints about other livestock operations. WSDA staff responded to at least two citizen complaints regarding dairy operations in the Duvall area during the course of this 2003-05 study.

King Conservation District

The King Conservation District (KCD) supported Snoqualmie basin TMDL goals by providing education and technical assistance to rural landowners and the agricultural community on how to manage land and animals in an environmentally sustainable manner. The KCD is not a regulatory agency. The KCD works closely with the Natural Resources Conservation Service, which provides technical assistance to the KCD, conducts training sessions for KCD personnel, and develops the practices and standards which the KCD uses to develop and implement its projects. Landowners within the KCD boundaries receive free information and technical assistance for water quality protection, farm management plans, soil and slope stability information, volunteer opportunities, stream restoration/enhancement assistance, and many other natural resource topics on an as-requested basis.

Between 1990 and 2000, the King Conservation District prepared about 132 farm plans for residents in the Snoqualmie basin (Figure 5). Farm plans detail the best management practices (BMPs) that are needed to make a farm healthy for animals and the environment. Dairies were required to develop Dairy Nutrient Management Plans, a version of a farm plan, by the Washington State Legislature, which was done through a partnership of the Natural Resources Conservation Service and the KCD. Among the most basic and important BMPs for the control of bacteria and nutrient inputs are the installation of fencing, use of heavy use protection areas and roof runoff management systems, and the establishment of trees and shrubs where needed. Locations where these BMPs were observed to be installed as part of farm plan implementation are shown in Figure 5.

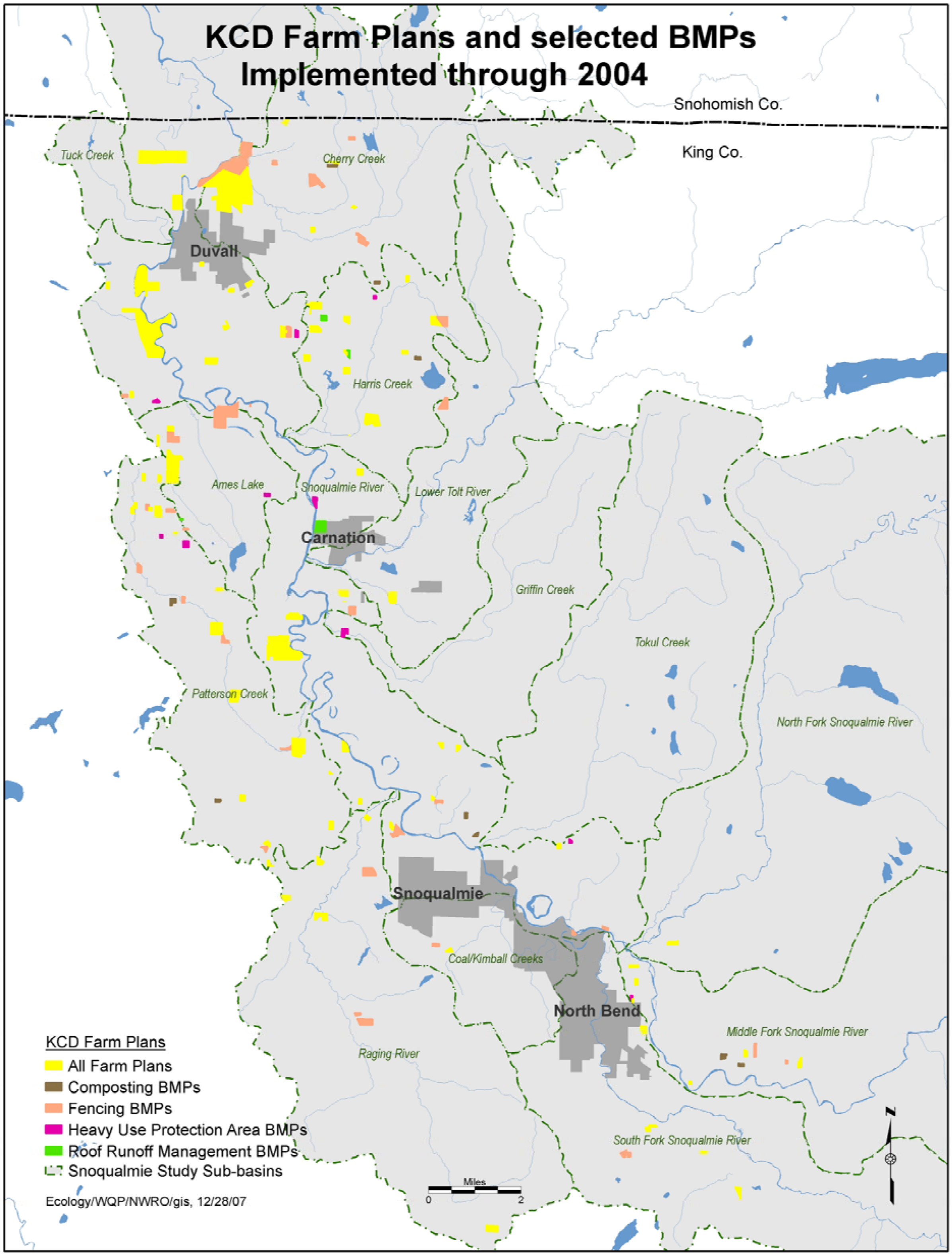

Figure 5. King Conservation District (KCD) activities in the Snoqualmie watershed.

As shown in Table 3, the implementation rate of key BMPs that reduce bacteria and nutrient loading is less than half of what was identified as being needed (KCD, unpublished data, 2004). However, good progress is being made. Best management practices were implemented to protect water quality such as (1) improvements to roof runoff management systems that prevent stormwater contamination, (2) use of off-stream watering point, and (3) installation of at least seven miles of fencing. Because KCD and King County resources do not allow for a comprehensive number of revisits to all farms, the numbers provided are likely to be underestimates. This report recommends that regular visits to all farms, or a large number of random visits, be conducted to accurately document farm plan implementation.

Table 3. Selected best management practices known to be installed as part of approximately 84 approved farm plans in Snoqualmie River watershed farms as of 2004.

Best Management Practice	Amount Planned	Amount Implemented	Percent installed
Composting (number of facilities)	21	9	43
Fence (feet)	136,099	37,893	28
Heavy Use Protection Area (acres)	21	7	36
Roof Runoff Management (number of facilities)	81	36	44
Tree and Shrub Establishment (acres)	45	17	38

Targeted efforts by the KCD include implementation of the Sensitive Areas Protection from Domestic Livestock Program in 1993. The KCD worked with citizens and local and state agencies to reduce nonpoint source pollution from livestock operations in King County. A farm plan was developed for a 67-acre commercial beef operation on the Snoqualmie River. A total of 51 farm practices were implemented, and a two-stage manure storage pond and five-million-gallon manure lagoon at Carnation Farms were included in this effort. During 1995-97, the Washington State Conservation Commission provided the KCD with a $48,000 grant for the Floodplain Fencing Demonstration Project. Three sites were planted in May 1996 - July 1997.

In recent years, the KCD applied for and received a competitive grant from Ecology to perform water quality monitoring and increased outreach to Snoqualmie watershed residents. This work supports the goals of the Snoqualmie TMDL and is ongoing through June 2008. The KCD has also created a new competitive grant program called the “Opportunity Fund” to support improvements on private property that promote salmon recovery and improve water quality.

Snohomish Conservation District

The Snohomish Conservation District (SCD) works with landowners and livestock owners throughout Snohomish County and on Camano Island to develop resource management plans. A principal focus of their work is surface water protection. The SCD provides information and services including, but not limited to, riparian and instream restoration, soils, water quality, livestock husbandry, backyard conservation, pasture management, nutrient management, and residential low impact development (LID) retrofits.

The SCD provides technical assistance, farm plans, and cost-share funds to help implement BMPs using county, state, and federal funds. TMDL-related BMPs that are recommended and implemented include: fencing livestock out of streams, improving pasture and nutrient management, installing gutters to keep water away from barnyard areas, composting and storage of manure, and planting riparian buffers. These BMPs help prevent the transport of mud, nutrients, and manure to surface waters and also improve watershed health overall.

The SCD also conducts water quality monitoring as part of many of its targeted projects. The SCD has a strong program of education and outreach including well-attended workshops and evening programs on Small Farms Management, Horses for Clean Water, and other topics. In July 2005 the SCD was awarded Centennial Grant funds to provide small farm BMP education, including riparian vegetation improvements, in the Harvey-Kackman-Armstrong, March, and Fish Creek sub-watersheds. Water quality monitoring will be performed to educate residents and other stakeholders on current status of pollution levels in these creeks. The SCD also has received state Salmon Recovery Funds to control erosion from forest roads in the Segelsen Creek area.

Natural Resources Conservation Service

The Natural Resources Conservation District (NRCS) works in partnership with the King and Snohomish Conservation Districts to provide technical guidance and funding for a number of programs that affect water quality. The NRCS works primarily with the agricultural community acting as the technical resource aid for farm plan preparation. In partnership with other parts of the U.S. Department of Agriculture, the NRCS also oversees the construction and operation of dikes, pump stations, and other devices associated with the engineering of floodplain areas in agricultural areas. The NRCS also administers several important financial assistance programs including the Conservation Reserve Enhancement Program (CREP), Environmental Quality Incentives Program (EQIP), Wild Life Incentive Program (WHIP), and the Wetland Reserve Program (WRP).

King County

King County has a number of programs that reduce and control pollution inputs into the Snoqualmie watershed. The most significant pollution reduction activities during the 1990s and early 2000s were related to agricultural assistance and salmon restoration activities. Stormwater management, road maintenance, and flood control activities also occurred; however, these activities probably had a smaller impact on controlling bacteria and nutrient pollution, which was the focus of the original *1994 Snoqualmie TMDL Study*.

Rural and Agricultural Assistance Programs

King County has several programs to help rural landowners and to support a strong and viable agricultural community. By doing so, landowners get technical assistance and will have the economic ability to both sustain their activities and do so in an environmentally acceptable manner.

King County developed the Rural Drainage Program (RDP) in 1999 by extending the surface water management fee to eastern King County (and Vashon Island) through the passage of Ordinance 13695. The fee was originally $85 and was increased 20% to $102 per residence in 2002. The RDP provides funding for a comprehensive approach to protecting water-related resources including drainage services; environmental enforcement; Snoqualmie technical assessment activities; five basin stewards (one each for the Vashon, Green River, Bear/Issaquah Creeks, Cedar River, and Snoqualmie watersheds); lake stewardship activities; the King County Agriculture Program; Rural Forest Preservation activities; and the Vashon groundwater project. These activities are discussed below:

Basic Education and Outreach Programs

King County helped to organize and staff the Livestock and Rural Landowner Assistance booth at the King County Fair (provided assistance to over 2,000 fairgoers in 2002). The County also helped organize the first King County Small Farm Fair Expo at the Enumclaw Fairgrounds, 500 rural landowners attended in 2002. County staff also attended planning workshops for existing and new farmers and developed a Ditch Maintenance Training Video that is available to landowners. County staff responded to over 500 requests for technical assistance in 2002 across the Rural Drainage Program service area. Three Agricultural Drainage Assistance flyers were produced and distributed. A questionnaire was sent to 2,000 residents of the Patterson Creek watershed in October 2001 to get feedback on water quality problems in their area.

Agricultural Cost Share Assistance

Since 1996, King County has helped livestock owners and horticultural operations install needed BMPs to protect the environment, especially water quality. This program was only a few years old at the time the 2003-05 TMDL *Effectiveness Monitoring Study* was started. King County had $85,000 available in the early 2000s to work with farms to put in fences to exclude animals from riparian areas. This grant money was awarded in anticipation of changes in sensitive area management requirements for fencing in agricultural areas. Manure management systems and composting structures were installed in several locations, along with stream and wetland buffer fencing, confinement area footing, and clean water diversion.

Puget Sound Fresh Program

King County works through the Puget Sound Fresh Program to market produce and help keep farms economically healthy. This farm marketing effort is important because a healthy farm is better equipped to properly manage pollution sources. The County started the program by providing $400,000 in 1997 and then $100,000 annually beginning in about 1999.

Forestry Program

King County's Forestry Program focuses on the retention of forest land for its environmental, social, and economic benefits. Healthy forests help maintain natural watershed hydrology (proper river flow) and introduce less sediment into local waters. The forestry program assisted in teaching several eight-week Forest Stewardship classes in 2001 and 2002. Additional outreach included the development of a color brochure explaining the value of forests and the mailing of Farm and Forest Newsletters to 10,000 residents in the Rural Drainage Program area. The County continues to mail these newsletters on a regular basis.

Snoqualmie Basin Steward

King County's Snoqualmie Basin Steward works directly with landowners to protect water quality and aquatic resources in many ways. In 2002, the basin steward prepared over $1,100,000 in grant applications for land acquisition and restoration activities in the Snoqualmie River watershed. The steward organized eight public planting events in 2000-02 located at Chinook Bend, Middle Fork Snoqualmie Park Natural Area, and the Griffin Creek Park Natural Area. About 4,000 plants were planted and 3-4 acres of noxious weeds were destroyed; steward activities improved 20 acres of floodplain and riparian habitat and engaged about 500 volunteers.

King County Livestock Program

The King County Council passed the King County Livestock Management Ordinance (LMO) in December 1993. Livestock Program staff facilitated a 9-member Livestock Oversight Committee (composed of livestock owners, environmentalists, tribal, federal, and Washington State Fish & Wildlife department representatives) whose purpose was to implement the ordinance. The LMO supports livestock management that minimizes adverse impacts to the environment, particularly with regard to water quality and salmon habitat. One staff person currently administers the LMO and may refer problem sites to the Department of Development and Environmental Services for enforcement, if necessary.

Beginning in 2004, the King County Agricultural Commission replaced the oversight committee while continuing to let farmers take an active role in developing and evaluating policies, regulations, and incentives that can affect King County agriculture.

The Livestock Ordinance required the preparation and implementation of Farm Plans on those farms of a specified animal density:

- Six large animals per acre if you: (1) Follow ordinance management standards or get a Conservation District Farm Management Plan, and (2) have a covered confinement area, and (3) keep no more than 3 animals on an uncovered grazing area at one time.
- Three large animals per acre if you: Don't get a Farm Management Plan but do follow the Ordinance management standards.
- One large animal per two acres if you: Just follow the Ordinance rules for manure management.

The ordinance originally required 25-foot to 50-foot buffers (buffer averaging allowed) between Class 1 and 2 streams, natural ponds, and wetlands for pastures and additional requirements for heavy confinement areas. Changes that became effective in 2005 are based on newer state stream and wetland classification systems. Previous regulations also required manure piles to be located at least 50 feet from streambanks, and covered or confined during winter months, with additional requirements for stockpiles uphill from a stream. The 2005 changes generally increase that setback with provisions for reductions to 50 feet based on the presence of composting and leachate containment systems.

Enforcement of the LMO is a complaint-driven system, meaning that County staff do not investigate compliance with the ordinance unless a complaint is received from an outside entity. Details on the LMO are at http://dnr.metrokc.gov/wlr/LANDS/livestoc.htm.

King County was developing a livestock manure management program during this 2003-05 *Effectiveness Monitoring Study,* but it was not completed or rolled out to the public in time to affect this study.

Farmland Preservation Program

This program buys development rights in existing King County farmlands. Covenants restrict land use to agriculture or open space, and limit housing density, to help preserve agricultural lands that would otherwise be susceptible to urban sprawl. Although this is not a water quality program, it can help protect the environment by providing farmers with a new source of funding that could be used to improve riparian areas, install fencing, or implement other best management practices.

Public Benefits Rating System and Timberland Program

The Public Benefit Rating System (PBRS) provides tax incentives to encourage private landowners to voluntarily conserve and protect land resources and open space. In return, the county assesses land at a value consistent with its "current use" rather than the "highest and best use." The reduction in assessed land value is greater than 50% and as much as 90% for the portion of the land participating in the program. Examples of eligible properties include stream buffers and farmland. Farm and agricultural lands used for livestock or agricultural production are eligible. The financial requirements depend on the size of the land and the gross annual revenue received for the land for three out of the past five years.

Snohomish County

Only a small portion of the Snoqualmie watershed is located in Snohomish County. Thus, many of the county's basic water quality programs have a limited impact on the Snoqualmie watershed. However, Snohomish County's contributions to the activities of the Snohomish River Basin Salmon Recovery Forum are significant (see *Snohomish Watershed Forum* on the next page).

Outside of that process, Snohomish County's Surface Water Management division actively develops streamside landowner, animal waste management, and urban watershed restoration programs for use across the entire county. The county also responds to water quality complaints. During the 1994-2004 TMDL implementation period, the county responded to three complaints of improper manure management. Only one of the complaints was determined to be a manure-related problem. Surface Water Management referred the situation to the Snohomish Conservation District after finding manure deposited in a ravine by the previous owner. The district began working with the landowner to properly manage manure on the farm along High Bridge Road.

Snohomish County does not have a Livestock Management Ordinance (LMO).

Snohomish and Snoqualmie Salmon Recovery Forums

During 1994 to 2004, state agencies, local governments, tribes, and others increased their efforts to restore chinook salmon populations through the Snohomish River basin salmon recovery process. To coordinate this work, the Snohomish Salmon Recovery and Snoqualmie Watershed Forums were created.

The primary tasks for these groups were to guide the initial planning and early implementation actions to help restore chinook populations. Early implementation focused on the acquisition and restoration of estuarine habitat. Although these efforts have not played a significant role in improving water quality during the 1994-2004 period examined by the *Effectiveness Monitoring Study*, Ecology expects that future activities will place greater emphasis on water quality in tributary streams where water quality is a greater factor in salmon health and survival.

Snohomish Salmon Recovery Forum

Founded in 1998, the Snohomish Forum is a 39-member voluntary group of citizens, businesses, tribal representatives, farmers and elected officials who guide conservation efforts in the Snohomish River basin. The Forum's mission is to protect, restore, and enhance the productivity and diversity of all wild salmon stocks in the Snohomish River basin by putting the Snohomish River Basin Salmon Recovery Plan into action. The State of Washington distributes most of its salmon recovery funds through prioritization processes performed largely by local salmon recovery groups such as the Snoqualmie Forum.

During its early years of implementing the Snohomish River Basin Salmon Recovery Plan, the Snohomish Forum prioritized projects that addressed the most significant limiting factors in salmonid survival. Early projects focused on acquisition and restoration of estuarine habitats to promote chinook salmon survival.

Ecology anticipates that work in future years will place more emphasis on improving water quality in tributary streams to assist with the recovery of threatened steelhead populations. These tributaries comprise a large part of the *Snoqualmie Dissolved Oxygen and Fecal Coliform TMDL* focus area. Because good water quality is essential to the health of salmonid stocks, Snohomish Forum activities support the goals of the Snoqualmie TMDL.

Snoqualmie Watershed Forum

In 1995, King County completed a Regional Needs Assessment for the watersheds of King County. It involved a collaborative decision-making process with surface water management staff from jurisdictions throughout King County, the King Conservation District, elected officials, tribes, and others. It resulted in the establishment of the Snoqualmie Watershed Forum in 1998.

Like the Snohomish Forum, the Snoqualmie Forum is comprised of representatives from local communities: the cities of Carnation, Duvall, North Bend, and Snoqualmie; King County; the Snoqualmie Tribe; and three citizens. The Snoqualmie Forum works to protect and restore the health of the Snoqualmie watershed in harmony with the cultural and community needs of valley residents. The Snoqualmie Forum makes recommendations to the Snohomish Forum and oversees the distribution of approximately $575,000 annually to support habitat protection and restoration projects, stewardship projects and programs, and studies. Financial support for Forum-sponsored projects is provided by King County, King Conservation District, and the participating entities.

The early activities of the Snoqualmie Forum emphasized research and planning. The Forum helped oversee the preparation of the *Snoqualmie Watershed Forum Strategy and Workplan* (2001), the *Snoqualmie River Aquatic Habitat Conditions Report*, and the *Salmon Habitat Limiting Factors Analysis* (2002). In recent years, the focus has shifted more to implementation of plans.

City of North Bend

The City of North Bend, which operates a wastewater treatment plant and stormwater management system, participates actively in the Snoqualmie Forum. The City discharges stormwater and treated wastewater into the South Fork Snoqualmie River just below the crossing of Highway 202 traveling from the edge of town to the city of Snoqualmie. The North Bend WWTP has undergone growth and upgrades during the 1994-2003 TMDL implementation period. Changes at the plant, its wastewater collection system, and compliance with its National Pollutant Discharge Elimination System (NPDES) permit are discussed later in this report under *Water Quality in the Upper Snoqualmie River*.

In 2001 the City of North Bend worked with King County and the City of Snoqualmie to purchase the 460-acre Meadowbrook Farm, which is home to Ribary Creek, a tributary of the South Fork Snoqualmie. Recently, the City teamed up with the Mountains to Sound Greenway Trust to remove invasive plant species and provide animal exclusion fencing along Ribary Creek.

City of Snoqualmie

The City of Snoqualmie, which operates a wastewater treatment plant and a stormwater management system, participates actively in the Snoqualmie Forum. Stormwater and treated wastewater are discharged to the mainstem Snoqualmie River just above Snoqualmie Falls. The city has undergone tremendous growth during 1994 to 2003. As discussed later in this report under *Water Quality in the Upper Snoqualmie River,* the Snoqualmie WWTP has undergone growth and upgrades during the 1994-2003 TMDL implementation period.

Most of the discharge from the WWTP during summer months is used to irrigate the Snoqualmie Ridge golf course, athletic fields at Snoqualmie Community Park, and landscaping at nearby businesses. The City recently agreed to accept sewage flow from Echo Glen Children's Center, a state Department of Social and Health Services juvenile rehabilitation facility. The sewage service connection will allow Echo Glen to decommission their out-dated sewage treatment plant that discharged to the Raging River via Icy Creek.

The City performed water quality testing in Kimball Creek and found high levels of nutrients, particulates, and bacteria (Herrera, 2004). Properties in the Kimball Creek subbasin are served by on-site sewage treatment systems, and there are numerous small farms. Several previous reports address follow-up actions needed to reduce pollutants in Kimball Creek. These reports are discussed later in this report with Ecology's monitoring data.

The City of Snoqualmie is currently developing a Stormwater Comprehensive Plan, although it is not covered under Ecology's Municipal Stormwater Permit. The plan will include a chapter that discusses Kimball Creek and incorporates the findings and recommendations of previous studies on the creek. The City of Snoqualmie has embarked on a voluntary, routine bacteria monitoring program for Kimball Creek to guide pollution source control efforts in the basin.

City of Carnation

The City of Carnation, which operates a stormwater management system, participates actively in the Snoqualmie Forum. Currently, all sewage in the city is treated via an on-site sewage treatment system.. To prevent pollution of the local aquifer and accommodate future growth, the city is working closely with King County to design, construct, and operate a wastewater treatment facility. The new plant will use a membrane filtration bioreactor with supplemental treatment by a constructed wetland. No specific pollution control activities in the city of Carnation were documented for 1994 to 2004.

City of Duvall

The City of Duvall, which operates a wastewater treatment plant and a stormwater management system, participates actively in the Snoqualmie Forum. The City upgraded its oxidation ditch treatment plant to a membrane filtration bioreactor. Performance at the City's WWTP during the 1994-2003 study period has been good. Although no specific pollution control activities in the city were documented for 1994 to 2004, the City undertook riparian planting projects along the mainstem Snoqualmie River in recent years. Duvall is covered under Ecology's Municipal Stormwater permit, which requires public education of citizens and businesses, examination of their stormwater system for illicit discharges, and other activities to ensure that pollution from stormwater is controlled. A more detailed discussion of the City's WWTP and its historical performance is provided later in this report under *Water Quality in the Lower Snoqualmie River*.

Washington State University, Cooperative Extension Program

Washington State University (WSU) works with King County and the King Conservation District to help educate livestock owners on the use of best management practices to protect the environment. One activity that contributes to the goals of the Snoqualmie TMDL is the Cooperative Extension Livestock Advisors Program. Livestock Advisors are trained and certified volunteers that receive 80 hours of intensive animal science training, and serve the public by fielding questions and volunteering their expertise at workshops and public events.

Recently, WSU was awarded grant funding to study nutrient and pathogen pathways related to dairy waste management at several sites in the lower Snoqualmie watershed. The project will evaluate changes between traditional liquid manure waste application and manure processed in a methane digester. WSU is collecting baseline data and awaiting the construction of the methane digester (Quilceda Power) on the site of the former Monroe Correctional Facility.

Public Health of Seattle/King County

Public Health of Seattle/King County (PHSKC) is responsible for permitting and overseeing the regulation of over 115,000 on-site sewage treatment systems (on-site systems) in King County. PHSKC had a much larger staff that focused on finding and correcting failing systems over a decade ago; however, due to budget cuts, this service is no longer provided. PHSKC provides general education and outreach on maintenance of on-site septic systems and now has an educational website in addition to written materials on proper on-site septic system maintenance.

Improperly functioning on-site systems and poorly handled solid waste can affect both dissolved oxygen and bacteria levels in the Snoqualmie River basin. PHSKC has the exclusive authority to enforce county and state codes regarding the treatment of residential wastewater by individual residential on-site systems. Similarly, PHSKC has specialized skills needed to investigate and evaluate on-site systems. On-site systems are considered a very likely and significant contributor to many areas showing high bacteria levels during summer months. Therefore, the PHSKC is among the most crucial organizations in resolving the bacterial pollution problems within the Snoqualmie River basin TMDL study area.

PHSKC focuses on permitting new on-site systems, working in areas with a high potential to create public health risks, and other special projects funded partially or wholly by grants. The PHSKC is nearing completion of a special county-wide project funded in part by Ecology Centennial Grant monies. The project provides public education and outreach to on-site system owners and upgrades the PHSKC data management system. Through targeted mailings and workshops, the education campaign focuses on areas prone to on-site system failure. When completed, the database conversion project will transfer information on about 130,000 on-site systems from the current paper and microfiche systems to a digital one. Eventually, the transfer of data to a digital format could assist in (1) identifying potential areas of pollution from on-site systems, and (2) on-line access of as-builts by the public.

Community requests encouraged the “King County Health Department” to initiate development of the East King County Groundwater Quality Management Plan for the rural areas north of Interstate 90 and east of the developed metropolitan areas. King County Solid Waste Management (1996) finalized that plan, which contains information on on-site system failure rates, well-head protection needs, and sampling data of water quality for fecal coliform and total coliform levels in 20 representative wells. The draft final plan was submitted to the King County Council for adoption in the fall of 1996. Maintenance of on-site systems is a key component of the plan. Recommendations to require on-site system inspections during installation and construction are working to minimize the possibility of failures and subsequent contamination of drainages and surface waterbodies.

The PHSKC will also help oversee new regulations that affect the operation and maintenance of on-site systems as of July 2007 (Chapter 246-272 WAC). These new state regulations require that owners of mechanical on-site systems have them inspected at least annually. Owners of conventional gravity systems must have their system inspected once every three years. These new requirements will help detect previously unknown problems and, therefore, help prevent failures that could lead to pollution of local surface waters.

Snohomish Health District

The Snohomish Health District (SHD) is responsible for regulating on-site systems in the northern most portion of the Snoqualmie River watershed, from just north of the confluence with Cherry Creek to the confluence with the Skykomish River. The SHD has a variety of responsibilities to protect human health including permitting and inspection of various activities and facilities such as food establishments, on-site systems, small drinking water systems, public swimming pools, and solid waste disposal facilities. A major portion of the activities of the SHD Water and Wastewater Section centers on permitting installation and repair of on-site systems.

The SHD has exclusive authority to enforce county and state codes regarding the treatment of wastewater by residential on-site systems. They have specialized skills needed to investigate and evaluate on-site systems. The SHD responds promptly to reports of failing or illegally connected on-site systems. About 3,000 inspections of existing systems are performed annually. In recent years, the SHD has also improved its ability to provide the public with information on on-site systems through the SHD website. Homeowners can get online information on the location of their on-site systems at www.snohd.org (click on "septic as builts" in their A-Z Index, or call 425-339-5250). Currently, the public is accessing the system about 2,000 times per month.

The SHD helps administer new regulations that affect the operation and maintenance of on-site septic systems as of July 2007 (Chapter 246-272 WAC). These new state regulations require owners of mechanical on-site systems to have them inspected at least annually. Owners of conventional gravity systems must have their system inspected at least once every three years. The SHD and Snohomish County Surface Water Management are developing a system to identify and prioritize on-site systems for closer inspection. Following the development and testing of the prioritization system, it will be evaluated for use county-wide.

Snoqualmie Tribe

The Snoqualmie Tribe is a federally recognized tribe which currently has approximately 650 members. During the last six years, the tribe reorganized tribal governance, administration, and services to its members. Tribal Environment and Natural Resources Department staff are engaged in significant environmental issues across the Snoqualmie watershed. Although no specific water cleanup activities have been reported for the 1994-2004 TMDL effectiveness monitoring period, the Snoqualmie Tribe is working to increase its capacity for water quality monitoring and habitat improvement.

Stewardship Partners

Stewardship Partners is a nonprofit conservation organization that promotes incentive-based programs to encourage private landowners to participate in voluntary conservation practices while promoting sustainable land management. Since 2002, Stewardship Partners restored three miles of riparian habitat and created bank protection for eroding farmland. They also developed the Snoqualmie Salmon-Safe Program to recognize and market farms that follow best management practices to protect water quality and habitat. Stewardship Partners educate the public on environmental issues associated with farms and other land uses in the Snoqualmie Valley. This has included the development and administration of the Environmental Discovery Program, which has delivered hands-on environmental education to over 1500 elementary school children.

Stilly/Snohomish Fisheries Enhancement Taskforce

The Stilly-Snohomish Fisheries Enhancement Task Force (Task Force) is a 501(c)(3) not-for-profit corporation registered as a charitable organization with Washington State. The Task Force's mission is to ensure the future of salmon in the Stillaguamish, Snohomish, and Island County watersheds. Funding for Task Force activities comes from the Washington Department of Fish and Wildlife, National Fish and Wildlife Foundation, Salmon Recovery Funding Board, grants, donations, and fee-for-service contracts. More information about projects and volunteer opportunities with the Task Force are at the website: www.stillysnofish.org/index.html.

Working with landowners of all types, the Task Force conducts volunteer events and stream restoration projects that improve water quality and fish habitat. Task Force activities help to both reduce bacterial pollution and improve dissolved oxygen levels. The Task Force has worked for many years in the Stillaguamish and Snohomish County portions of the Snohomish watershed, and began working in the Snoqualmie watershed in 2003. Current and past projects include tree planting along the mainstem Snoqualmie on public property in the city of Duvall; at the Oxbow Farm; along Griffin Creek; and at the Members Club at Alderra along Canyon Creek, a tributary of Patterson Creek.

The Task Force offers educational programs, including the Restoration Education for Young Stewards (REYS), to elementary through high school classrooms. These programs provide hands-on opportunities for students to learn about water quality, salmon, and the importance of good stewardship of both land and water. Their outreach helps educate watershed residents about the importance of mature native riparian vegetation in improving water quality and providing quality salmon habitat. Citizens living in the Snoqualmie watershed can volunteer to complete hands-on restoration activities and participate in educational programs that improve water quality.

Tulalip Tribes

The Tulalip Tribes is a federally recognized Indian Tribe with tribal lands located near the mouth of the Snohomish River. As signatories of the Treaty of Point Elliott of 1855, the Tulalip Tribes' adjudicated usual and accustomed area extends from the Canadian border south to Vashon Island and includes the Snohomish/Snoqualmie/Skykomish watersheds. The Tribe has a continuous interest in activities taking place outside of the reservation, particularly those that might affect the Tribes' cultural and archaeological resources and treaty-protected fishery resources.

The Tulalip Tribes shares a common interest in and responsibility for the protection and enhancement of the environment. The Tribe performed water quality monitoring throughout the Snoqualmie in the late 1980s discovering bacterial pollution problems in a number of tributaries and supporting the original TMDL for the Snoqualmie. During 1994 to 2003, the Tribe focused resources for the Snohomish basin on activities related to salmon recovery, primarily recovery plan development and acquisition/restoration of chinook salmon habitat.

No specific actions to reduce nutrient or bacteria levels were observed during the 2003-05 TMDL effectiveness monitoring period; however, recent efforts to build a methane digester are nearing the construction phase. The Tulalip Tribes worked with local farmers to create Quilceda Power, a nonprofit entity that will make electricity from dairy manure waste. Land and funding have been acquired, and negotiations over the value of the newly generated power are still ongoing. Washington State University (WSU) is also working with Quilceda Power to evaluate the environmental and agricultural benefits of using processed manure products for agricultural purposes. Baseline water quality data collection in local waters began in 2007.

Wild Fish Conservancy

The Wild Fish Conservancy (WFC; formerly Washington Trout) is a nonprofit, conservation-ecology organization dedicated to the preservation and recovery of the Northwest's native fish and ecosystems. The WFC seeks to improve conditions for all of the Northwest's wild fish by conducting important research on populations and habitats; advocating for better land-use, salmon-harvest, and hatchery management; and developing model habitat-restoration projects. Since its founding in 1989, the WFC has built a reputation for effectiveness, expertise, credibility, and a focus on the needs of the resource.

The WFC performed several successful stream relocation and restoration projects in 1999. Working with King County and Jobs for the Environment, 3000 feet of streambank along Griffin Creek was replanted, 350 feet was re-engineered with large woody debris, and 7000 feet of fencing was relocated or installed. Work was also done to relocate Weiss Creek (just south of Carnation), which grew in length from 800 feet to nearly a mile in length as part of the restoration project. In 2002, the WFC taught stream restoration techniques to high school students using Weiss Creek as an outdoor learning center.

During 2006, the WFC conducted fish passage research in an agricultural tributary of Cherry Creek near Duvall and discovered dissolved oxygen levels so low that juvenile study fish died during their experiments. The WFC and the Tulalip Tribe are collecting water quality data in the lateral drain to further understand the problem and the possible pollution sources involved.

Other organizations

Other public service organizations are working to improve and protect the health of the Snoqualmie watershed. Their past and future activities are discussed below.

Mountains to Sound Greenway Trust

The Mountains to Sound Greenway Trust is a nonprofit organization created to protect the Mountains to Sound Greenway. The Greenway stretches along 100 miles of Interstate 90 in Washington State from the waterfront in Seattle to the edge of desert grasslands in Central Washington. Thus, much of the Greenway is located in the headwaters of the Snoqualmie watershed. The Greenway includes historic towns and over 700,000 acres of foothills, working farms and forests, spectacular alpine scenery, wildlife habitat, campgrounds, trails, lakes, and rivers.

The Mountains to Sound Greenway Trust is currently working to remove invasive species, re-plant riparian areas, and provide animal exclusion fencing as needed along over two miles of stream at Ribary and Gardner Creeks, which are located in the Meadowbrook Farm adjacent to the South Fork Snoqualmie River. In 2003 the Trust has also worked with the cities of North Bend, Snoqualmie, Carnation, and Duvall in 2003 to assist 30 private property owners in restoring critical areas (both design and implementation).

Friends of the Trail

Friends of the Trail was organized in March 1996 to address the problem of dumping and littering on public lands, waterways, and scenic areas in eastern King County. They work to remove years of accumulated trash, abandoned vehicles, and appliances to restore public areas to their original state. In addition to direct cleanup activities, they use public outreach and education to achieve their overall goal to keep Washington State's public lands and waterways healthy.

Friends of the Trail plan and implement cleanup projects using people who owe community service hours through the judicial court systems, along with volunteers and required school community service. Friends of the Trail project sites are designated worksites set up with the Washington State Department of Corrections and county court systems. The group has performed watershed cleanup activities at 12 or more locations in the Snoqualmie watershed using a combination of private and public grant funds.

How did Ecology Conduct this Effectiveness Monitoring Project?

Monitoring Goals and Objectives

Study Goal

The goal of the this 2003-05 *Effectiveness Monitoring Study* is to determine compliance with water quality standards (Table 4) and/or TMDL targets (Table 5); to support regulation, enforcement, and maintenance of Washington State water quality standards; and to support the systematic review and improvement of water quality.

Study Objectives

Objectives of the study are as follows:

- Determine if fecal coliform bacteria, dissolved oxygen, and ammonia-nitrogen concentrations as well as biochemical oxygen demand (BOD) levels are at recommended TMDL compliance targets at selected points on the mainstem Snoqualmie River and its tributaries.
- Determine if other conventional parameters, such as temperature and pH, are meeting water quality criteria on the Snoqualmie River and its tributaries.
- Determine streamflow from U.S. Geological Survey (USGS) mainstem data, and by wading tributaries and taking periodic flow measurements.
- Perform diagnostic studies of nitrate/nitrite-nitrogen, chloride, fecal coliform/E. coli bacteria, and conductivity levels around the Fall City area to provide additional information on the possibility of on-site sewage treatment system failures in the near-shore area.
- Determine if designated uses of study area waters are supported.
- Recommend any additional measures needed to return local waters to compliance with state standards.
- Identify specific pollutant sources (as resources allow).

The results of this post-TMDL evaluation study will allow Ecology and other basin stakeholders to engage in adaptive management of basin activities to control the level of polluting substances within the Snoqualmie River watershed study area. Possible outcomes include:

- Recommendation to move waters from the polluted category to the clean water category.
- Redirection of existing resources to control nonpoint pollution.
- New TMDL target limits or NPDES permit limitations or other appropriate actions.
- Recommendations for additional resources, studies, or approaches to reduce pollutant levels.

As described earlier, the primary data of interest are the TMDL-recommended parameters of fecal coliform bacteria, dissolved oxygen, and ammonia-nitrogen. There are also comparisons of data to TMDL targets. Table 4 includes the information on the specific portions of the Washington State water quality standards that are addressed by the 1994 *Snoqualmie River TMDL Study* (Joy, 1994).

Table 4. Water quality criteria used to determine beneficial uses in the Snoqualmie River basin.

Parameter	Criteria Category	Statistic	Criterion	Ancillary Data Required
Dissolved oxygen	Water Quality Standards: Freshwater	Daily average	10.5 mg/L	September 15 to May 31 in salmon, steelhead, and non-resident cutthroat spawning areas.
		Minimum	9.0 mg/L	
			8.0 mg/L	June 1 to September 14 in salmon, steelhead, and non-resident cutthroat spawning areas.
			8.0 mg/L	Salmon, steelhead, and non-resident cutthroat migration and rearing areas.
Fecal coliform	Water Quality Standards: Primary Contact Recreation	Geometric mean	100 cfu/ 100 mL	NA
		90th percentile value*	200 cfu/ 100 mL	
	Water Quality Standards: Extraordinary Primary contact Recreation	Geometric mean	50 cfu/ 100 mL	
		90th percentile value*	100 cfu/ 100 mL	
pH	Freshwater	Maximum	8.5 SU	
		Minimum	6.5 SU	

Parameter	Criteria Category	Statistic	Criterion
Ammonia-nitrogen	Freshwater Acute	Maximum	$\frac{0.275}{1+10^{7.204-pH}} + \frac{39.0}{1+10^{pH-7.204}}$
	Freshwater Chronic	Maximum	$\frac{0.0557}{1+10^{7.204-pH}} + \frac{2.487}{1+10^{pH-7.204}}$

* Criteria wording states that not more than 10% of the samples used to calculate the geometric mean exceed the stated value.

Table 5 includes TMDL targets recommended in the TMDL. For select parameters, the TMDL targets are more restrictive than the criteria. These more restrictive targets were set as a result of the *TMDL Study* (Joy, 1994) and are tailored for the Snoqualmie River to ensure water quality beneficial uses are met.

Table 5. TMDL recommended water quality targets for the August-October critical period (Joy, 1994)*.

Parameter	Target Source	Statistic	Criterion	Ancillary Data Required
Dissolved oxygen	Mainstem Snoqualmie River	Minimum	7.9 mg/L	Snoqualmie mainstem pool above Falls
		Minimum	8.3 mg/L	Snoqualmie mainstem confluence with Skykomish River
Biochemical oxygen demand (BOD)	WWTPs: North Bend, Snoqualmie, Fall City, Carnation, Duvall	Critical period arithmetic mean	15 mg/L	Targets for BOD loading are described in the TMDL
	WWTP: Weyerhaeuser		4.7 mg/L	
	Background and most tributaries		2.0 mg/L	
Ammonia-nitrogen	WWTPs: North Bend, Snoqualmie, Fall City, Carnation	Critical period arithmetic mean	9.00 mg/L	Targets for ammonia-nitrogen loading are described in the TMDL
	WWTP: Duvall		8.00 mg/L	
	WWTP: Weyerhaeuser		0.08 mg/L	
	Background and tributaries		0.03 mg/L, Tokul Creek ≤ 0.04 mg/L	
Soluble reactive phosphorus or orthophosphate	Mainstem Snoqualmie River	Critical period arithmetic mean	10 µg/L	Targets for soluble reactive phosphorus loading are described in the TMDL
	Background and tributaries		20 µg/L	
Fecal coliform	Mainstem Snoqualmie and tributaries	Geometric mean	80 cfu/ 100 mL	Targets for fecal coliform loading are described in the TMDL
		90th percentile value**	200 cfu/ 100 mL	

* TMDL targets listed are based on wastewater treatment plant (WWTP) expansion to five WWTPs and nonpoint source controls in place (Table 8 in the 1994 TMDL).

** Criteria wording states that not more than 10% of the samples used to calculate the geometric mean exceed the stated value (cfu/100 mL).

Study Design

The study design is described in detail in the *Quality Assurance Project Plan for the Snoqualmie River Total Maximum Daily Load Effectiveness Evaluation* (Onwumere and Batts, 2004). The study area for this TMDL consists of the mainstem Snoqualmie from river mile (RM) 45.0 (North Bend area) to RM 2.7 (above Crescent Lake Road) and all major tributaries described in Table 6.

Table 6. Snoqualmie River TMDL *Effectiveness Monitoring Study* sampling locations.

Station	River Mile	Latitude	Longitude	Waterbody Segment	Location	County
Middle Fork Snoqualmie R.	45.3	47.5160	121.7693	WA-07-1140	Near mouth	King
North Fork Snoqualmie R.	44.9	47.5218	121.7697	WA-07-1150	Near mouth	King
South Fork (RM 2.8)	-	47.49241	121.78972	WA-07-1110	At Hwy 202 bridge crossing just NE of I-90	King
North Bend WWTP	-	47.50033	121.78753	WA-07-1130	North Bend WWTP outfall	King
South Fork (RM 2.0)	44.4	47.50197	121.78635	WA-07-1110	At Snoqualmie Trail crossing downstream of WWTP	King
Snoqualmie River	42.3	47.5271	121.8109	WA-07-1100	Above Snoqualmie WWTP and below North Bend at Meadowbrook Rd bridge	King
Kimball Creek	41.1	47.5354	121.8302	WA-07-1108	At Hwy 202 bridge	King
Snoqualmie WWTP	40.8	47.5392	121.83216	WA-07-1100	Snoqualmie WWTP outfall	King
Snoqualmie River	40.7	47.5390	121.8324	WA-07-1130	Pooled water above Snoqualmie Falls at Hwy 202	King
Tokul River	39.6	47.5506	121.8434	WA-07-1106	Mouth of river	King
Raging River	36.2	47.5678	121.8839	WA-07-1104	Mouth of river	King
Snoqualmie River (Fall City)	35.3	47.5754	121.8964	WA-07-1100	Bridge below Fall City	King
Patterson Creek	31.2	47.5915	121.9268	WA-07-1102	At W. Snoqualmie River Rd bridge	King
Griffin Creek	27.5	47.6171	121.9099	WA-07-1101	At Hwy 203 crossing	King
Snoqualmie River	25.2	47.6385	121.9282	WA-07-1100	Pooled water just above the Tolt River (Tolt Pool)	King
Tolt River	24.9	47.6399	121.9264	WA-07-1070	At mouth WA Dept of Fish & Wildlife boat launch	King
Harris Creek	21.3	47.6783	121.9070	WA-07-1068	Hwy 203 bridge NE 87th St	King
Ames Creek	17.5	47.6863	121.9832	WA-07-1066	At NE 100th St. bridge	King
Duvall WWTP	11.0	47.7351	121.9910	WA-07-1060	Duvall WWTP outfall	King
Tuck Creek	10.3	47.7375	121.9904	WA-07-1064	At mouth	King
Cherry Creek	6.7	47.7703	121.9600	WA-07-1062	At mouth Hwy 203 bridge	King
Snoqualmie River	2.7	47.8037	122.0029	WA-07-1060	25 ft upstream of Crescent Lake Rd	Snohomish

Field and Laboratory Methods

Several types of monitoring schemes were conducted. Table 7 describes the monitoring period for the different types of sampling. Details of the sampling regimes are described below.

Table 7. Snoqualmie River TMDL *Effectiveness Monitoring Study* sampling regimes.

Type of Sampling	Sample Location	Sampling Period	Number of Sample Events	Sampling Parameters
Synoptic Surveys	Snoqualmie mainstem and tributaries	Aug 2003-Feb 2005:	Total: n=43	Fecal coliform bacteria, occasionally obtained nutrients, BOD, DO, temperature, conductivity, pH, or flow.
		Critical period: Aug-Oct	n=26	
		Wet season: Nov-Apr	n=17	
Intensive Survey	Snoqualmie mainstem, tributaries, and WWTPs	August 30-31, 2005	AM and PM for 2 consecutive days n=4	Fecal coliform bacteria, orthophosphate, nitrogen parameters, TOC, inhibited BOD, temperature, DO, pH, conductivity, and flow at most sites.
Continuous In-Situ Monitoring	Snoqualmie mainstem at RM: 40.7, 25.2, 2.7	2003-2005 during July, August or September	1-3 sampling periods for 2-9 consecutive days	Temperature, DO
Fall City Transect Survey	Snoqualmie mainstem in the vicinity of RM 35.3, occasionally Raging River	September 2003-September 2005	Sampled 12 times	Fecal coliform bacteria, orthophosphate, nitrogen parameters, chloride, conductivity, and temperature at most sites.

WWTP – wastewater treatment plant
RM – river mile
BOD – biological oxygen demand
DO – dissolved oxygen
TOC – total organic carbon

Synoptic Surveys

Ecology conducted sampling for synoptic surveys in the Snoqualmie River watershed from August 2003 through February 2005. Mainstem and tributary sites were sampled for fecal coliform bacteria 26 times during the critical period (Aug-Oct) and 17 times during the wet season (Nov-Apr). Sites were sampled for ammonia-nitrogen approximately 14 times during the critical period and 10 times during the wet season. Orthophosphate samples were collected with the same frequency at the mainstem Snoqualmie River sites. Other sites and tributaries were sampled infrequently for orthophosphate, nitrate-nitrite nitrogen, and total persulfate nitrogen. Field measurements were obtained for temperature, dissolved oxygen, and pH, and occasionally flow during sampling events.

Intensive Monitoring Survey

Ecology sampled all sites, including the wastewater treatment plants (WWTP), in the morning and afternoon for two days, August 30 and 31, 2005 for fecal coliform bacteria, total persulfate nitrogen, nitrite-nitrate and ammonia-nitrogen, orthophosphate, total organic carbon, dissolved oxygen, temperature, and pH. Results from this survey represent steady-state conditions ideal for TMDL environmental modeling.

Continuous Instream Monitoring

Ecology conducted continuous instream monitoring at three mainstem Snoqualmie River sites, RM 40.7, 25.2, and 2.7. Monitoring was conducted for temperature, pH, and dissolved oxygen during the August-October critical period in 2003, 2004, and 2005. Unfortunately, quality control standards were not met for at least one of the three years monitored.

Fall City Transect Study

During September 2003 – September 2005, Ecology conducted a special diagnostic study on the mainstem Snoqualmie River near Fall City (river mile 35.3). The objective of the study was to determine levels of nitrite-nitrate nitrogen, chloride, fecal coliform/*E. Coli* bacteria, and conductivity levels around the Fall City area to provide additional information on the possibility of on-site sewage treatment system failures in the nearshore area. Samples were obtained along the mainstem Snoqualmie shoreline (left and right banks), at the mouth of the Raging River, and the Snoqualmie mainstem upstream of the Raging River. Sample results and dates for this study are described in Appendices E and H.

Data Analysis Methods

Field and laboratory data were compiled and organized using Excel® spreadsheet software (Microsoft Corporation, 2001). Water quality results from field and laboratory work were also entered into Ecology's Environmental Information Management (EIM) database. Statistical analyses, plots, and mass balance calculations were made using Excel® software. For statistical trend analysis, WQHYDRO software (Aroner, 2002) was used.

For data analysis and comparison to water quality standards, laboratory duplicates were arithmetically averaged. Field duplicates were used solely for quality assurance and not for data analysis.

A non-parametric Wilcoxon paired sample test was used to compare water quality between upstream and downstream sites. Sites were evaluated for differences in fecal coliform concentration and loading. A two-tailed test with a significance level of $\alpha = 0.05$ was used.

WQHYDRO software (Aroner, 2002) was used to conduct trend analysis. A Seasonal Kendall with correction for correlation was used to test trends. This test is a modification of their original Seasonal Kendall test where an attempt is made to account for serial correlation between adjacent seasons (Aroner, 2002). A two-tailed test with a significance level of $\alpha = 0.05$ was used.

Analysis of the fecal coliform bacteria data included using the statistical rollback method to determine the load reduction necessary to achieve fecal coliform water quality standards. The statistical rollback method (Ott, 1995) has been used by Ecology to determine the necessary reduction for both the geometric mean (GM) and 90th percentile bacteria concentration (Roberts, 2003; Joy, 2000) to meet water quality standards. Compliance with the most restrictive of the dual fecal coliform criteria determines the bacteria reduction needed.

Fecal coliform sample results for each site in this study were found to follow lognormal distributions. The 90th percentile was calculated as the antilog of the mean of the log-transformed data plus 1.28 times the standard deviation of the log-transformed data.

The rollback method uses the statistical characteristics of a known data set to predict the statistical characteristics of a data set that would be collected after pollution controls have been implemented and maintained. In applying the rollback method, the target fecal coliform GM and the target 90th percentile are set to the corresponding water quality standard. The reduction needed for each target value to be reached is determined. The rollback factor, $f_{rollback}$, is

$$f_{rollback} = \text{minimum}\ \{(\text{fecal coliform water quality standard GM/sample GM}),\ (\text{fecal coliform water quality standard 10\% value not to exceed/sample } 90^{th} \text{ percentile})\}$$

The percent reduction ($f_{reduction}$) needed is

$$f_{reduction} = (1 - f_{rollback}) \times 100\%$$

which is the percent reduction that allows both GM and 90th percentile target values to be met.

The result is a revised target value for the GM or 90th percentile. In most cases, a reduction of the 90th percentile is needed, and application of this reduction factor to the study GM yields a target GM that is usually more restrictive than the water quality criterion. The 90th percentile is used as an equivalent expression to the "no more than 10%" criterion found in the second part of the water quality standards for fecal coliform bacteria. If fecal coliform reductions are needed, the reduction factors are included in this report.

Quality Assurance and Quality Control Results

Laboratory samples were analyzed according to quality assurance and quality control procedures used by Ecology's Manchester Environmental Laboratory (MEL) (MEL, 2001). A detailed discussion of the laboratory and field data quality assurance and quality control results is in Appendix F.

Comparison of Environmental Conditions

Environmental conditions such as weather and streamflow can affect water quality. Higher air temperatures can lead to higher water temperatures. Warmer water has less potential to hold dissolved oxygen. Both of these conditions can be detrimental for fish. Rainfall can lead to run-off conditions where pollutants are carried to the stream. Higher flows during the low-flow period may mean more oxygen in the water due to reaeration.

Improvements in water quality may be due to environmental conditions and not implementation of good water quality practices. To determine the causes of water quality changes, it is important to look at environmental conditions during the 1989-1991 *TMDL Study* (Joy, 1994) and the 2003-05 *TMDL Effectiveness Monitoring Study*.

Flow Conditions

All of the TMDL water quality targets were set based on critical conditions. Critical conditions for the TMDL were based on 7-day, 20-year low flows (7Q20) for August through October. The 7Q20 flow values used in the *TMDL Study* are described in Table 8. Table 8 also includes the flow statistics for the continuous monitoring surveys.

Table 8. Flow conditions (cfs) at select mainstem sites for the TMDL study and the effectiveness monitoring continuous diurnal surveys, 1989-2005.

Study Periods	Snoqualmie RM 40.7	Snoqualmie RM 23.0
TMDL Study (1989-91)		
TMDL 7Q20 flow (Aug-Oct)	340	456
August 29-30, 1989		
Minimum	619	848
Maximum	660	891
Average	640	870
Effectiveness Monitoring Study (2003-05)		
September 8-18, 2003		
Minimum	400	582
Maximum	1920	2480
Average	797	1099
July 13-22, 2004		
Minimum	681	957
Maximum	1050	1450
Average	832	1174
August 29-September 1, 2005		
Minimum	428	590
Maximum	534	680
Average	469	636

The TMDL minimum dissolved oxygen targets were set based on 7Q20 flow conditions. The *Effectiveness Monitoring Study* continuous dissolved oxygen monitoring was done to capture low dissolved oxygen levels which occur during the early morning. It is important to capture dissolved oxygen levels in the early morning hours because that is when the lowest oxygen levels occur. During the day, plants produce oxygen through photosynthesis; at night (as well as day), plants consume oxygen through respiration. If plant growth is excessive, plants at night can use up oxygen in the water.

Oxygen depletion also occurs when plants die and decompose. When plants die, photosynthetic production of oxygen ceases. Also, the bacteria, which break down the decaying plant material, use oxygen in their own respiration (Lembi, 2000).

Excessive nutrients (especially phosphorus in freshwater) can cause excessive algal growth which may cause dissolved oxygen problems. The continuous monitoring conducted during 2003, 2004, and 2005 did not capture the critical 7Q20 condition as described in the TMDL. The lowest flows sampled were 60-126 cfs higher than 7Q20 flow (Table 8). Table 8 presents flow conditions for the mainstem Snoqualmie during (1) the TMDL study and (2) the effectiveness monitoring continuous diurnal surveys. During the continuous diurnal dissolved oxygen monitoring, all three sites (RM 40.7, 25.2, and 2.7) were within TMDL targets. However to adequately determine if dissolved oxygen targets are being met, continuous diurnal dissolved oxygen and temperature monitoring should occur during 7Q20 flows, or the environmental model should be run again for dissolved oxygen.

Synoptic surveys were conducted to determine compliance with the other TMDL target parameters. Flows for the TMDL survey, the 7Q20 flow, and flows for the *Effectiveness Monitoring Study* synoptic surveys are presented in Table 9.

During the 2003-05 *Effectiveness Monitoring Study*, a wider range of flows were sampled. All sites with the exception of Tokul Creek and the Tolt River were sampled during periods where flow was less than the 7Q20 flow condition. The *Effectiveness Monitoring Study* synoptic survey captured critical low-flow conditions as described in the TMDL.

Table 9. Flow statistics for the seven-day, 20-year flow (7Q20), the *TMDL Study,* and the *TMDL Effectiveness Monitoring Study.*

TMDL 7Q10 (Annual)	TMDL 7Q20 (Aug-Oct)	Flow statistics for study period	TMDL Study (July-Oct, 1989 and 1991)	Eff. Mon. Study (Aug-Oct, 2003-05)	Intensive Survey (Aug 30-31, 2005)
Snoqualmie Middle Fork					
125 cfs	130 cfs	Minimum	161 cfs	117 cfs	168 cfs
		Maximum	462 cfs	5290 cfs	218 cfs
		Arith. Average	299 cfs	742 cfs	193 cfs
		No. of Samples	4	26	2
Snoqualmie North Fork					
75 cfs	73 cfs	Minimum	58 cfs	35 cfs	
		Maximum	163 cfs	2760 cfs	
		Arith. Average	112 cfs	340 cfs	90.6 cfs
		No. of Samples	4	26	1
Snoqualmie South Fork					
79 cfs	81 cfs	Minimum	109 cfs	84 cfs	137.9 cfs
		Maximum	215 cfs	1110 cfs	150.6 cfs
		Arith. Average	151 cfs	277 cfs	143.6 cfs
		No. of Samples	5	26	3
Snoqualmie RM 40.7					
346 cfs	343 cfs	Minimum	409 cfs	314 cfs	479 cfs
		Maximum	912 cfs	5943 cfs	534 cfs
		Arith. Average	634 cfs	1427 cfs	507 cfs
		No. of Samples	4	26	2
Kimball Creek					
	0.95 cfs	Minimum	1.20 cfs	0.51 cfs	1.2 cfs
		Maximum	2.70 cfs	20.09 cfs	1.7 cfs
		Arith. Average	1.74 cfs	4.48 cfs	1.5 cfs
		No. of Samples	4	7	4
Tokul Creek					
	16.6 cfs	Minimum	25.0 cfs	17.9 cfs	24.9 cfs
		Maximum	35.4 cfs	78.5 cfs	29.5 cfs
		Arith. Average	29.9 cfs	33.5 cfs	26.9 cfs
		No. of Samples	4	25	4
Raging River					
7.2 cfs	7.7 cfs	Minimum	10 cfs	4 cfs	12.7 cfs
		Maximum	15 cfs	1415 cfs	16.4 cfs
		Arith. Average	13 cfs	95 cfs	14.1 cfs
		No. of Samples	6	26	3
Snoqualmie RM 35.3					
	Not available	Minimum	419 cfs	322 cfs	493 cfs
		Maximum	1325 cfs	7003 cfs	552 cfs
		Arith. Average	831 cfs	1504 cfs	523 cfs
		No. of Samples	7	26	2

TMDL 7Q10 (Annual)	TMDL 7Q20 (Aug-Oct)	Flow statistics for study period	TMDL Study (July-Oct, 1989 and 1991)	Eff. Mon. Study (Aug-Oct, 2003-05)	Intensive Survey (Aug 30-31, 2005)
Patterson Creek					
	7.4 cfs	Minimum	6.5 cfs	7.0 cfs	7.7 cfs
		Maximum	8.1 cfs	29.1 cfs	8.8 cfs
		Arith. Average	7.2 cfs	16.0 cfs	8.3 cfs
		No. of Samples	4	4	4
Griffin Creek					
	Not available	Minimum	2.9 cfs	1.7 cfs	2.8 cfs
		Maximum	3.7 cfs	13.8 cfs	3.3 cfs
		Arith. Average	3.4 cfs	4.3 cfs	3.0 cfs
		No. of Samples	4	22	4
Snoqualmie RM 25.2					
443 cfs	456 cfs	Minimum	501 cfs	283 cfs	521 cfs
		Maximum	1145 cfs	27742 cfs	540 cfs
		Arith. Average	799 cfs	2313 cfs	531 cfs
		No. of Samples	7	26	2
Tolt River					
72 cfs	65 cfs	Minimum	117 cfs	86 cfs	112.5 cfs
		Maximum	186 cfs	175 cfs	120.5 cfs
		Arith. Average	155 cfs	128 cfs	117.7 cfs
		No. of Samples	7	14	3
Harris Creek					
	Not available	Minimum	2.7 cfs	1.9 cfs	2.6 cfs
		Maximum	3.5 cfs	12.5 cfs	3.0 cfs
		Arith. Average	3.0 cfs	3.7 cfs	2.8 cfs
		No. of Samples	3	22	4
Ames Creek					
	2.1 cfs	Minimum	3.8 cfs	3.4 cfs	3.4 cfs
		Maximum	4.5 cfs	5.6 cfs	5.4 cfs
		Arith. Average	4.1 cfs	4.2 cfs	4.0 cfs
		No. of Samples	4 cfs	7	4
Tuck Creek					
	Not available	Minimum	0.6 cfs	0.1 cfs	0.3 cfs
		Maximum	0.9 cfs	0.4 cfs	0.4 cfs
		Arith. Average	0.7 cfs	0.2 cfs	0.4 cfs
		No. of Samples	4	14	4
Cherry Creek					
	5 cfs	Minimum	3.0 cfs	0.8 cfs	5.5 cfs
		Maximum	8.9 cfs	62.0 cfs	6.5 cfs
		Arith. Average	6.1 cfs	11.3 cfs	6.0 cfs
		No. of Samples	5	22	4
Snoqualmie RM 2.7					
	475 cfs		no flow data	no flow data	no flow data

Rain Event Sampling

During the 1989-1991 *TMDL Study,* one sample event out of the six was a rain event. For the September 26-27, 1989 sample event, 0.72″ of rain fell on September 26. Sampling during the *Effectiveness Monitoring Study* included numerous rain events including 2.2″ of rain on October 2003. The 2.2″ rain event included 0.87″ of rain in the previous 48 hours, resulting in basin-wide flood conditions (Figure 6). The *Effectiveness Monitoring Study* included a more in-depth view of water quality during rain events than the *TMDL Study*. Rainfall for both sampling studies is described in Appendix G.

Figure 6. Flooding in the Ames Creek subbasin during the October 21, 2003 sampling event, typical of flooding in other subbasins from about RM 35.3 to RM 2.7.

Air Temperature Levels

Average monthly air temperatures for the TMDL Study (1989, 1991) and *Effectiveness Monitoring Study* (2003-05) are described in Table 10. Average monthly air temperatures and average maximum air temperatures for the August-October critical period were generally higher during the *Effectiveness Monitoring Study* than during the TMDL.

Table 10. Monthly average and average maximum air temperatures (°F) for Snoqualmie Falls during the *TMDL Study* and *Effectiveness Monitoring Study*.

Year	August		September		October	
	Average	Average Maximum	Average	Average Maximum	Average	Average Maximum
1989	63.1	73.8	59.9	74.0	50.5	59.9
1991	65.6	77.2	59.5	71.6	50.4	61.4
2003	65.5	78.8	59.6	71.8	53.5	61.5
2004	69.0	81.3	60.6	72.0	53.9	64.3
2005	66.4	78.7	57.7	68.9	54.7	61.6
Period of Record Statistics						
Average for 74-5 years of record	63.1	75.5	58.1	69.8	50.9	69.8

Interpreting Fecal Coliform Data

During long summer dry periods, contaminants accumulate on land where they are washed into streams and rivers during the first large rain event. This type of rain event can represent a worst-case condition and provides valuable information about pollution sources, especially stormwater sources. In addition, high-flow events that result in flood conditions can increase bacteria due to flood waters inundating normally dry land.

Several high-flow events had an effect on fecal coliform levels in the Snoqualmie River and its tributaries. Samples taken on October 20-21, 2003 reflected a dramatic change over baseflow conditions. Flows increased from 1,150 cfs to 25,000 cfs at the Carnation USGS gauge in a period of two days. This resulted in a 10-foot rise in river height, one foot over flood stage. This was likely caused by a "rain on snow" event in the upper headwaters. Similarly, another high-flow event occurred on August 23-24, 2004 where the baseflow of 575 cfs rose to 10,000 cfs in a period of four days, with river height rising five feet over that time period. Flows had steadily decreased for the previous two months due to low rainfall. Previous rainfall totals for the sample dates above are described in Table 11.

Table 11. Hourly rainfall totals (inches) for select sample events.

Sample Day	Sample Day Rainfall	Previous 24-hour Rainfall	Previous 48-hour Rainfall
10/20/2003	.076	.11	1.02
10/21/2003	2.2	0.76	0.87
8/23/2004	0.58	1.10	1.10
8/24/2004	1.39	0.58	1.68

Thus, fecal coliform results from the August 23-24, 2004 sampling show that many sites fail the second part of the fecal coliform bacteria standard (10% of all samples obtained for calculating the geometric mean shall not exceed 200 cfu/100 mL). High rainfall before and during the sampling event after a 14-day dry period likely resulted in the high results at many sites. Appendix G presents previous rainfall totals for all synoptic and intensive survey sample events.

Summary of Environmental Conditions

During the 2003-05 *Effectiveness Monitoring Study*, more rain events were captured and higher air temperatures occurred during critical period (Aug-Oct) synoptic sampling than during the 1989-91 *TMDL Study*. Flows sampled during the 2003-05 continuous monitoring surveys were higher than critical conditions, but during the synoptic survey sampling, critical low flows were captured. Generally the *Effectiveness Monitoring Study* captured critical environmental conditions perhaps more so than the TMDL.

The exception would be continuous dissolved oxygen monitoring that was conducted during higher flows than the 7Q20 critical period. This may have resulted in higher dissolved oxygen levels due to reaeration. However air temperatures were generally higher during the *Effectiveness Monitoring Study* which may have resulted in higher water temperatures and less capability for water to hold oxygen. To adequately determine if dissolved oxygen TMDL targets are being met in the Snoqualmie River mainstem, diurnal dissolved oxygen and temperature monitoring should occur during 7Q20 flows or the environmental model should be run again for dissolved oxygen.

Water Quality Results by Pollution Parameter

Following are results from this 2003-05 *Effectiveness Monitoring Study*. The critical period is August-October. The wet season is November-April.

Fecal Coliform Bacteria

Fecal coliform bacteria levels have improved at many sites throughout the Snoqualmie River basin since 1994. Tokul Creek was the only site that met TMDL targets for fecal coliform bacteria during the critical period, wet season, and all months (2003-05). Pollution control actions still need to occur in several areas to improve water quality. Actions to control transport of fecal coliform bacteria to surface water will also reduce nutrient inputs. Control of nutrients would limit algal growth and increase dissolved oxygen levels.

Upper Snoqualmie basin fecal coliform statistics for the critical period and wet season are presented in Figure 7. Lower Snoqualmie basin fecal coliform bacteria statistics for the critical period and wet season are presented in Figures 8 and 9. Table 12 presents fecal coliform bacteria reductions needed for the sites that did not meet standards.

While the mainstem sites met fecal coliform standards during the critical period, many of the tributaries did not. The following sites met the TMDL target for fecal coliform bacteria during the critical period, but did not meet the standard for the month of August. Fecal coliform reductions needed are minimal at these sites.

- Snoqualmie River mainstem
- North and Middle Fork Snoqualmie River
- South Fork Snoqualmie at RM 2.0
- Raging River
- Tolt River

The following sites did not meet TMDL fecal coliform targets during the critical period and needed significant reductions to meet targets:

- Kimball
- Patterson
- Griffin*
- Harris*
- Ames
- Tuck
- Cherry Creek

* These creeks are generally in good condition unless there is a rain event.

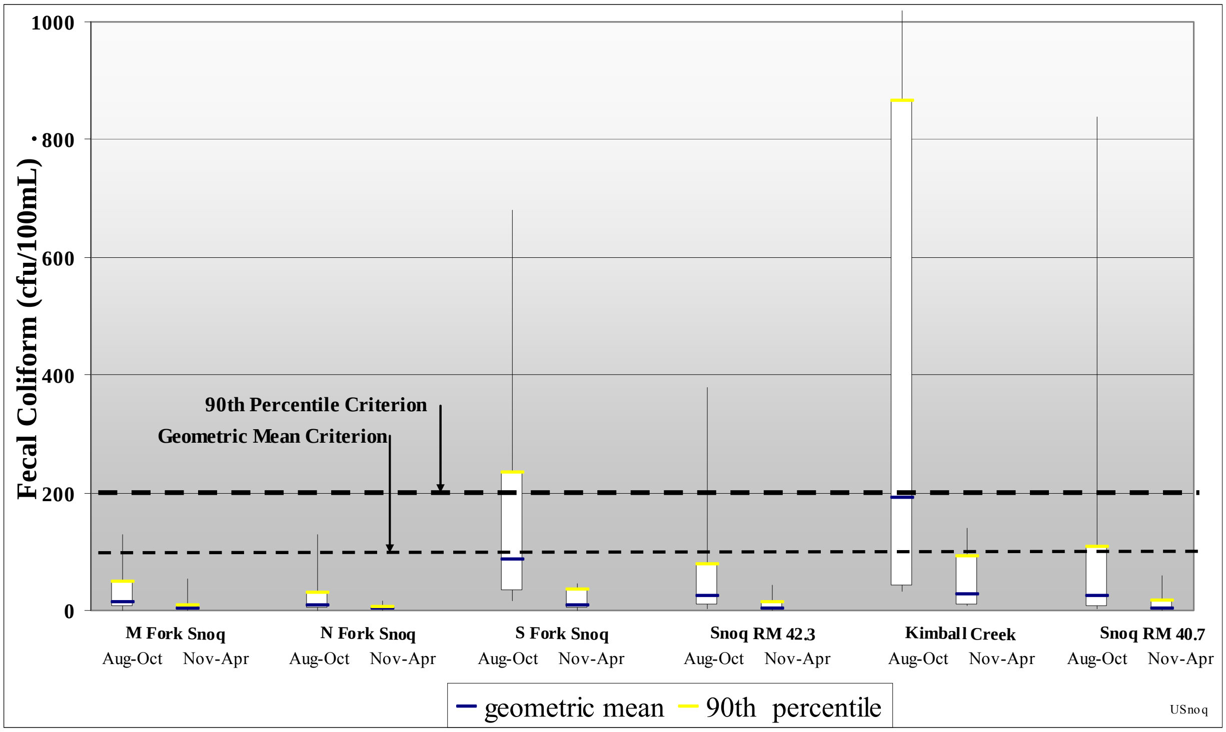

Figure 7. Fecal coliform bacteria results for the upper Snoqualmie basin sites during the critical period and wet season.

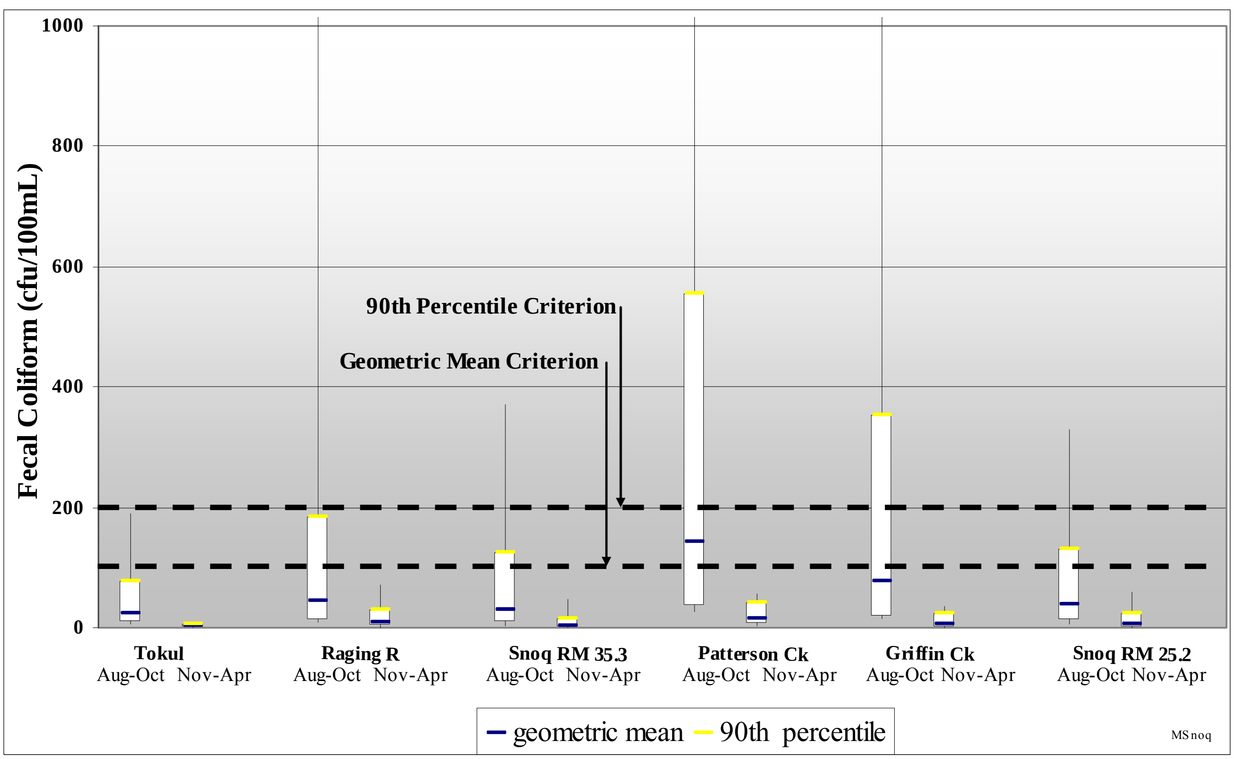

Figure 8. Fecal coliform bacteria results for the lower Snoqualmie basin sites (RM 40 – 25) during the critical period and wet season.

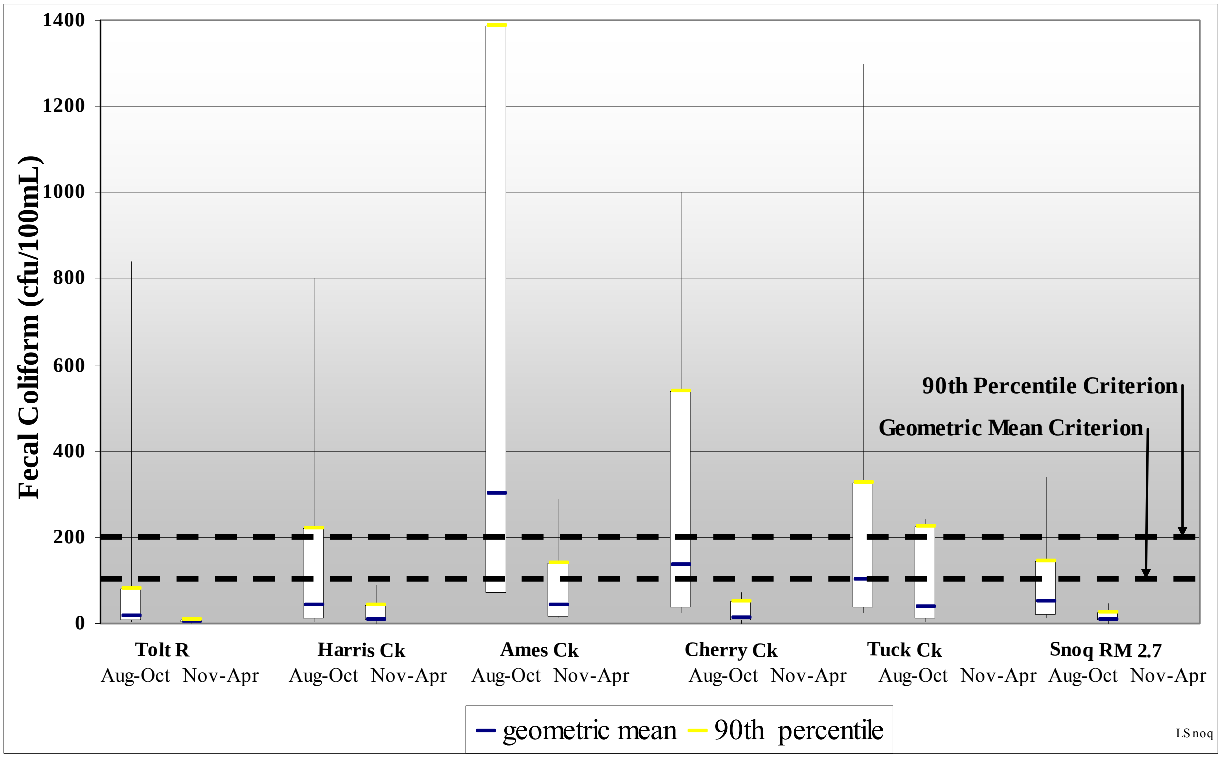

Figure 9. Fecal coliform bacteria results for the lower Snoqualmie basin sites (RM 25 – 2.7) during the critical period and wet season.

Table 12. Summary of fecal coliform bacteria reductions needs at sites that did not meet water quality standards during the critical period, August-October.

Location	Fecal Coliform Reduction	Limiting Criterion
South Fork Snoqualmie RM 1.5	14.3%	90th percentile
Kimball Creek	76.9%	90th percentile
Patterson Creek	64.1%	90th percentile
Griffin Creek	43.4%	90th percentile
Harris Creek	9.5%	90th percentile
Ames Creek	85.6%	90th percentile
Tuck Creek	38.7%	90th percentile
Cherry Creek	62.8%	90th percentile

Orthophosphate

Minimal orthophosphate sampling was conducted during the *Effectiveness Monitoring Study*. Figure 10 presents mean orthophosphate levels during the critical period and wet season.

Upper basin surface water orthophosphate levels were the highest at South Fork Snoqualmie RM 1.5, likely due to the North Bend Wastewater Treatment Plant (WWTP) or other sources between RM 2.0 and 1.5 (Figure 10).

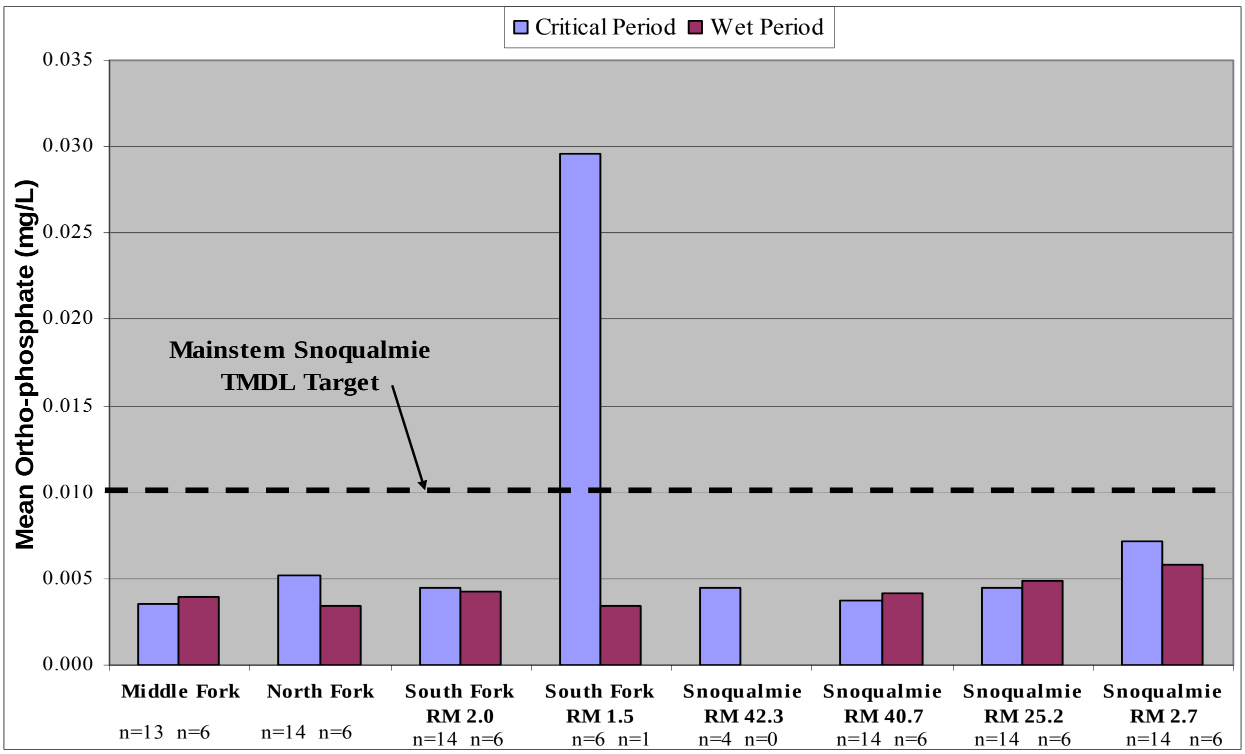

Figure 10. Snoqualmie mean orthophosphate levels during the critical period and wet season.

The *TMDL Study* (Joy, 1994) recommended tributary and background orthophosphate levels not exceed 20 µg/L. Levels > 20 µg/L occurred at:

- Patterson Creek
- Harris Creek
- Ames Creek
- Tuck Creek

Results for the intensive survey showed that aside from the WWTPs the South Fork at RM 1.5, Ames, Patterson, Tuck, and Harris Creeks had some of the higher orthophosphate levels.

Nitrogen

All Snoqualmie River sites met the TMDL target recommendations for BOD_5 and ammonia-nitrogen. With the exception of Ames Creek, all tributaries sampled met the TMDL targets for ammonia-nitrogen.

Samples were obtained for ammonia-nitrogen during most of the synoptic surveys. Figures 11, 12, and 13 present mean ammonia-nitrogen levels for the critical period and wet season. The *TMDL Study* (Joy, 1994) recommended that ammonia-nitrogen levels not exceed 0.030 mg/L in the tributaries during the critical period. Aside from the WWTPs, Ames and Tuck Creeks had the highest levels of ammonia-nitrogen with higher levels during the wet season (November – April). Ames Creek ammonia-nitrogen levels were > 0.030 mg/L in the critical period. During the intensive survey (August 30-31, 2005), the highest ammonia-nitrogen levels were seen on Ames, Tuck, and Cherry Creeks.

Limited nitrite-nitrate nitrogen sampling was done. Nitrite-nitrate nitrogen levels were low in most of the tributaries and the Snoqualmie mainstem. Harris Creek had the highest mean nitrite-nitrate nitrogen levels (0.732 mg/L; n=3) followed by Ames Creek (0.607 mg/L) and Tokul Creek (0.560 mg/L).

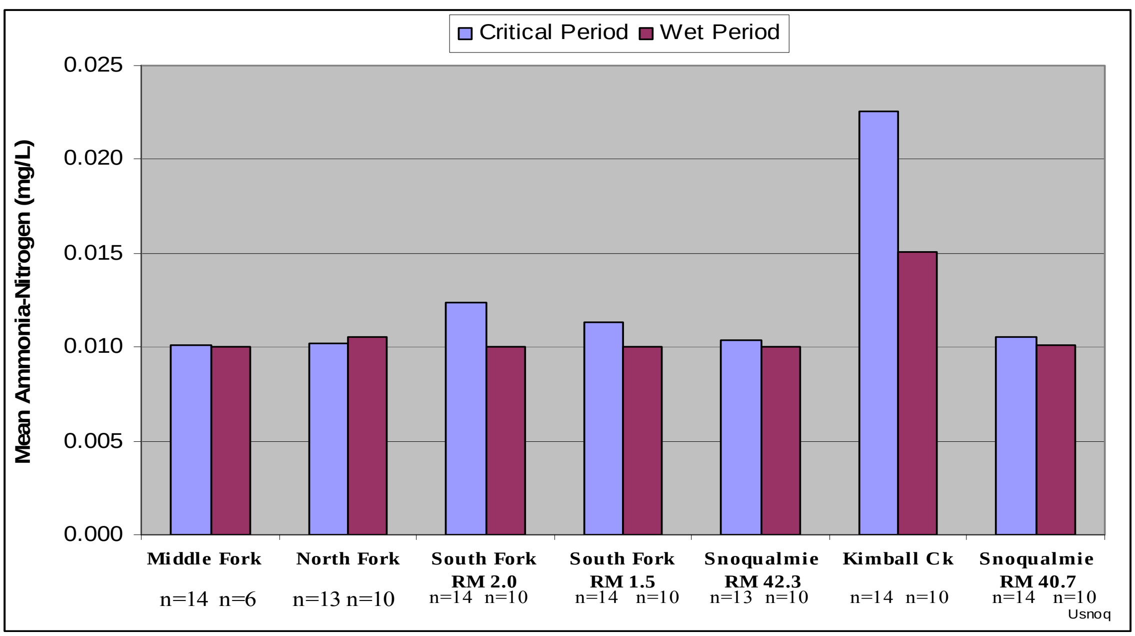

Figure 11. Upper Snoqualmie mean ammonia-nitrogen levels during the critical period and wet season.

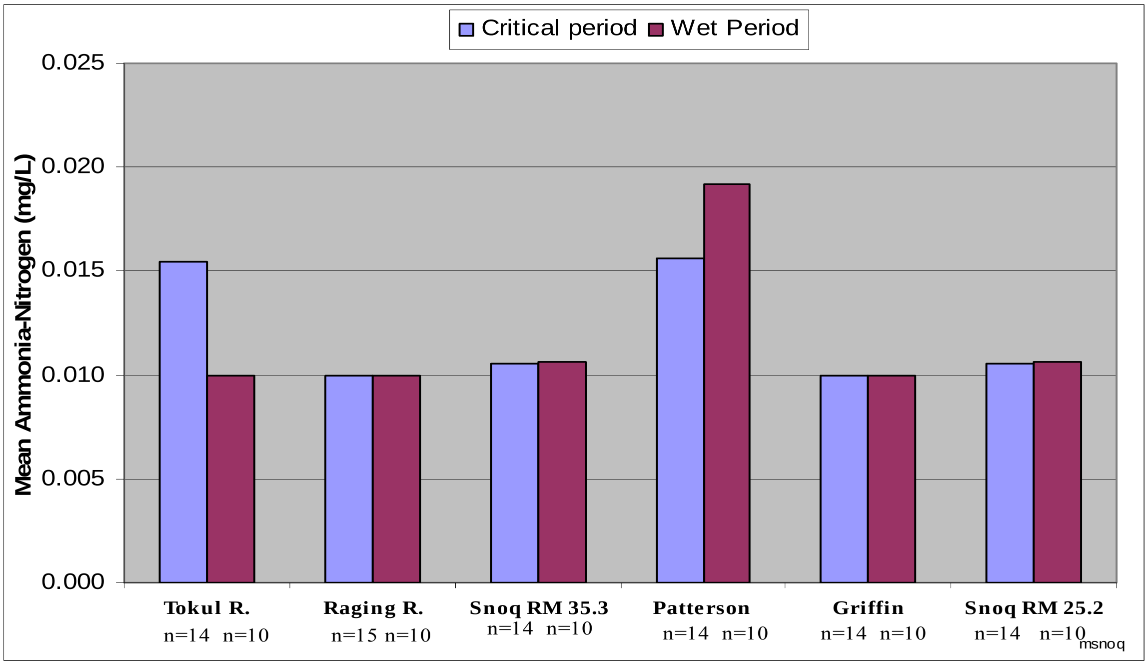

Figure 12. Lower Snoqualmie mean ammonia-nitrogen (RM 40-25) levels during the critical period and wet season.

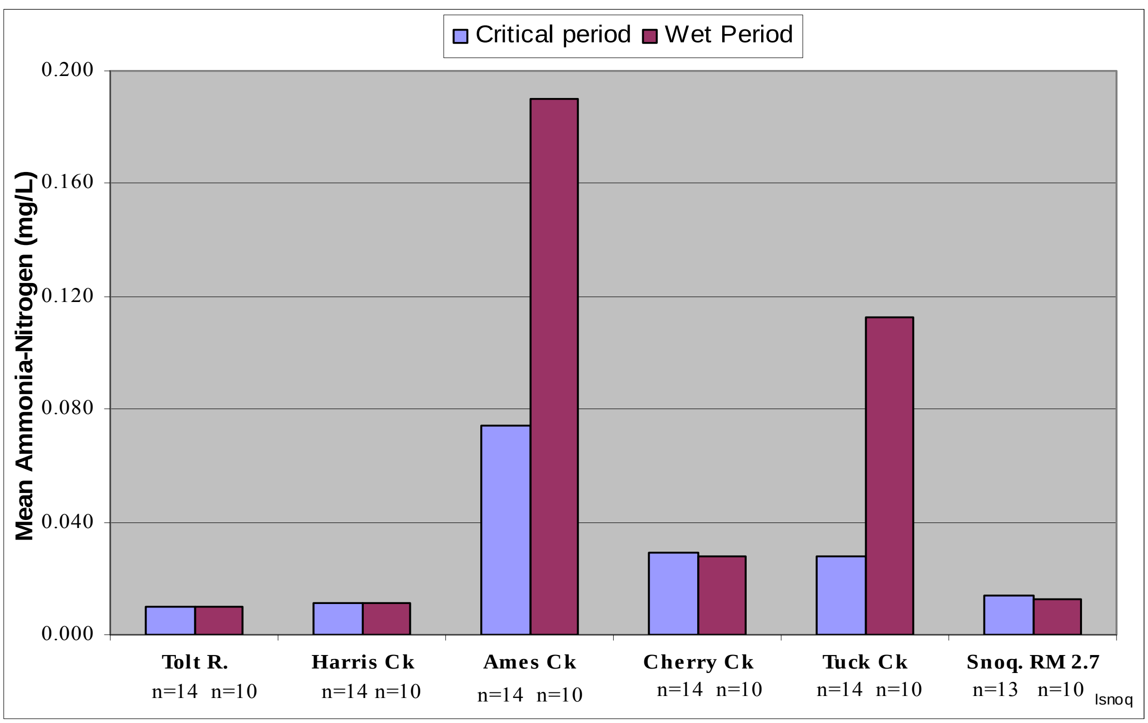

Figure 13. Lower Snoqualmie mean ammonia-nitrogen (RM 25-2.7) levels during the critical period and wet season.

Dissolved Oxygen

The mainstem Snoqualmie sites met the dissolved oxygen water quality standard and TMDL recommended target limits for all sampling conducted. While mainstem dissolved oxygen levels met TMDL targets, monitoring did not occur during the 7Q20 critical period. To adequately determine if TMDL targets were met, additional continuous diurnal dissolved oxygen and temperature monitoring should occur during the 7Q20 period or the environmental model should be re-run to determine if targets were met.

During the synoptic and intensive sampling surveys, the following tributaries did not meet the dissolved oxygen standard during three or more sample events:

- Kimball Creek
- Patterson Creek
- Ames Creek
- Cherry Creek

Follow-up studies should include dissolved oxygen as a sampling parameter.

pH

pH criteria violations occur at various times of the year. Higher pH may occur when instream primary productivity results in large diurnal pH swings. Higher pH values also increase the toxicity of ammonia-nitrogen to aquatic organisms. The mainstem Snoqualmie sites met water quality standards for pH. Several high pH exceedances were seen in the Raging River during the critical period. A study to determine the cause of high pH values in the Raging River should be conducted during the critical period.

Low pH levels generally occurred during the wet season. Streams that drain coniferous forests such as Puget Sound lowland areas are usually acidic. Organic soils in wetlands often tend to be acidic, particularly in peatlands in which there is little groundwater inflow. In addition most rainwater has a pH of 5.6 to 5.8 due to the presence of carbonic acid (H_2CO_3). Normally these acids are neutralized as rainwater passes through the soil. However, in watersheds with heavy rainfall, little buffering capacity and acidic soils surface water may be largely reflective of the rainwater pH values.

For some sites, pH values fell slightly below the standard once or twice. For these areas, if water quality studies are being conducted, pH should be included as a sampling parameter to determine if pH might be a concern. These areas are:

- South Fork Snoqualmie at RM 2.0
- Ames Creek
- Tuck Creek

Temperature

Elevated stream temperatures greater than the water quality standard were found at many sites. The sites where three or more violations were detected merit follow-up study:

- Middle Fork Snoqualmie River
- Kimball Creek
- Raging River
- Mainstem Snoqualmie RM 35.3, 25.2, and 2.7

A TMDL temperature study is currently being conducted on the Snoqualmie River and its tributaries. The Quality Assurance Project Plan for the Snoqualmie River Temperature TMDL describes the monitoring study (Kardouni and Cristea, 2006).

Has Water Quality Improved?

Snoqualmie River Water Quality Trend Analysis

Ecology conducts monthly water-quality monitoring at two stations on the Snoqualmie River at RM 42.3 near Snoqualmie (ID 07D130), and RM 2.7 near Monroe (ID 07D050). Measured indicators of water quality include temperature, pH, conductivity, dissolved oxygen, turbidity, total suspended solids, fecal coliform bacteria, orthophosphate, total phosphorus, ammonia, nitrite-nitrate, and total nitrogen. A Seasonal Kendall trend test with a correction for correlation was used to determine trends for all parameters. A two-tailed test with a significance level of α= 0.05 was used.

At Snoqualmie RM 42.3, the period examined was water year (WY) 1989-2005; at Snoqualmie RM 2.7, the period examined was WY 1991-2005. Trends were examined for all parameters. Both sites showed a significant trend in ammonia-nitrogen with a slope of 0.0. This is likely due to the large number of non-detection limit values and is not considered a valid trend.

At Snoqualmie RM 42.3, there were no statistically significant trends for any of the parameters tested. At Snoqualmie RM 2.7, lower fecal coliform and total persulfate nitrogen levels were seen. Figures 14 and 15 present graphic results of the Seasonal Kendall analysis for fecal coliform and total nitrogen.

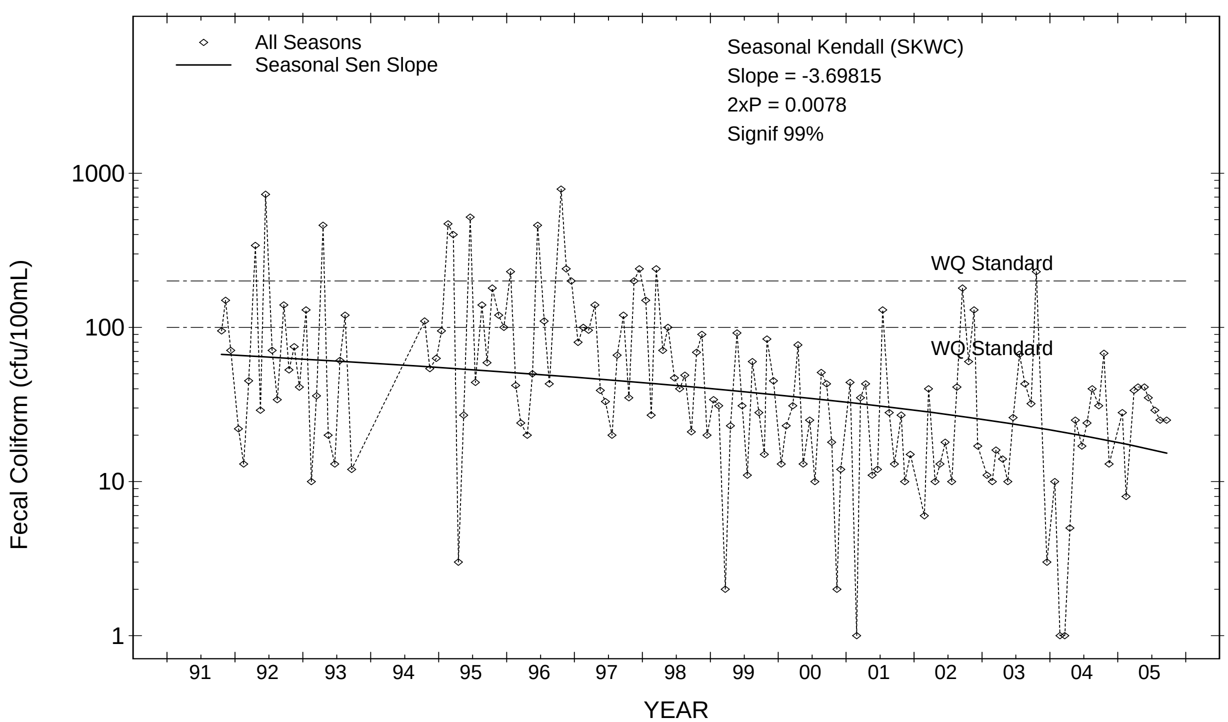

Figure 14. Snoqualmie RM 2.7 trend analysis results for fecal coliform bacteria, Water years 1991 – 2005. Results show decreasing fecal coliform levels at this site.

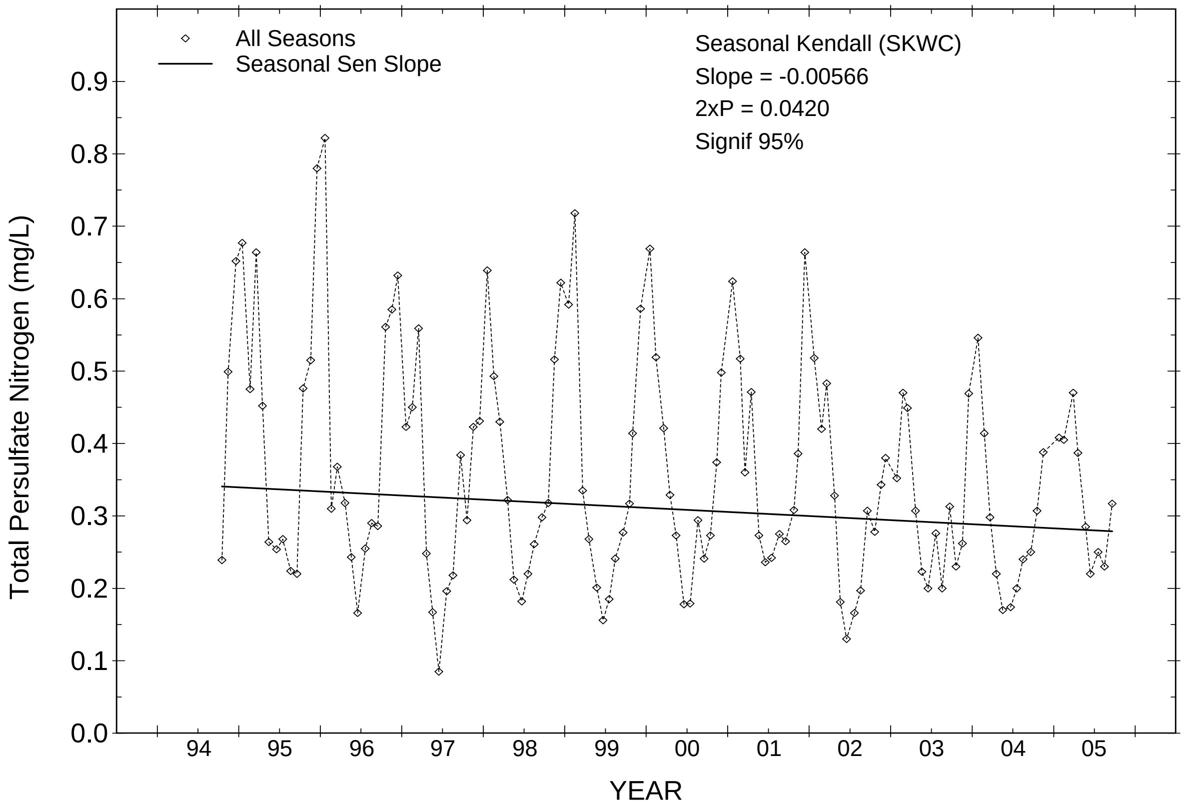

Figure 15. Snoqualmie RM 2.7 trend analysis results for total persulfate nitrogen, Water years 1991 – 2005. Results show decreasing fecal coliform levels at this site.

Comparison of TMDL Water Quality and Water Quality Now

Much more sampling was done for the 2003-05 *Effectiveness Monitoring Study* than for the original *TMDL Study* (Joy, 1994). For the TMDL, site parameters were sampled 4-6 times. For the *Effectiveness Monitoring Study,* site parameters were sampled 6-26 times. A comparison of the TMDL results and the *Effectiveness Monitoring Study* results are presented in Appendix I. The comparison includes a summary of the number of samples obtained, as well as the minimum, maximum, and mean values found for each site.

Many more fecal coliform samples were obtained during the *Effectiveness Monitoring Study* (n=26) than the *TMDL Study* (n=4-6). It is difficult to characterize bacterial water quality with 4-6 sample events. The TMDL data may not have accurately characterized water quality due to the low number of samples. Generally an improvement in fecal coliform levels is seen in the Snoqualmie River and tributaries from Snoqualmie RM 25.2 downstream. Kimball, Griffin, and Ames Creeks had great improvements in fecal coliform levels. Slightly higher geometric and arithmetic mean fecal coliform levels were noted on the mainstem Snoqualmie sites above RM 35.0. This is likely due to the high rainfall events that were sampled during the *Effectiveness Monitoring Study*. Rainfall events were not well captured during the *TMDL Study.*

During the *Effectiveness Monitoring Study,* orthophosphate sampling was conducted more frequently on the mainstem Snoqualmie River where orthophosphate levels did not vary greatly from TMDL data. Ammonia-nitrogen levels improved at all sites except Kimball and Tuck Creeks where a slight increase in the mean ammonia-nitrogen levels was seen.

The continuous monitoring data showed that the Snoqualmie River met TMDL targets for dissolved oxygen, but continuous monitoring was not conducted during the critical 7Q20 low-flow period. It is not reasonable to compare instantaneous readings for field parameters such as dissolved oxygen, pH, and temperature because the time of day sampled can greatly vary the results.

Water Quality in the Upper Snoqualmie River

This section includes results for the upper Snoqualmie basin including the three forks of the Snoqualmie River and downstream to Snoqualmie Falls at river mile (RM) 40.2. The Middle and North Fork Snoqualmie Rivers are designated Extraordinary Primary Contact Recreation (formerly Class AA). The remainder of the study area is classified as Primary Contact Recreation (formerly Class A). Sample sites in the upper basin are presented in Figure 16.

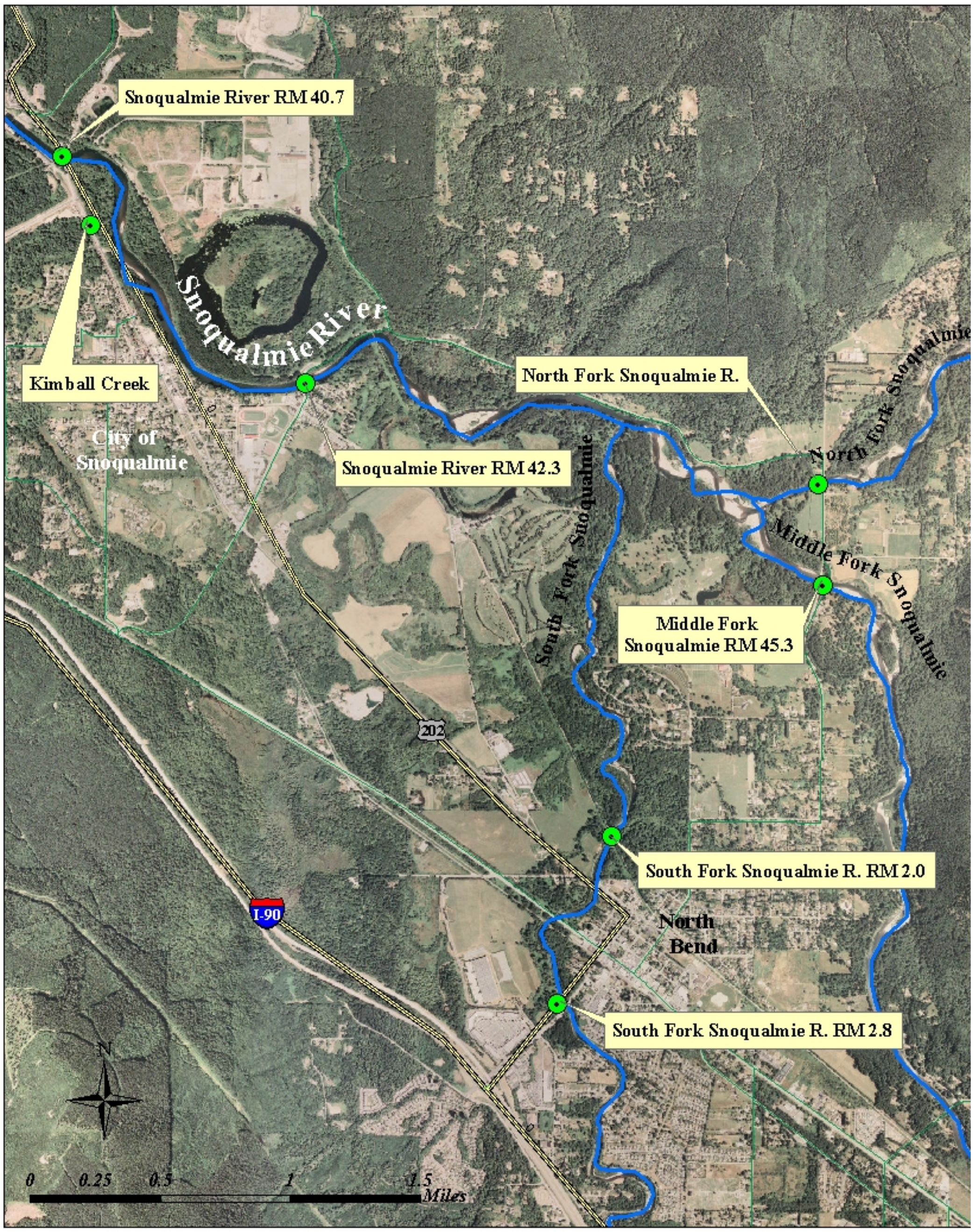

Figure 16. Upper Snoqualmie River and tributary sample sites.

Middle Fork Snoqualmie River: Snoqualmie RM 45.3

TMDL Implementation and Basin Changes in the Middle Fork Snoqualmie

There has been and continues to be relatively little development in the upper watershed. No TMDL implementation activities were documented above Snoqualmie RM 45.3.

Water Quality Results for the Middle Fork Snoqualmie

Fecal Coliform Bacteria

The Middle Fork Snoqualmie River site met water quality standards for fecal coliform bacteria during all the critical period, wet season, and all months, with the exception of August (2003-05). Fecal coliform results for the August 23 -24, 2004 sampling events indicate that many sites violate the second part of the fecal coliform bacteria standard for August (10% of all samples obtained for calculating the geometric mean shall not exceed 100 cfu/100 mL for this site). One value of 130 cfu/100 mL in August (n=9) caused the water quality standard violation. Monthly fecal coliform statistical summaries for the Middle Fork Snoqualmie River are presented in Figure 17.

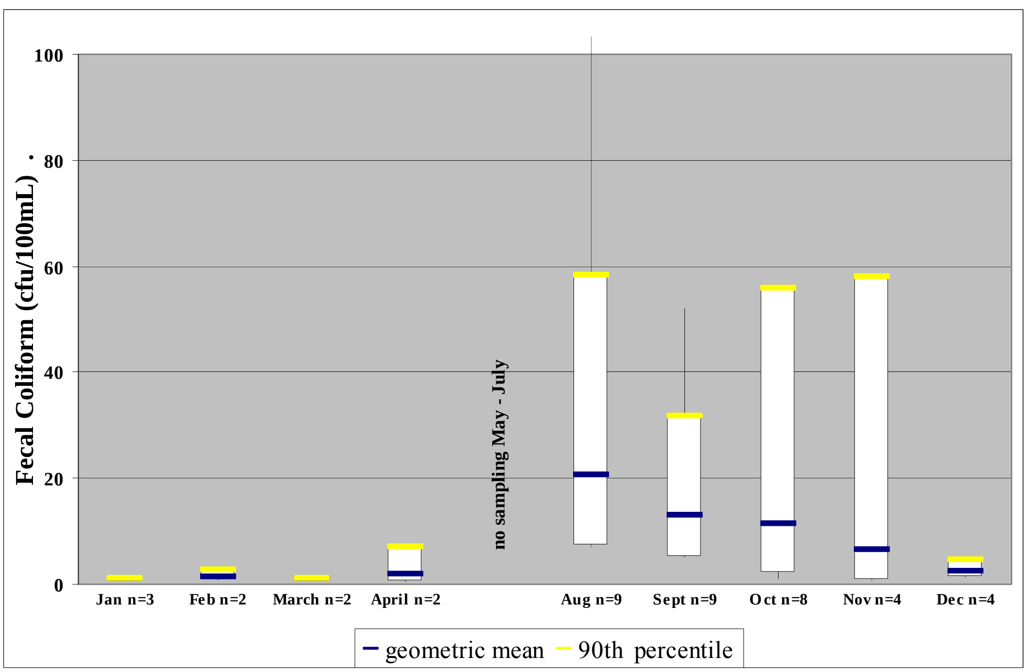

Figure 17. Middle Fork Snoqualmie River monthly fecal coliform statistics for August 2003 – February 2005.

Estimated fecal coliform loading for the Middle Fork Snoqualmie River RM 45.3 is presented in Figure 18. Loading was estimated using flow discharge measurements from the USGS gauging station 12141300 at the Middle Fork Snoqualmie River, RM 55.6. Loading estimates are likely underestimated. The monitoring station is located at RM 45.3; several tributaries discharge to the Middle Fork between RM 55.6 and RM 45.3.

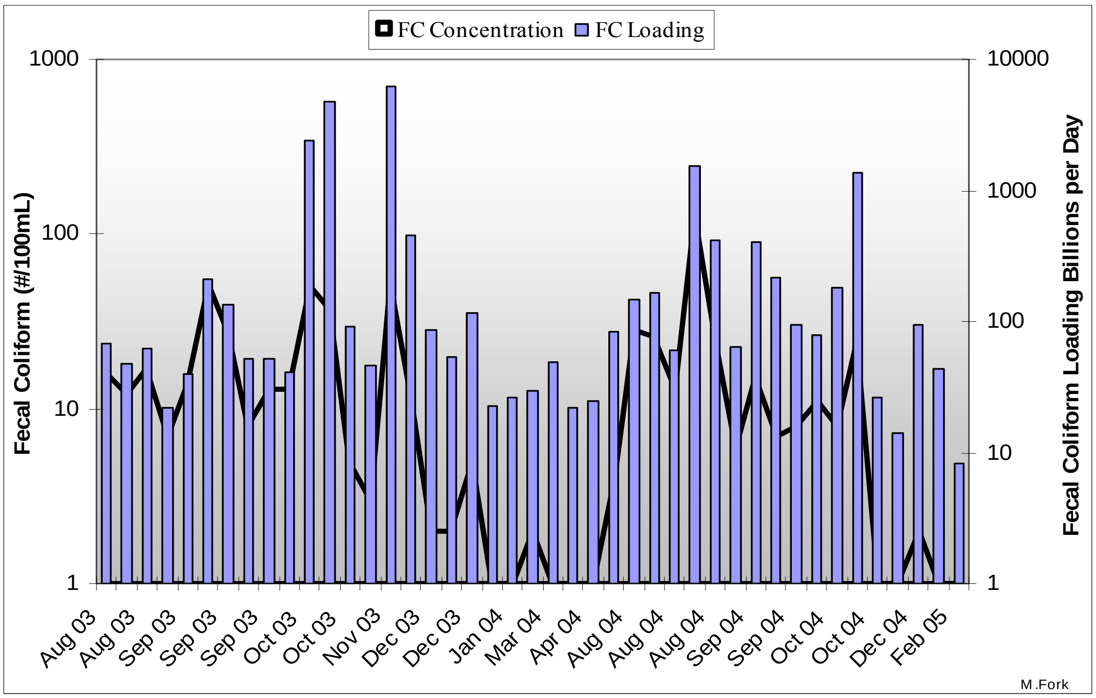

Figure 18. Middle Fork Snoqualmie instantaneous fecal coliform concentrations and estimated fecal coliform loading for August 2003 – February 2005.

Nutrients

Nitrogen and phosphorus levels were low in the Middle Fork Snoqualmie River. Orthophosphate levels were well below the TMDL mainstem recommendation of 10 µg/L with an average of 4 µg/L (n=13) during the August-October critical period.

Field Parameters

No continuous monitoring was conducted on the Middle Fork Snoqualmie River. During the synoptic survey, pH values met water quality standards. Temperature exceedances were noted during August. There was one excursion of the dissolved oxygen standard at 9.3 mg/L.

Intensive Monitoring Survey (August 30-31, 2005)

Compared to other sites, the Middle Fork Snoqualmie River had lower levels of nutrients and fecal coliform bacteria. Water quality standards were met for dissolved oxygen, but temperature exceeded the standard and pH levels were slightly below the standard at 6.4 SU. Intensive survey monitoring results are fully described in Appendix J.

Conclusions and Recommendations for Middle Fork Snoqualmie

With the exception of temperature problems, the Middle Fork Snoqualmie has excellent water quality. Bacteria concentrations were low and within the range measured in the original 1989-91 *TMDL Study* (Joy, 1994). To address temperature concerns, Ecology is conducting a temperature TMDL for the Snoqualmie watershed to examine this problem in more detail. Field work began in 2006, and a technical report is due in September 2008. The following general practices are recommended to maintain or improve water quality in the upper Middle Fork:

- Improve shading through riparian restoration where needed. Improving temperature levels could increase, or help maintain, dissolved oxygen levels in downstream areas.
- Conduct additional study of upstream conditions leading to high temperatures. Because Ecology is currently preparing a temperature TMDL for the Snoqualmie River, any proposed studies should coordinate with that effort.

North Fork Snoqualmie River: Snoqualmie RM 44.9

TMDL Implementation and Basin Changes for the North Fork Snoqualmie River

No TMDL implementation activities have been documented for the upper watershed. There has been and continues to be relatively little development in this area.

Water Quality Results for the North Fork Snoqualmie River

Fecal Coliform Bacteria

The North Fork Snoqualmie River site met water quality standards for fecal coliform bacteria during the critical period, wet season, and all months, with the exception of August (2003-05). Fecal coliform results for the August 23 -24, 2004 sampling events indicate that many sites violate the second part of the fecal coliform bacteria standard for August (10% of all samples obtained for calculating the geometric mean shall not exceed 100 cfu/100 mL for this site). One sample event (130 cfu/100 mL) in August (n=9) caused the water quality standard violation. Monthly fecal coliform statistical summaries for the North Fork Snoqualmie River are presented in Figure 19.

Fecal coliform concentrations and loading estimates for this site are presented in Figure 20. Loading was estimated using flow discharge from the USGS gauging station 12142000 at the North Fork Snoqualmie River, RM 9.2, just upstream of Calligan Creek. The sampling site for the North Fork was at approximately RM 0.5. Only three flow discharge measurements were obtained at this sampling site so a flow curve could not be developed due to limited data. The three low-flow season measurements obtained at the sampling site ranged from 30-60% higher than flows at the USGS site. Loading presented in Figure 20 underestimated the actual fecal coliform loading.

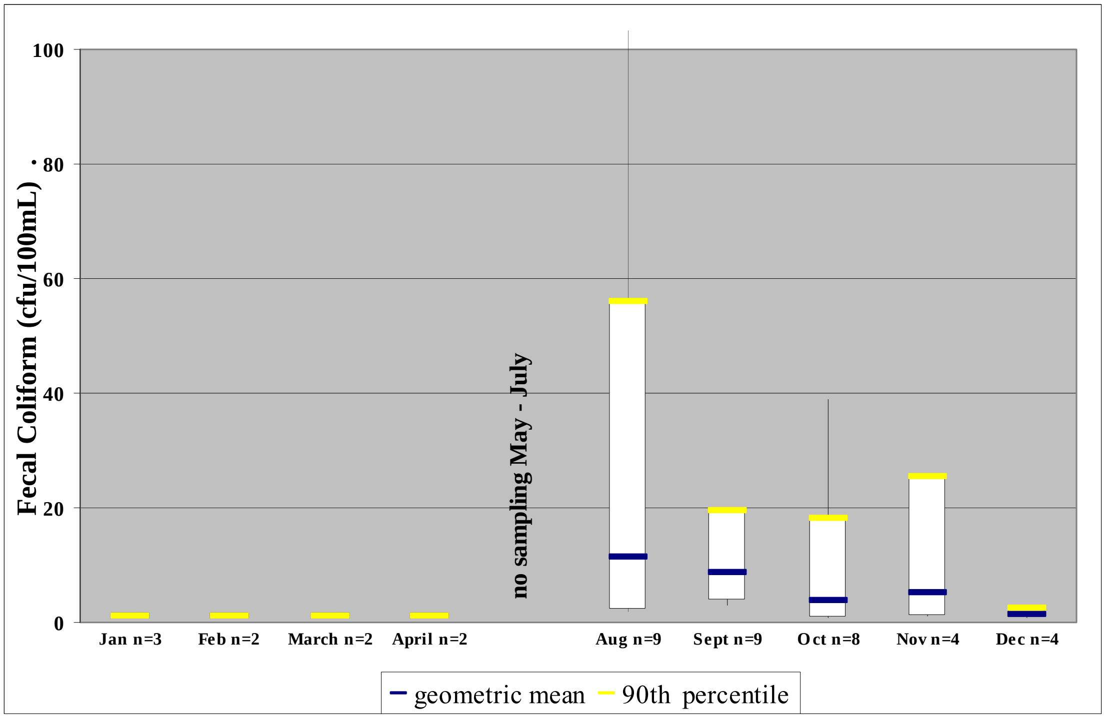

Figure 19. North Fork Snoqualmie River fecal coliform statistics for August 2003 – February 2005.

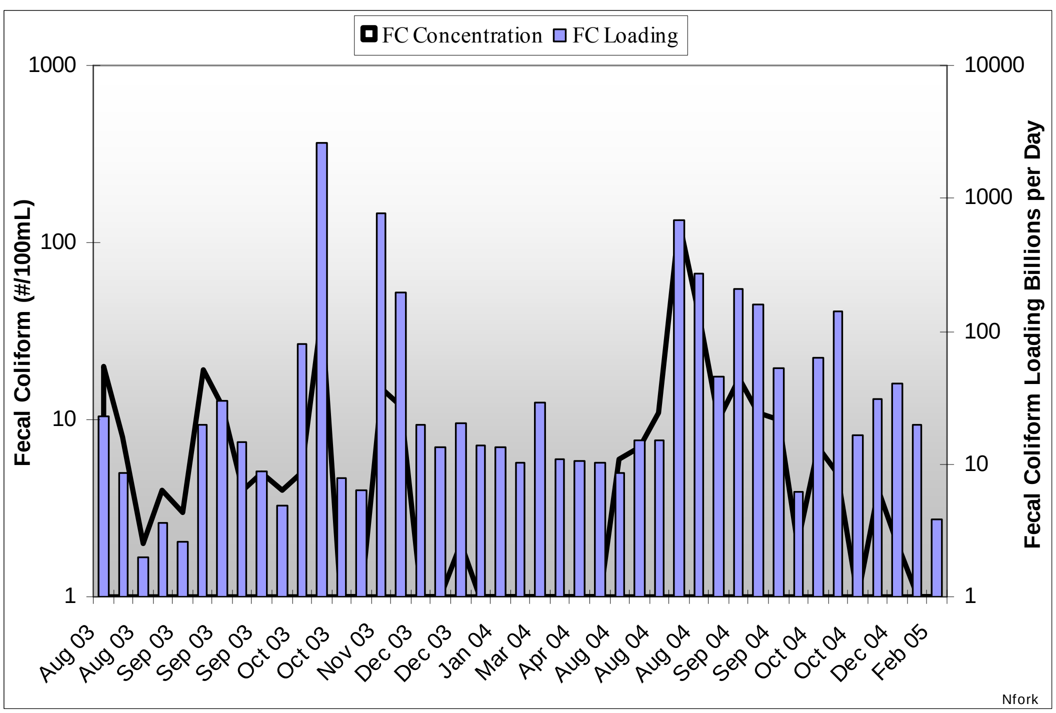

Figure 20. North Fork Snoqualmie River instantaneous fecal coliform concentrations and estimated daily loading (loading is underestimated) for August 2003 – February 2005.

Nutrients

Nitrogen and phosphorus levels were generally low in the North Fork Snoqualmie River. Orthophosphate levels were well below recommended mainstem TMDL targets during all but one sample event. The mean orthophosphate level was 5 µg/L (n=14) during the critical period. No phosphate data was collected on the North Fork in the original *TMDL Study* so a comparison could not be made.

Field Parameters

No continuous monitoring was conducted on the North Fork. During the synoptic survey, pH values met water quality standards. There was one excursion of the dissolved oxygen and temperature standard with readings of 9.2 mg/L for dissolved oxygen and 17.2 °C for temperature in August.

Intensive Monitoring Survey (August 30-31, 2005)

Compared to other sites, the North Fork Snoqualmie River had lower levels of nutrients and fecal coliform bacteria. Water quality standards were met for dissolved oxygen, temperature, and pH. Intensive survey monitoring results are fully described in Appendix J.

Conclusions and Recommendations for the North Fork Snoqualmie

With the exception of temperature problems, the North Fork Snoqualmie has excellent water quality. Bacteria levels have remained relatively unchanged since the original *TMDL Study*. Ecology began a temperature TMDL for the Snoqualmie watershed in 2006 to examine this problem in more detail. The following general practices are recommended to maintain or improve water quality in the upper North Fork:

- Improve shading through riparian restoration where needed. Improving temperature levels could increase, or help to maintain, dissolved oxygen levels in downstream areas, especially the pool above Snoqualmie Falls.
- Conduct additional study of upstream conditions leading to high temperatures. Because Ecology is currently preparing a temperature TMDL for the Snoqualmie River, any proposed studies should coordinate with that effort.

South Fork Snoqualmie River, RM 44.4, North Bend Wastewater Treatment Plant

TMDL Implementation and Changes at the North Bend WWTP

The North Bend WWTP discharge is located between South Fork sampling points at RM 2.0 and RM 2.8. In the *TMDL Study* (Joy, 1994), WWTP controls for oxygen-depleting compounds (ammonia and biological oxygen demand) were required for the North Bend WWTP (five municipal WWTPs scenario including WWTP and nonpoint source controls shown below).

Because excessive periphyton growth was observed at RM 2.0 during the original *TMDL Study*, recommendations were made to reduce orthophosphates.

The required and recommended controls included:

- Biochemical oxygen demand (5-day) ≤ 15 mg/L (required)
- Ammonia-Nitrogen ≤ 9 mg/L (required)
- Orthophosphate ≤ 0.22 mg/L = 220 µg/L (recommended)
- Fecal coliform geometric mean ≤ 400 cfu/100 mL (This is the daily concentration recommended by the TMDL. Technology-based minimum permit requirements set an average monthly geometric mean of 200 cfu/100 mL, and a maximum weekly geometric mean of 400 cfu/100 mL)

Ecology revised the North Bend WWTP permit to reflect TMDL requirements. To improve performance, meet all permit conditions, and increase capacity, the North Bend WWTP and its collection system has undergone a number of changes since the original *TMDL Study*.
Since 1998, the City has implemented the following sewer system improvements:

Date	Improvements
1998	WWTP Phase I – Secondary Clarifier
1998	I/I Phase I Improvements
2000	WWTP Phase IIA – Ultraviolet Disinfection, Effluent Pump Station
2003	WWTP Phase IIB – Effluent Reuse (3W system)
2003	I/I Improvement Phase II
2005	WWTP Phase IIC – Sludge Dryers, Rotors in Oxidation Ditch

Performance at the plant has improved significantly since the original TMDL was prepared. North Bend has increased its capacity, corrected considerable inputs of inflow and infiltration, and installed ultraviolet disinfection to replace the previous system of chlorination.

North Bend Wastewater Treatment Plant: Ecology Sampling and Discharge Monitoring Report (DMR) Analysis

Ecology conducted minimal sampling of the North Bend WWTP discharge during the 2003-05 *Effectiveness Monitoring Study*. Sampling was not conducted the same day as the South Fork Snoqualmie River sites so the data could not be compared. As shown in discharge monitoring report data (Figure 21), BOD_5/$CBOD_5$ discharges from the plant at this time appear to be well below the anticipated 5-plant TMDL allocations expected in the future. Ammonia levels are generally low, especially during the August-October critical period.

Fecal coliform levels in samples taken by Ecology at the WWTP discharge were generally good with values below 15 cfu/100 mL (n=12). The one exception was November 19, 2003 when the fecal coliform concentration was 25,000 cfu/100 mL. The greatest ammonia-nitrogen, orthophosphate, and inhibited biochemical oxygen demand levels were seen the same day. Although there was good compliance with permit limits, the maximum weekly average fecal coliform values tended to increase during the summer months.

Minimal nutrient sampling was conducted at the WWTP discharge. Occasionally, high nitrogen values were seen. On November 19, 2003, ammonia-nitrogen was 4.15 mg/L, high but less than the TMDL recommended target limit. Most ammonia-nitrogen values were low with the next highest value at 0.026 mg/L (n=9). On December 17, 2003, nitrate-nitrite nitrogen levels were high at 10.2 mg/L. Orthophosphate samples taken by Ecology during the *Effectiveness Monitoring Study* exceeded the TMDL recommended limit of 220 µg/L with a mean of 2,330 (n=4) µg/L during the critical period, and 1,817 (n=6) µg/L during the November- April wet season. Orthophosphate levels collected monthly by the City of North Bend during 2001 through 2003 were higher on average during the critical period (1,240 µg/L) than during the wet season (980 µg/L). These values are also higher then the recommended TMDL target of 220 µg/L.

Ecology occasionally measured temperature, pH, and conductivity at the WWTP discharge point. During the synoptic survey, pH standards were met. Values for pH measured during the August 2005 intensive survey were very low ranging from 2.8 to 4.3 SU. No reports of low pH were made by the facility that month (required by their permit), and it is unclear how pH values could be so low given the use of ultraviolet light (non-chemical) disinfection at the facility.

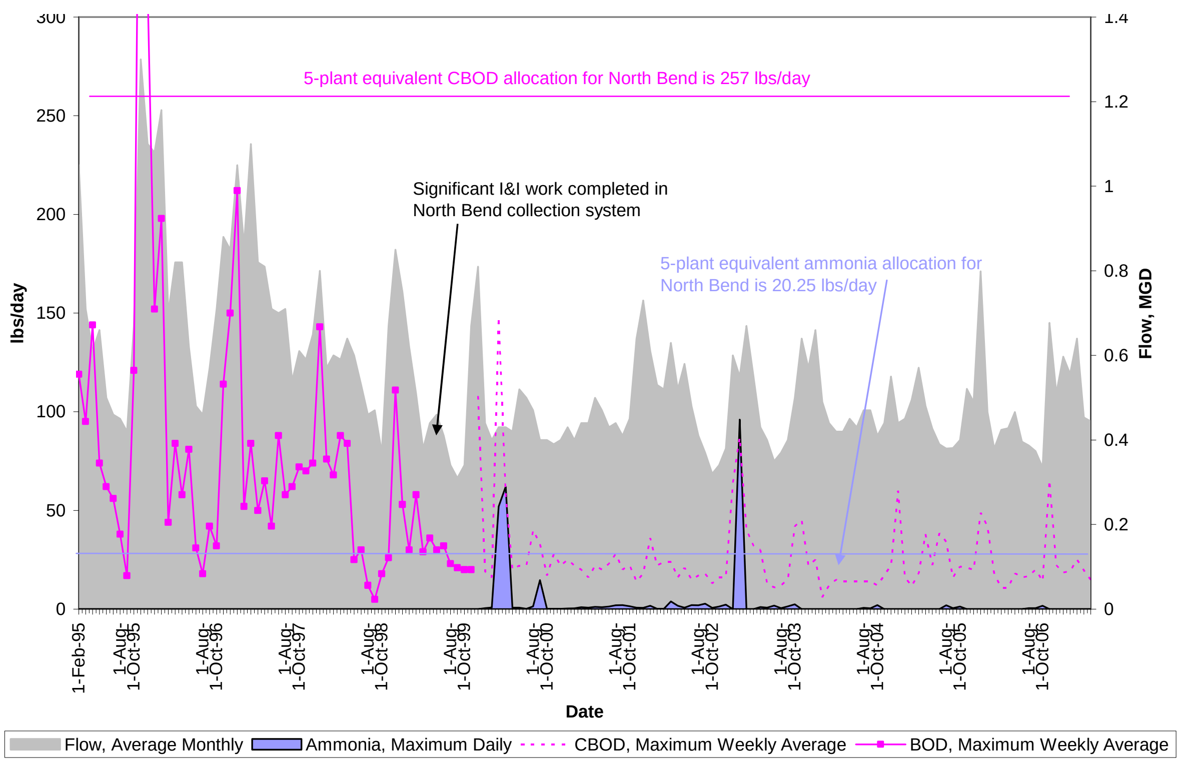

Figure 21. North Bend WWTP performance with TMDL-required permit limitations, 1995-2006. (I&I – inflow and infiltration to the sewage conveyance system)

Conclusions and Recommendations for the North Bend WWTP

This study recommends that the disinfection system of the North Bend WWTP be monitored closely during the August-October critical period. Although there has been good compliance with NPDES limits, weekly average fecal coliform values from 2000 to the present show generally higher values during summer months. Downstream areas are heavily used for recreation during the summer months.

Additional study of dissolved oxygen levels is needed in the lower South Fork Snoqualmie to determine if nutrient limits are needed. Diurnal dissolved oxygen monitoring should occur during the low-flow critical period at select sites in the lower South Fork Snoqualmie. The goal of the study should be to determine if nutrient levels contribute to excessive periphyton growth and low dissolved oxygen levels in the lower stretch of the South Fork Snoqualmie River. Nutrient discharge for the North Bend WWTP should be considered during this study. If results show that phosphorus levels are an issue, the City of North Bend should evaluate treatment strategies or land application strategies as part of any engineering analyses related to improving plant performance or increasing plant capacity.

South Fork Snoqualmie River: Snoqualmie RM 44.4

TMDL Implementation and Basin Changes for the South Fork Snoqualmie

There has been considerable growth in the city of North Bend since the original *TMDL Study* was conducted (Joy, 1994). A review of water connection data from the city's Comprehensive Water System Plan for 2002 indicates that the number of connections in 1993 was about 1,100. That number grew to 1,560 in 1998, and the low growth prediction for 2005 was over 3,700 connections. With this increase in growth, it is expected that impervious surface levels, stormwater discharges, discharges from the North Bend WWTP, and perhaps illicit connections have increased.

Although no specific TMDL activities were documented to address possible nonpoint pollution problems prior to 2004, work has been performed in recent years to remove invasive species along Ribary Creek in the Meadowbrook Farm. Future work to ensure livestock are excluded from Ribary Creek is planned by the Mountains to Sound Greenway Trust; this may reduce bacteria inputs between RM 2.0 and RM 2.8.

Changes to the North Bend WWTP have affected the amount of pollutants discharged between RM 2.0 and RM 2.8. These improvements should be expected to improve the water quality at RM 2.0 over previous monitoring conditions.

Fecal Coliform Bacteria

The South Fork Snoqualmie River was sampled at two sites, RM 2.8 and 2.0 (just below the WWTP discharge). Figure 22 presents fecal coliform results for both South Fork sites. The upstream site met fecal coliform standards during the August-October critical period while the downstream site did not. Both sites met standards during the wet season.

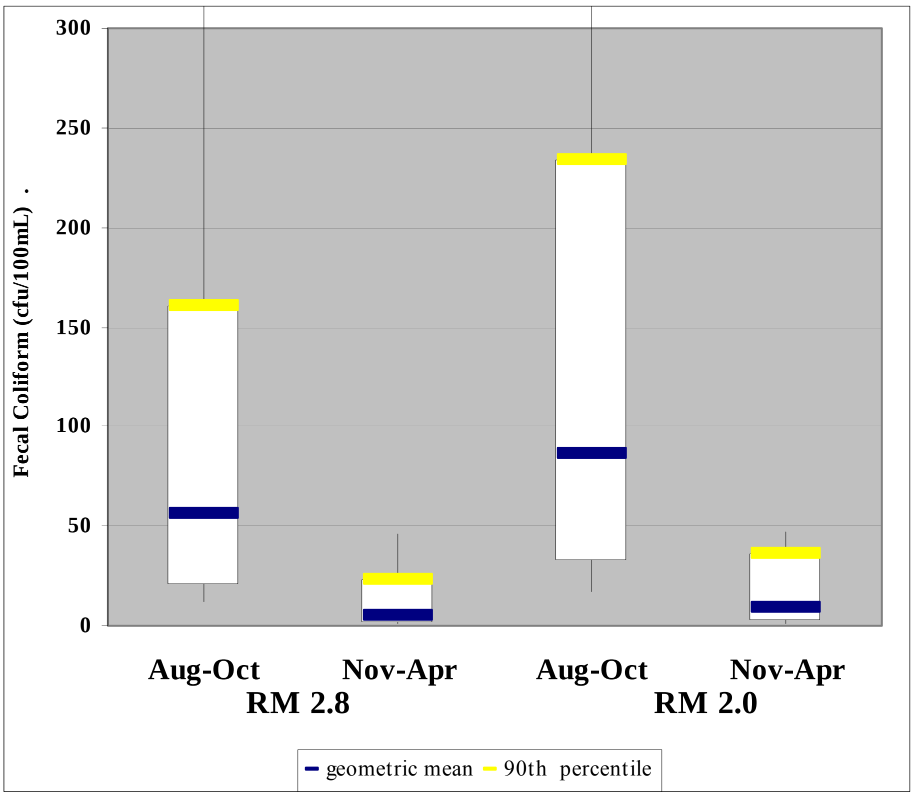

Figure 22. South Fork Snoqualmie River fecal coliform bacteria statistics for the critical and wet periods during August 2003 – February 2005.

Fecal coliform bacteria reductions are still needed for the South Fork Snoqualmie River at RM 2.0. Based on the roll-back method for the critical period, a 14% reduction in fecal coliform levels is needed at the South Fork Snoqualmie River, RM 2.0.

Figure 23 presents monthly fecal coliform statistics for the South Fork Snoqualmie River. South Fork sampling locations at RM 2.8 and 2.0 met the fecal coliform standards for all months, except August. The South Fork site at RM 2.0 did not meet the standards during the critical period due to high fecal coliform levels in August. In August 2004, many sites had fecal coliform values > 200 cfu/100 mL, likely due to a large rain event.

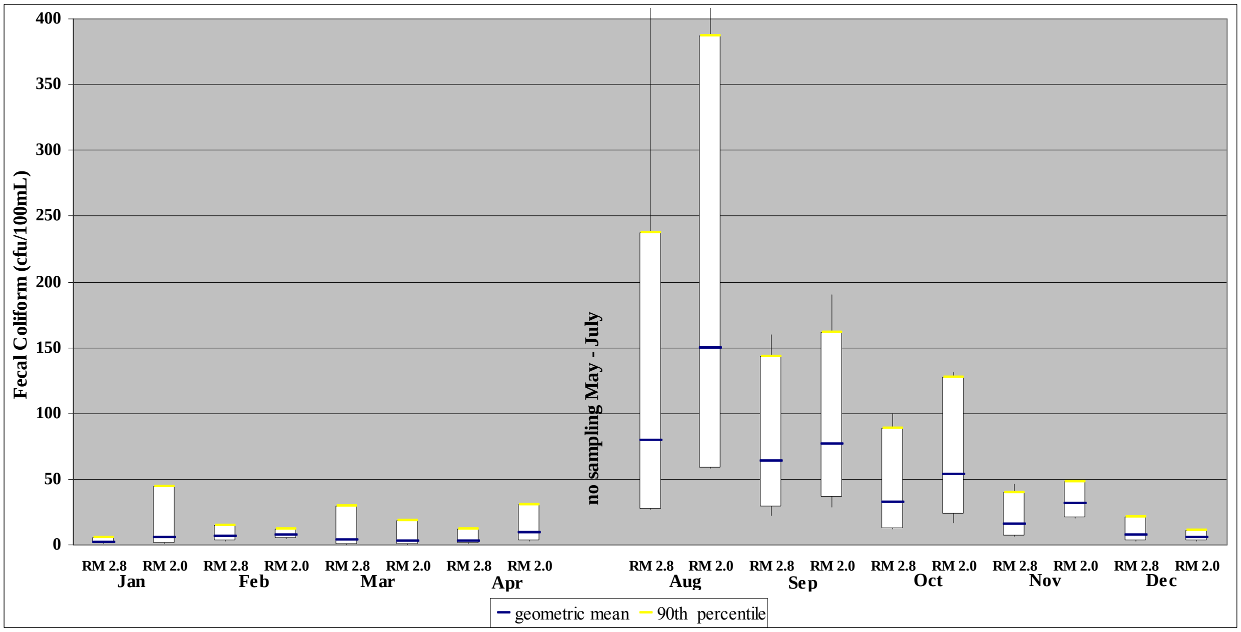

Figure 23. South Fork Snoqualmie RM 2.8 and 2.0 monthly fecal coliform statistics for August 2003 – February 2005.

Fecal coliform concentration and estimated fecal coliform loading for the South Fork Snoqualmie River at RM 2.0 are presented in Figure 24. Loading was estimated using flow discharge measurements from the USGS gauging station 12144000 at the South Fork Snoqualmie River, RM 2.8. No major flow inputs were observed between RM 2.8 and 2.0, hence flow estimates apply to RM 2.0 as well.

A non-parametric Wilcoxon paired sample test was used to compare water quality between upstream and downstream sites. Significantly higher fecal coliform concentrations were seen at RM 2.0 compared to the upstream site at RM 2.8. No significant flow inputs occur between these two sites.

Nutrients

Both sites were sampled irregularly for nutrients. The upstream site at RM 2.8 was sampled 14 times during the critical period for orthophosphate, and the values were all below 10 µg/L. The downstream site (RM 2.0) had higher orthophosphate levels with a mean of 30 µg/L (n=6). The downstream site did not meet the TMDL recommended target for orthophosphate of 20 µg/L. Orthophosphate levels appear to have increased slightly compared to the mean value of 11 µg/L (n=4) measured during the *TMDL Study*.

Nitrogen values were generally low. Ammonia-nitrogen was sampled frequently at both sites and was generally at or near the detection limit.

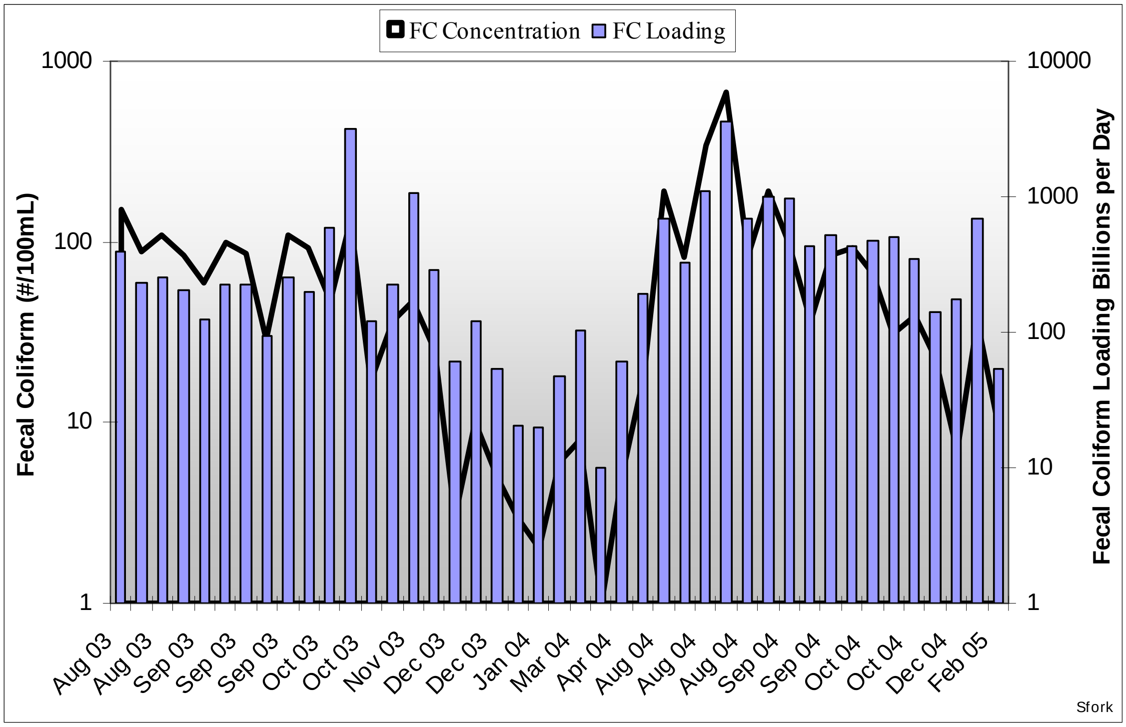

Figure 24. South Fork Snoqualmie RM 2.0 instantaneous fecal coliform concentrations and estimated daily loading.

Field Parameters

No continuous monitoring was conducted at either South Fork Snoqualmie River site. During the synoptic surveys, the South Fork site, RM 2.8, met standards for dissolved oxygen and temperature. There were two minor pH excursions of 6.3 SU in December, and a 6.4 SU in August. The South Fork site, RM 2.0, met standards for dissolved oxygen, temperature, and pH.

Intensive Monitoring Survey (August 30-31, 2005)

During the intensive survey, the South Fork Snoqualmie River site at RM 2.0 had low levels of orthophosphate, while the RM 2.0 site had the highest orthophosphate levels of all the surface water sites sampled. The North Bend WWTP discharge had the highest orthophosphate levels during the intensive survey with a mean orthophosphate value of 3.3 mg/L. While the upstream site had lower nitrogen levels, the downstream site at RM 2.0 had some of the highest total nitrogen and nitrite-nitrate nitrogen levels in surface water. North Bend WWTP discharges had the highest levels of total nitrogen, nitrite-nitrate nitrogen, and total organic carbon. Downstream levels of fecal coliform bacteria were higher than upstream. Intensive survey monitoring results are fully described in Appendix J.

At both South Fork Snoqualmie sites, water quality standards were met for dissolved oxygen, temperature, and pH. During the intensive sampling, the North Bend WWTP discharge had very low pH levels, ranging from 2.8-4.3 SU.

Conclusions and Recommendations for the South Fork Snoqualmie

The South Fork Snoqualmie River was measured at two locations. Water quality at South Fork RM 2.8 is good, but deteriorates as it travels downstream to RM 2.0. The South Fork at RM 2.0 did not meet standards for fecal coliform bacteria during the month of August for both 2003 and 2004. Orthophosphate levels and nitrogen levels were also higher at RM 2.0 than RM 2.8. Increases in observed nutrients and fecal coliform bacteria levels between South Fork RM 2.8 and 2.0 were probably due to pollutant inputs in this river reach, including discharge from the North Bend WWTP.

Ecology recommends the following actions to improve bacteria and nutrient pollution levels in the South Fork Snoqualmie River at RM 2.0.

- Because the City of North Bend is not receiving a Phase II municipal stormwater permit, they are not required to perform stormwater pollution control activities like most other urbanized areas in the Seattle/Tacoma/Everett corridor. Because of the demonstrated pollution problem in the South Fork, the City should examine the location of municipal and private stormwater conveyance systems discharging between RM 2.0 and RM 2.8 and perform illicit discharge detection and elimination (IDDE). Other aspects of the six minimum controls should be evaluated and implemented as resources allow.

- The City of North Bend should consider establishing a regularly scheduled monitoring program in the South Fork Snoqualmie and in any small urban tributaries within its jurisdiction. The City has laboratory facilities and personnel skilled in water quality measurement. Due to the large size of the Snoqualmie watershed, the combined effort of local municipalities is needed to track long-term water quality trends in local waters.

- Streamside areas and drainage conveyances should be examined for livestock access or other nonpoint pollution sources between RM 2.0 and RM 2.8 and tributary streams to this area. Where necessary, farm plans should be required and best management practices such as exclusion fencing and off-channel watering should be installed where needed. Areas served by on-site sewage treatment systems should be identified and their potential for contributing bacterial pollution should be evaluated.

- Additional study of dissolved oxygen levels is needed in the lower South Fork Snoqualmie. Diurnal monitoring should occur during the low-flow critical period at select sites in the lower South Fork Snoqualmie. The goal of the study should be to determine if nutrient levels contribute to excessive periphyton growth and low dissolved oxygen levels in the lower stretch. Nutrient discharge from the North Bend WWTP should be considered during this study. If results show that phosphorus levels are an issue, the City of North Bend should evaluate treatment strategies, or land application strategies as part of any engineering analyses related to improving plant performance or increasing plant capacity.

Mainstem Snoqualmie RM 42.3 (Meadowbrook Way Bridge Crossing)

TMDL Implementation and Basin Changes, Mainstem Snoqualmie at RM 42.3

Relatively little change is thought to have occurred just upstream of the RM 42.3 site. The land is primarily zoned for rural use, and growth in the area has not been significant. The 1989-91 *TMDL Study* (Joy, 1994) included a nonpoint loading source above RM 42.3 that contributed both nutrients and bacteria. This source was likely a dairy farm with approximately 220 animals on 630 acres. This facility has ceased its operations in the lower North Fork watershed.

Water Quality Results for the Mainstem Snoqualmie River at RM 42.3

Fecal Coliform Bacteria

The Snoqualmie River site at RM 42.3 met water quality standards for fecal coliform bacteria during the critical period, wet season, and all months (2003-05), with the exception of August. Monthly fecal coliform statistics are presented in Figure 25. Fecal coliform results for the August 23-24, 2004 sampling events indicate that many sites violated the second part of the fecal coliform bacteria standard for August (10% of all samples obtained for calculating the geometric mean shall not exceed 200 cfu/100 mL). Adequate flow data were not obtained for this site, so fecal coliform loading was not calculated.

Nutrients

Minimal nutrient sampling was conducted at this site. Four orthophosphate samples were obtained during the August-October critical period; all were less than the mainstem TMDL target limit of 10 µg/L and were close to the values observed in the *TMDL Study*. Nitrogen levels were also low. Ammonia-nitrogen levels rarely exceeded detection limits.

Field Parameters

No continuous monitoring was conducted at the Snoqualmie River RM 42.3 site. During the synoptic surveys, this site met water quality standards for temperature, dissolved oxygen, and pH.

Intensive Monitoring Survey (August 30-31, 2005)

Compared to other sites, the mainstem Snoqualmie River at RM 42.3 had lower levels of nutrients and fecal coliform bacteria. Water quality standards were met for dissolved oxygen, temperature, and pH. Intensive survey monitoring results are fully described in Appendix J.

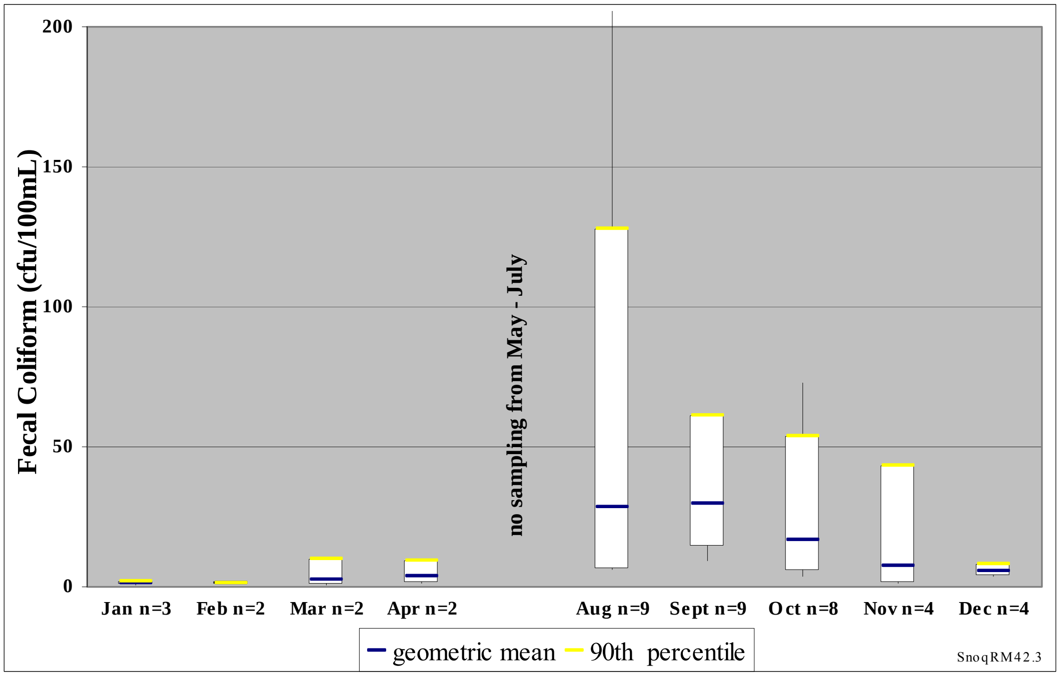

Figure 25. Mainstem Snoqualmie River RM 42.3 monthly fecal coliform statistics for August 2003 – February 2005.

Conclusions and Recommendations for Mainstem Snoqualmie RM 42.3

Water quality is good at this site. This report recommends that local authorities carefully manage stormwater as future growth or other changes in land use occur in the area.

Kimball Creek Watershed: Snoqualmie RM 41.1

TMDL Implementation and Basin Changes for the Kimball Creek Watershed

The Kimball Creek watershed is comprised of several tributaries: Coal Creek, Kimball Creek, and Creeks D and E. During this study, Ecology collected data at the mouth of the watershed; thus, our analysis can only describe the Kimball Creek watershed as a whole.

A large amount of residential growth occurred in the Kimball Creek watershed after the 1989-91 *TMDL Study*, especially in the Snoqualmie Ridge development. This may have led to increased stormwater pollution inputs. In 2006, the City of Snoqualmie expanded its stormwater utility to include its entire incorporated area. Previously, the utility included only Snoqualmie Ridge. Less growth has occurred in the lower part of the subbasin. The lower subbasin continues to be served by on-site sewage treatment systems only.

The City of Snoqualmie conducted several monitoring studies on Kimball Creek to determine pollutant sources. In 2001 Herrera Environmental Consultants did a water quality inventory and assessment of Kimball Creek (Herrera, 2001). Part of this project included habitat restoration of Kimball Creek from the mouth to the State Route 202 Bridge. Invasive plants were removed on both sides of the Creek, and the City replanted cleared areas with native trees and shrubs. Limited sampling was conducted, but several fecal coliform values above 1,000 cfu/100 mL were reported at five of six sites, with the highest values reported during dry months. Dissolved oxygen levels in the Kimball Creek watershed at the Meadowbrook Way, SE 384th St, and SE Northern Street crossings exhibited very low dissolved oxygen levels.

The City of Snoqualmie commissioned Herrera Environmental Consultants (2004) to conduct traditional water quality monitoring combined with an optical brightener and a small-scale microbial source tracking study on Kimball Creek. Although sampling size for the water quality monitoring study was limited to seven sample events (2 during dry weather, 5 during storm events) elevated fecal coliform bacteria levels occurred, particularly during the November-April wet season.

An extensive dissolved oxygen dataset from King County was also provided in the Herrera report. This dataset confirmed low dissolved oxygen levels coming from the watershed above the SE 384th crossing. At the beginning of the 2003-05 *Effectiveness Monitoring Study,* a visual observation by Ecology staff at the Meadowbrook Way crossing revealed considerable iron oxidizing bacteria (orange-colored bacteria growth). This bacteria is associated with mineral rich, low-oxygen groundwater inputs into many streams and ditches in western Washington.

Optical brightener testing was performed as part of the Herrera 2004 study to test for laundry chemicals associated with domestic wastewater. The tests were conducted during wet weather months and did not detect potential human sources. The microbial source tracking study showed that there were anthropogenic (human-caused) sources such as human, canine, and domestic animal waste as well as wildlife sources. Some of the recommendations from the Herrera report included sanitary surveys of on-site sewage treatment systems, surveys of agricultural practices, implementation of a pet waste cleanup programs, and planting of trees along the riparian corridor.

King County acquired five homes in the lower Kimball Creek drainage that have been subject to repeated inundation with flood waters during regular flood events on the Snoqualmie River. FEMA hazard mitigation grants made these purchases possible in the spring of 1996, following two flood events in quick succession. The elimination of these homes' waste disposal systems subject to regular flooding may reduce contamination impacts to Kimball Creek and the Snoqualmie River.

Water Quality Results for the Kimball Creek Watershed

Fecal Coliform Bacteria

Kimball Creek bacteria levels do not meet water quality standards during the August-October critical period. The *TMDL Study* geometric mean was 1066 cfu/100 mL (n=4) compared to 190 cfu/100 mL (n=26) during the 2003-05 *Effectiveness Monitoring Study.* Water quality standards were met during the wet season. Monthly fecal coliform statistical summaries for Kimball Creek are presented in Figure 26. Highest fecal coliform levels are seen during the critical period. Based on the roll-back method for the critical period, a 77% reduction in fecal coliform levels is needed in Kimball Creek to meet the 90th percentile bacteria water quality standards. Adequate flow data were not obtained for this site, so fecal coliform loading information is not available.

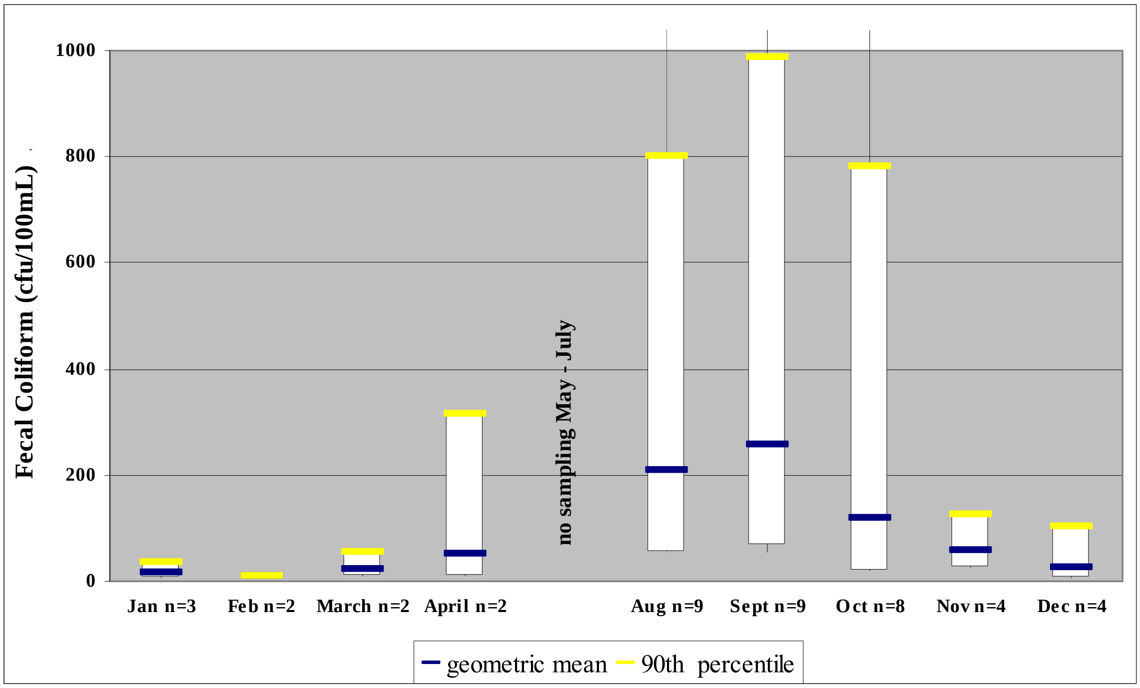

Figure 26. Kimball Creek monthly fecal coliform statistics for August 2003 – February 2005.

Nutrients

Minimal nutrient sampling was conducted. Ammonia-nitrogen levels were slightly higher than other tributaries with a mean of 0.023 mg/L (n=14) during the critical period. Field staff noted significant periphyton growth during the summer sample events in Kimball Creek.

Field Parameters

No continuous monitoring was conducted in Kimball Creek. During the synoptic surveys, Kimball Creek met water quality standards for pH. Temperature did not meet water quality standards during some of the August sampling events.

Dissolved oxygen levels were low and did not meet standards. Mean dissolved oxygen was 7.9 mg/L. Due to the sampling schedule, dissolved oxygen measurements were obtained during afternoon hours when dissolved oxygen levels should be at there highest. It is likely lower dissolved oxygen levels are occurring during the early morning hours.

Intensive Monitoring Survey (August 30-31, 2005)

During the intensive survey, Kimball Creek had some of the highest levels of fecal coliform bacteria compared to other sites. Orthophosphate levels were below the TMDL recommended target limit of 20 µg/L. Nitrogen levels were mid-range compared to other sites. Temperature and pH values were within standards. Dissolved oxygen levels fell as low as 7.4 mg/L during afternoon hours. No measurements were taken during the critical early morning hours. Intensive survey monitoring results are fully described in Appendix J.

Conclusions and Recommendations for the Kimball Creek Watershed

While Kimball Creek fecal coliform levels have improved since the 1989-91 *TMDL Study* was published, there are water quality issues that need to be addressed. Fecal coliform levels still do not meet water quality standards. In addition, water temperatures are high, and the cause of low dissolved oxygen levels should be investigated.

The following actions should be taken to improve bacteria and nutrient pollution levels in Kimball Creek.

- Because the City of Snoqualmie is not receiving a Phase II municipal stormwater permit. The City will not be required to perform stormwater pollution control activities like most other urbanized areas in the Seattle/Tacoma/Everett corridor. For that reason, and because of the demonstrated pollution problem in Kimball Creek, the City should examine the location of municipal and private stormwater conveyance systems discharging to the creek and perform illicit discharge detection and elimination (IDDE). Other aspects of the six minimum controls should be evaluated and implemented as resources allow.
- Examine small farm practices and require farm plans and implementation of best management practices as needed.
- Evaluate on-site sewage treatment systems in the Kimball Creek watershed (and all tributary streams in the system as needed). Require repairs or other long-term corrective actions as needed.
- Implement a pet-waste cleanup program in the Kimball Creek watershed to inform residents of the impacts of pet waste to water quality (Herrera, 2004).
- Restore shade to creek as needed to reduce stream temperatures and improve the pollution filtering capability of buffer areas.
- Additional study of water quality is needed in Kimball Creek. The Snoqualmie Tribe and the City of Snoqualmie should consider establishing a regularly scheduled monitoring program in Kimball Creek. The City has laboratory facilities and personnel skilled in water quality measurement. Due to the large size of the Snoqualmie watershed, the combined effort of local municipalities and Tribes is needed to track long-term water quality trends in local waters.

Snoqualmie Wastewater Treatment Plant at Snoqualmie RM 40.8

TMDL Implementation and Changes at the Snoqualmie WWTP

The Snoqualmie lagoon treatment system was replaced with an advanced secondary treatment plant (oxidation ditch) in 1997. The new facility was required to handle the dramatic increase in flows and loadings that were anticipated from the planned Snoqualmie Ridge development. Originally constructed to treat a maximum monthly average flow of 1.24 million gallons per day (MGD), a recent addition of a second oxidation ditch has increased the constructed treatment capacity to 2.15 MGD. However, only one ditch is currently operated at any given time and, as a result, the facility's practical operating capacity is limited to approximately 1.3 MGD. The layout of the WWTP will allow at least one more oxidation ditch and two more clarifiers to be built on the site.

While the new facility was necessary for community growth, the switch to modern advanced treatment technology also improved discharge water quality, as can be seen in Figure 27. The Snoqualmie WWTP is currently discharging at a rate far below the estimated TMDL monthly average allocation. The plant appears to be susceptible to considerable inflow and infiltration during the winter months.

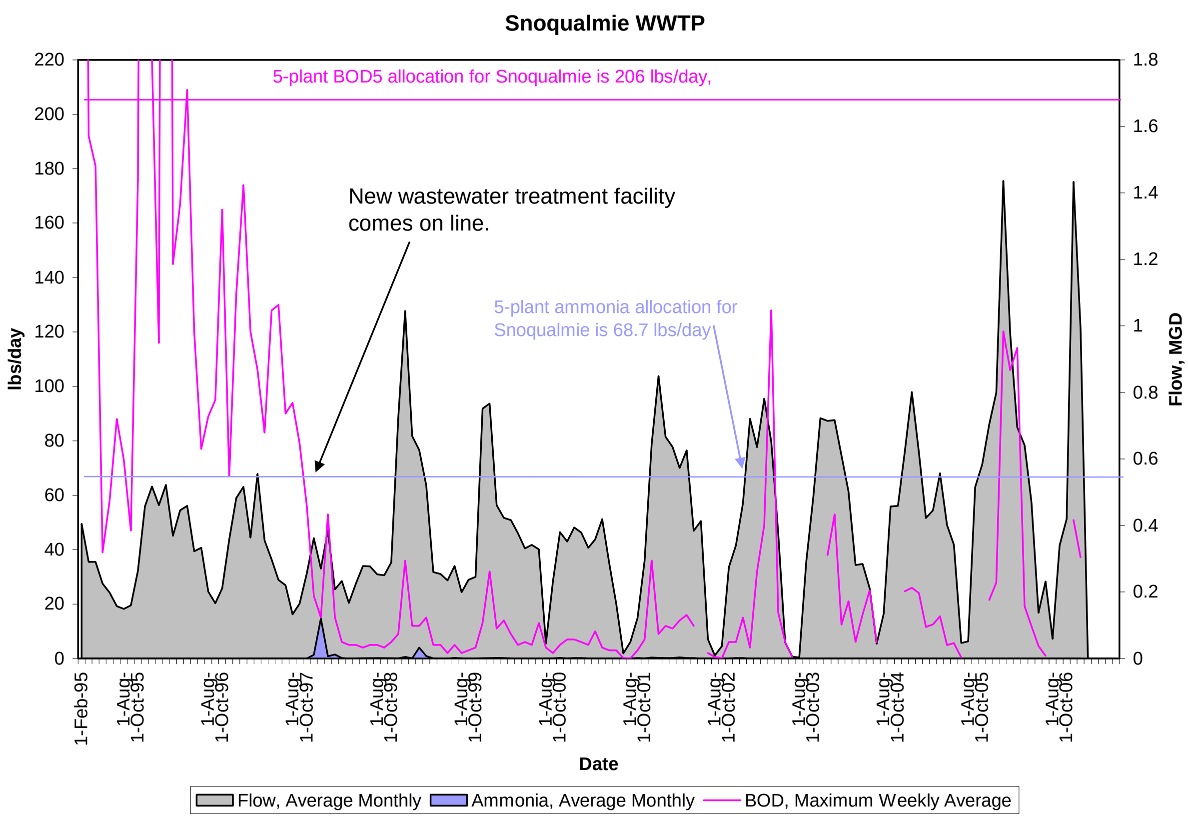

Figure 27. Snoqualmie WWTP performance with TMDL-required permit limitations.

The Snoqualmie WWTP produces Class A reclaimed water that is used for irrigation by a number of customers in the Snoqualmie Ridge area or discharged to the river. As shown in Figure 27, withdrawal rates vary during the August-October critical period. According to WWTP staff, recent summer withdrawal patterns are expected to continue at the same rate as recent years, and no new irrigation projects are underway. Withdrawal rates were higher when the golf course first started using the reused water but have decreased due to improved efficiencies within the golf course system. As the dry season progresses, more water is diverted to the golf course storage pond, and usually discharges approach zero during one or two months. The golf course must pay for the reclaimed water. Water usage can be expected to fluctuate yearly depending on the length of the dry season and severity of summer weather and heat.

Figure 27 also shows flows peaking in winter months indicating that some amount of inflow/infiltration is occurring. Inflow and infiltration into wastewater collection systems is expected and allowable as long as it is not considered "excessive" as defined by EPA (Ecology 1997). Because it occurs during winter months, inflow/infiltration does not adversely affect dissolved oxygen levels in the Snoqualmie watershed.

Water Quality Results for the Snoqualmie WWTP

Ecology conducted minimal sampling of the Snoqualmie WWTP discharge. Sampling was not conducted the same day as the rest of the Snoqualmie sites, so the data could not be compared.

In the *TMDL Study* (Joy, 1994), WWTP controls were required for the Snoqualmie WWTP (five municipal WWTP scenario including WWTP and nonpoint source controls). Required and recommended controls included:

- BOD5 ≤ 15 mg/L (required)
- Ammonia-nitrogen ≤ 9 mg/L (required)
- Orthophosphate ≤ 1.05 mg/L = 105 µg/L (recommended)
- Fecal coliform geometric mean ≤ 400 cfu/100 mL. This is the daily concentration recommended by the TMDL. Technology-based minimum permit requirements set an average monthly geometric mean of 200 cfu/100 mL, and a maximum weekly geometric mean of 400 cfu/100 mL.

A review of permit compliance since the new WWTP components came on line showed generally good compliance during the critical period. The plant exceeded daily ammonia-nitrogen discharge limits during portions of July 2004 and October 2005. Both violations were caused by equipment failures and were resolved in a timely manner. No effluent was being discharged to the river during the July 2004 water quality exceedance.

Fecal coliform levels as measured by four Ecology samples were generally good with a maximum value of 330 cfu/100 mL. Orthophosphate levels in samples taken by Ecology averaged 1.4 mg/L, which is above the TMDL target of 1.05 mg/L. The mean orthophosphate level as measured weekly by the Snoqualmie WWTP staff during 2004 and 2005 was about 1.69 mg/L. Values were higher during the critical period at 2.08 mg/L. Mean ammonia-nitrogen levels were 0.017 mg/L, well below the concentrations set in the TMDL. One sampling event included monitoring of temperature and pH, and the obtained data met water quality standards and permit requirements.

Intensive Monitoring Survey (August 30-31, 2005)

During the intensive survey, the three WWTPs evaluated had the highest levels of total persulfate nitrogen, orthophosphate, and total organic carbon. Of those three WWTPs, the Snoqualmie plant had the lowest levels of nutrients and total organic carbon. The Snoqualmie WWTP discharge also had lower fecal coliform levels than any other site sampled during the intensive survey. Water quality standards were met for pH. Intensive survey monitoring results are fully described in Appendix J.

Conclusions and Recommendations for the Snoqualmie WWTP

The Snoqualmie WWTP is properly designed to meet BOD and ammonia limitations set by the five-plant, no nonpoint source control scenario. TMDL recommendations for phosphorus are a challenge for the plant. Definitive conclusions regarding the water quality discharge from the Snoqualmie WWTP could not be made from the samples collected by Ecology during the 2003-05 study due to limited sampling during the critical period. However, discharge monitoring report (DMR) data submitted since 2000 show generally good compliance with NPDES permit limits during the critical period. Of the three WWTPs, the Snoqualmie WWTP appeared to discharge the lowest levels of nutrients and bacteria.

Mainstem Snoqualmie at RM 40.7 (Hwy 202 crossing at Falls)

TMDL Implementation and Basin Changes, Mainstem Snoqualmie RM 40.7

Relatively little land-use change has occurred just upstream of the RM 40.7 site. Much of the land between RM 42.3 and RM 40.7 is primarily zoned for rural use, and growth in the area east of the watershed has not been significant. The Weyerhaeuser lumber mill is no longer discharging to Borst Lake, which empties into the Snoqualmie River. There is considerable residential growth occurring in the Snoqualmie Ridge area, and the location of stormwater discharge outfalls was not examined as part of the 2003-05 study. Some of the stormwater from Snoqualmie Ridge is discharged just below the RM 40.7 monitoring location on the left bank.

Water Quality Results for the Mainstem Snoqualmie RM 40.7

Fecal Coliform Bacteria

The Snoqualmie River at RM 40.7 met water quality standards for fecal coliform bacteria during the critical period, wet season, and all months (2003-05), with the exception of August. Fecal coliform results for the August 23 -24, 2004 sampling events showed that many sites failed the second part of the fecal coliform bacteria standard for August (10% of all samples obtained for calculating the geometric mean shall not exceed 200 cfu/100 mL). Monthly fecal coliform statistics were very similar to the average values measured in the original 1989-91 *TMDL Study* (Figure 28).

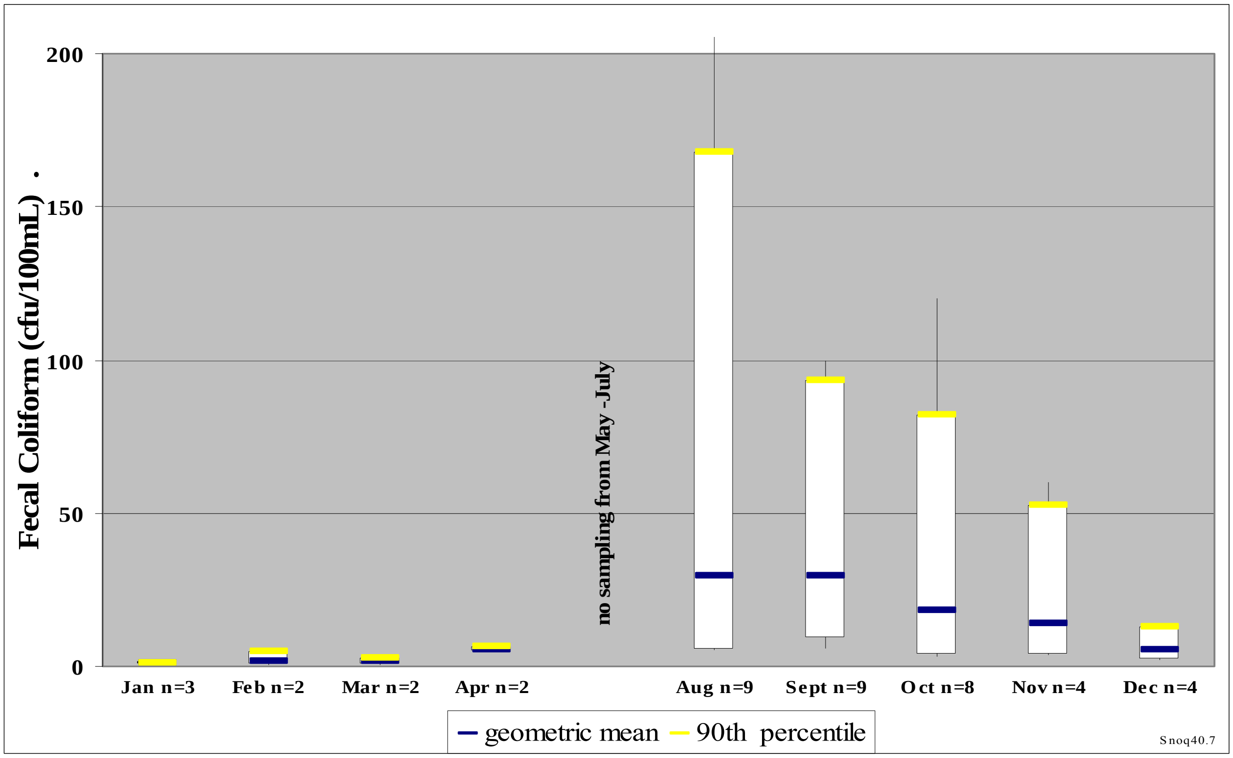

Figure 28. Mainstem Snoqualmie RM 40.7 fecal coliform statistics for August 2003 – February 2005.

No statistically significant differences were seen in fecal coliform concentrations between the mainstem Snoqualmie River sites RM 42.3 and 40.7 (α=0.05) for the August-October critical period, the November-April wet season, or both periods combined.

Estimated fecal coliform loading for the Snoqualmie River site at RM 40.7 was calculated using flow discharge data obtained from the USGS station 12144500, Snoqualmie River near Snoqualmie, Washington at RM 40.0. There are no significant tributaries that contribute streamflow between the monitoring station at RM 40.7 and the flow site at RM 40.0. Figure 29 presents instantaneous fecal coliform concentrations and estimated daily fecal coliform loading for the Snoqualmie River at RM 40.7.

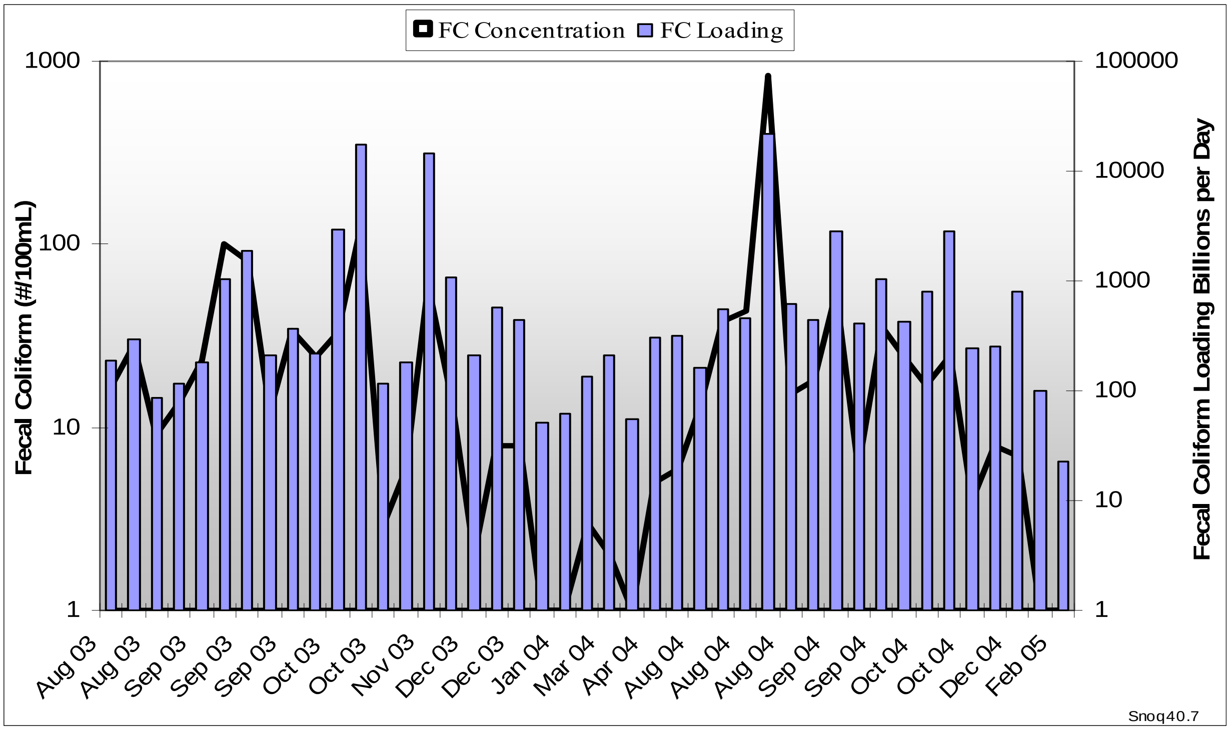

Figure 29. Mainstem Snoqualmie RM 40.7 instantaneous fecal coliform concentrations and estimated daily loading.

Nutrients

Mean nutrient concentrations for the critical period and the wet season are presented in Table 13. Nutrient levels were generally low. All orthophosphate samples obtained were less than the mainstem TMDL target limit of 10 µg/L.

Table 13. Snoqualmie RM 40.7 mean nutrient concentrations for the 2003-2005 sample events.

Sample Period	Ortho-phosphorus (µg/L)	No. of Samples	Nitrate/nitrite Nitrogen (mg/L)	No. of Samples	Ammonia-Nitrogen (mg/L)	No. of Samples	Total Persulfate Nitrogen (mg/L)	No. of Samples
Critical: Aug – Oct	4	14	0.172	13	0.011	14	0.239	13
Wet: Nov – April	4	6	0.206	5	0.010	10	0.248	6

Field Parameters

During the synoptic surveys, this site met water quality standards for pH and dissolved oxygen. There was one temperature exceedance of 18.1°C during August.

A continuous recording in-situ field meter was deployed at this site during the critical period in 2003, 2004, and 2005. Data from 2004 were rejected because meter accuracy could not be determined; no quality control data were available. Data from 2003 did not meet data quality objectives due to meter drift. Data from 2005 met data quality objectives and are presented in Figure 30.

The TMDL target minimum daily dissolved oxygen concentration for the Snoqualmie River site at RM 40.7 is 7.9 mg/L, with not more than an additional 0.1 mg/L deficit allowed for human-caused sources. For the 2005 continuous monitoring survey, the lowest dissolved oxygen levels were around 8:00-9:00 AM; maximum diurnal variation was 1.7 mg/L (Figure 30). During the 2003 continuous monitoring period, dissolved oxygen readings drifted upward over time, and results toward the end of the monitoring period were unreliable. The 2003 results did show a similar pattern of lower dissolved oxygen levels in the morning and a maximum diurnal variation of 1.2 mg/L. Minimum results for 2003 and 2005 were 9.0 and 8.4 mg/L respectively. The dissolved oxygen average daily minimum value for 2005 was 8.5 mg/L.

These results meet TMDL dissolved oxygen target targets, but monitoring did not occur during the 7Q20 critical period.

Continuous temperature results met standards for both 2003 and 2005 with maximum temperatures of 16.8 and 16.7°C, respectively.

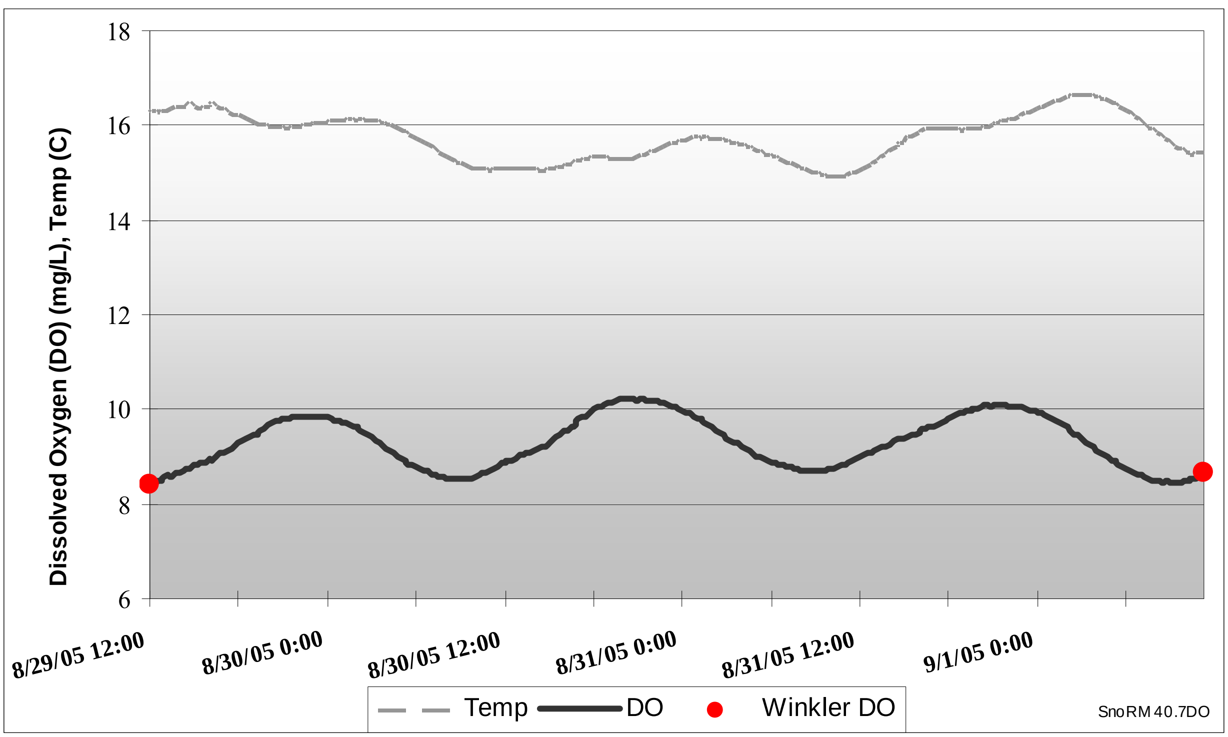

Figure 30. Mainstem Snoqualmie RM 40.7 continuous temperature and dissolved oxygen levels for August 29 – September 1, 2005.

Intensive Monitoring Survey (August 30-31, 2005)

During the intensive survey, the mainstem Snoqualmie River site at RM 40.7 had some of the lowest nutrient levels. Fecal coliform levels were moderate compared to other sites. Water quality standards were met for temperature, dissolved oxygen, and pH. Intensive survey monitoring results are fully described in Appendix J.

Conclusions and Recommendations for Mainstem Snoqualmie RM 40.7

The mainstem Snoqualmie River site at RM 40.7 had good water quality for the parameters measured. Recommendations include:

- Conduct continuous diurnal dissolved oxygen and temperature monitoring during the 7Q20 low-flow critical period to determine compliance with TMDL targets for dissolved oxygen.

Water Quality in the Lower Snoqualmie River

This section includes results for the lower Snoqualmie River basin from the base of Snoqualmie Falls at RM 40.0 downstream to Snoqualmie RM 2.7. Snoqualmie RM 2.7 is just upstream of the confluence with the Skykomish River. Lower Snoqualmie River and tributary sample sites are presented in Figure 31.

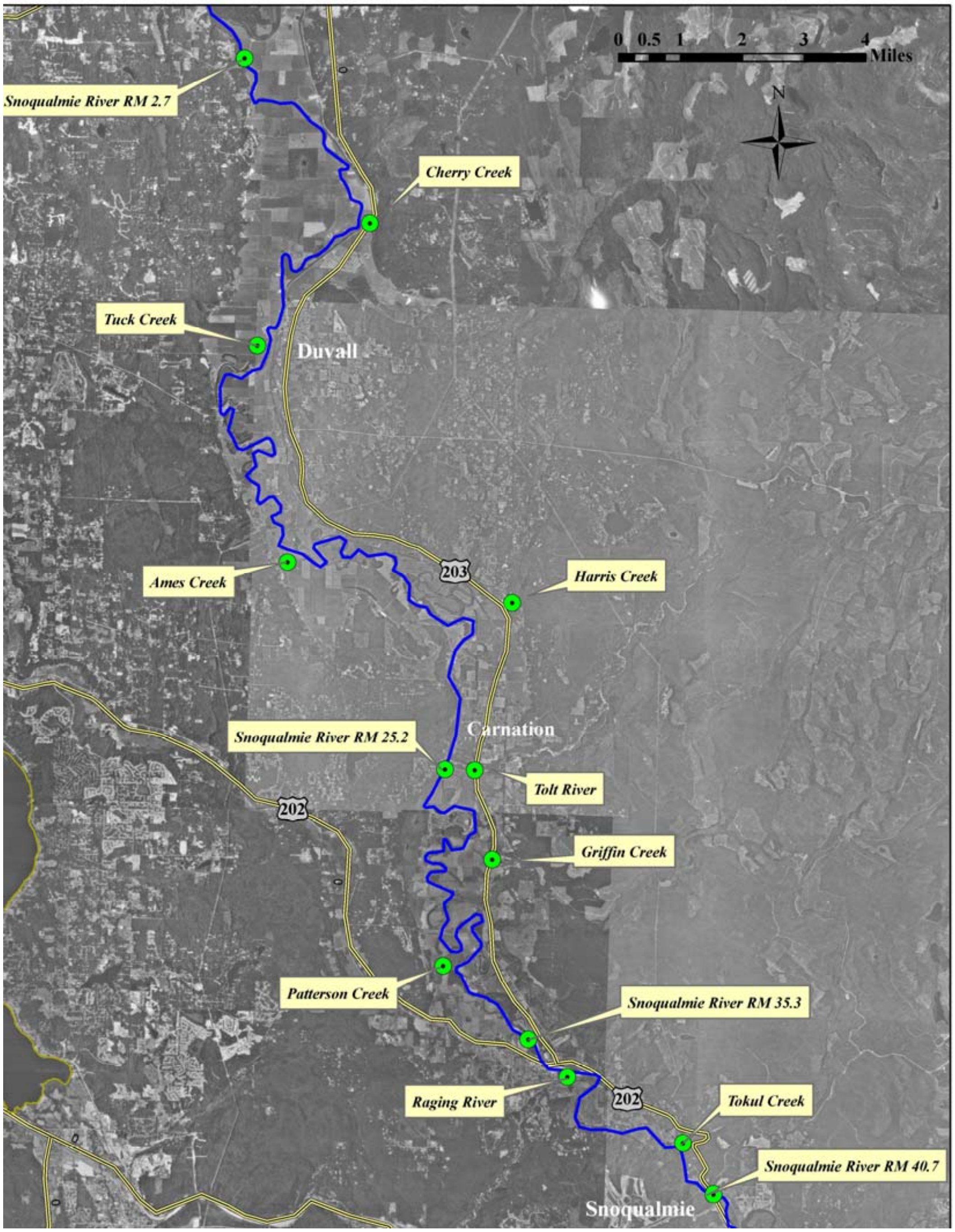

Figure 31. Lower Snoqualmie River and tributary sample sites.

Tokul Creek: Snoqualmie RM 39.6

TMDL Implementation and Basin Changes for Tokul Creek

Based on a review of 2006 orthophoto coverage for the Tokul Creek basin, the entire basin remains relatively undeveloped. Water quality is expected to be dominated by upper watershed land use, which is a forest production area. No significant changes have occurred at the Tokul Creek Fish Hatchery, which has an NPDES permit. A significant landslide occurred just above the hatchery in the winter of 2002-2003, and a sediment pond was installed to help control turbidity at the hatchery. No permit violations have occurred at the Tokul Creek Hatchery from 2000 to the present.

Water Quality Results for Tokul Creek

Fecal Coliform Bacteria

Tokul Creek met water quality standards for fecal coliform bacteria during the critical period, wet season, and all months (2003-05). Monthly fecal coliform statistical summaries for Tokul Creek are presented in Figure 32.

Estimated fecal coliform loading for Tokul Creek is presented in Figure 33. Loading was estimated by developing a flow curve relationship with flow at USGS gauging station 12148500 at the Tolt River near Carnation (RM 8.7). Flow estimates were based on n=10 and the r^2=0.97. Flows > 79 cfs and < 17 cfs are extrapolated and are not considered reliable.

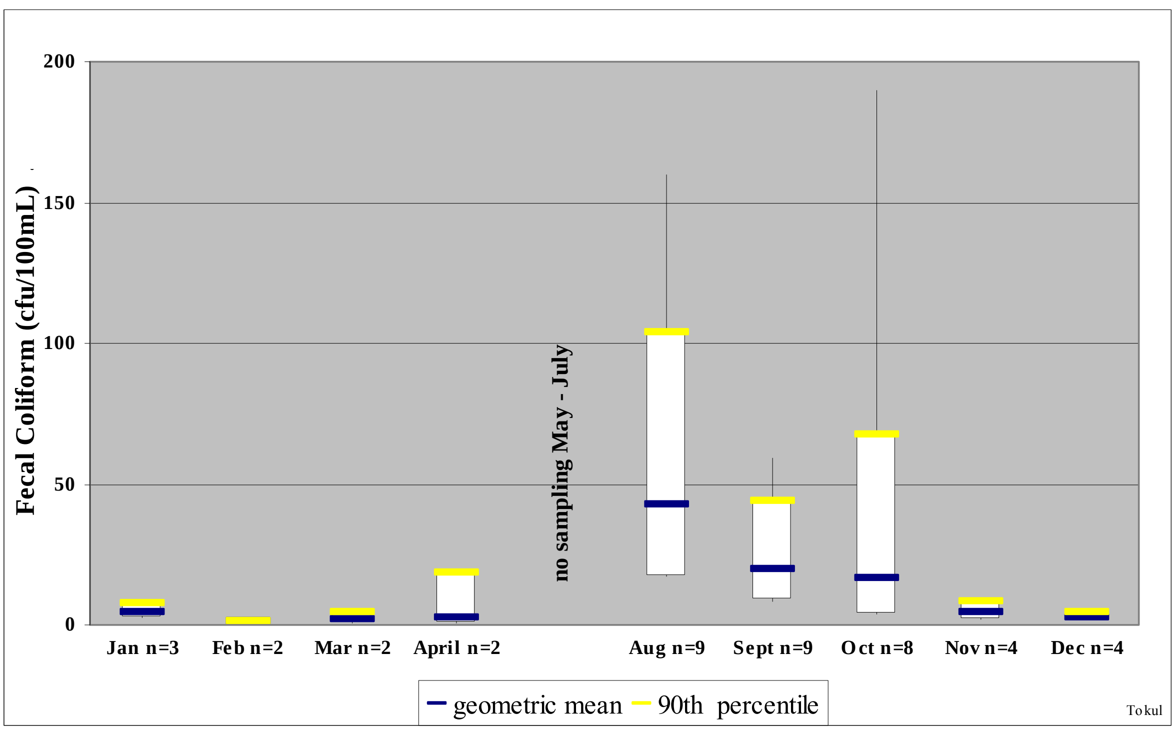

Figure 32. Tokul Creek monthly fecal coliform statistics for August 2003 – February 2005.

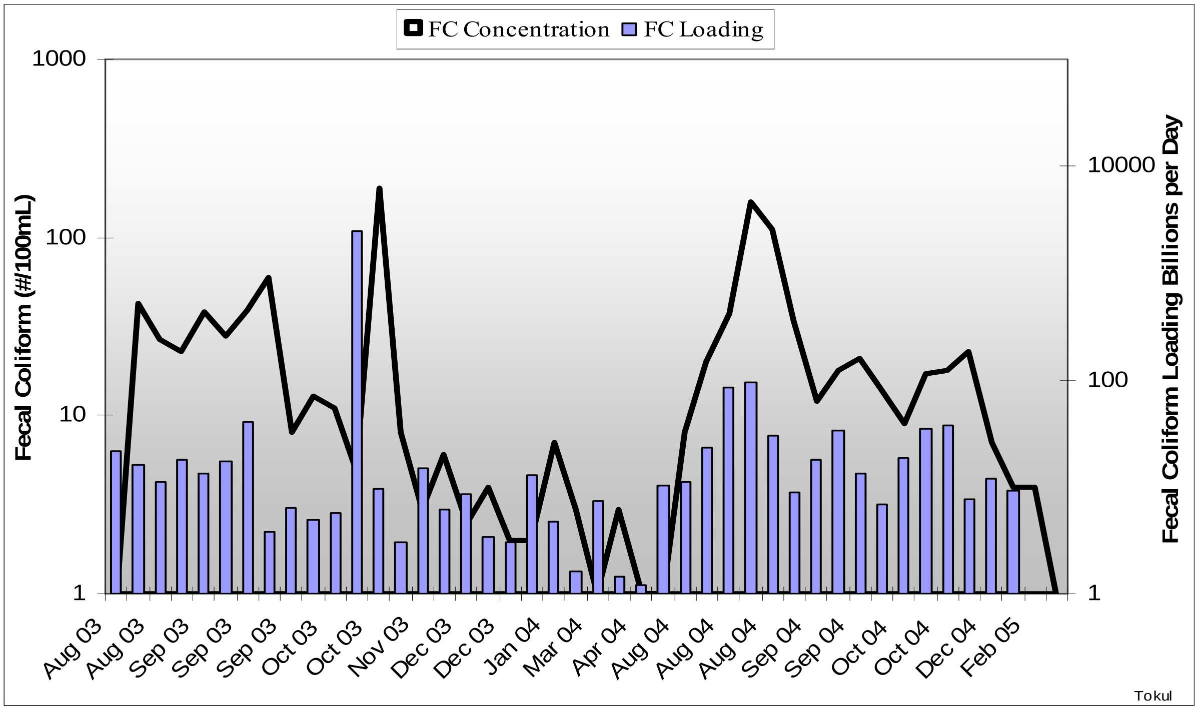

Figure 33. Tokul Creek instantaneous fecal coliform concentrations and estimated daily loading.

Nutrients

Minimal nutrient sampling was conducted on Tokul Creek. The only orthophosphate level obtained was 16 µg/L, under the suggested TMDL guideline of ≤ 20 µg/L. Ammonia-nitrogen levels were generally low, but nitrite-nitrate nitrogen were slightly elevated with a mean of 0.560 mg/L (n=3) during the August-October critical period.

Field Parameters

No continuous monitoring was conducted on Tokul Creek. During the synoptic surveys, Tokul Creek met water quality standards for temperature and dissolved oxygen. In September, there was one exceedance of the pH standard at 8.6 SU.

Intensive Monitoring Survey (August 30-31, 2005)

During the intensive survey, Tokul River had moderate nutrient and bacteria levels as compared to the other sites. As with the synoptic surveys, nitrite-nitrate nitrogen levels were slightly higher than other sites. Water quality standards were met for temperature, dissolved oxygen, and pH. Intensive survey monitoring results are fully described in Appendix J.

Conclusions and Recommendations for Tokul Creek

Bacterial water quality continues to be good in Tokul Creek. Higher pH values were seen in Tokul Creek with one exceedance of the standard. It is unknown if higher pH levels are a natural condition or an indicator of periphyton growth due to excessive nutrients. Nitrogen levels were elevated, likely as a result of the fish hatchery.

- Upstream and downstream sampling for nitrogen should be done at the Tokul Creek Fish Hatchery to determine if the hatchery contributes nitrogen to Tokul Creek.

Raging River: Snoqualmie RM 36.2

TMDL Implementation and Basin Changes for the Raging River

Relatively little growth has occurred in the Raging River subbasin since the 1989-91 *TMDL Study*. Most properties have a rural, low-density character with the exception of the area immediately around Fall City. King County purchased 53 acres along the lower Raging River for salmon recovery and flood control purposes.

In 2006, King County completed a major levee removal project along the Raging River downstream of Preston. The project reconnected a portion of the river to its floodplain, created new side-channels, and increased habitat complexity through this reach. The lower half mile of the Raging River is dynamic and has a fairly large meander zone. Flows in the winter can get very high, resulting in significant movement of gravel and changes in this lower river location where sampling was performed. Gravel transported from upstream areas accumulates in this stretch of the river, creating an opportunity for considerable solar warming.

Water Quality Results for the Raging River

Fecal Coliform Bacteria

The Raging River met standards for fecal coliform bacteria during the August-October critical period overall but not for August and October. During those months, one fecal coliform value > 200 cfu/100 mL in each month occurred during flood conditions and caused violations of the fecal coliform standard. Figure 34 presents monthly fecal coliform bacteria statistics for the Raging River. Fecal coliform loading estimates for the Raging River are presented in Figure 35. Loading was estimated using flow discharge measurements from the USGS gauging station 12145500, Raging River near Fall City at RM 2.6.

Nutrients

Minimal nutrient sampling was conducted on the Raging River. The only orthophosphate sample obtained was less than the TMDL guideline for the tributaries of ≤ 20 µg/L. Ammonia-nitrogen levels were all below detection limits, and other nitrogen parameters were generally low.

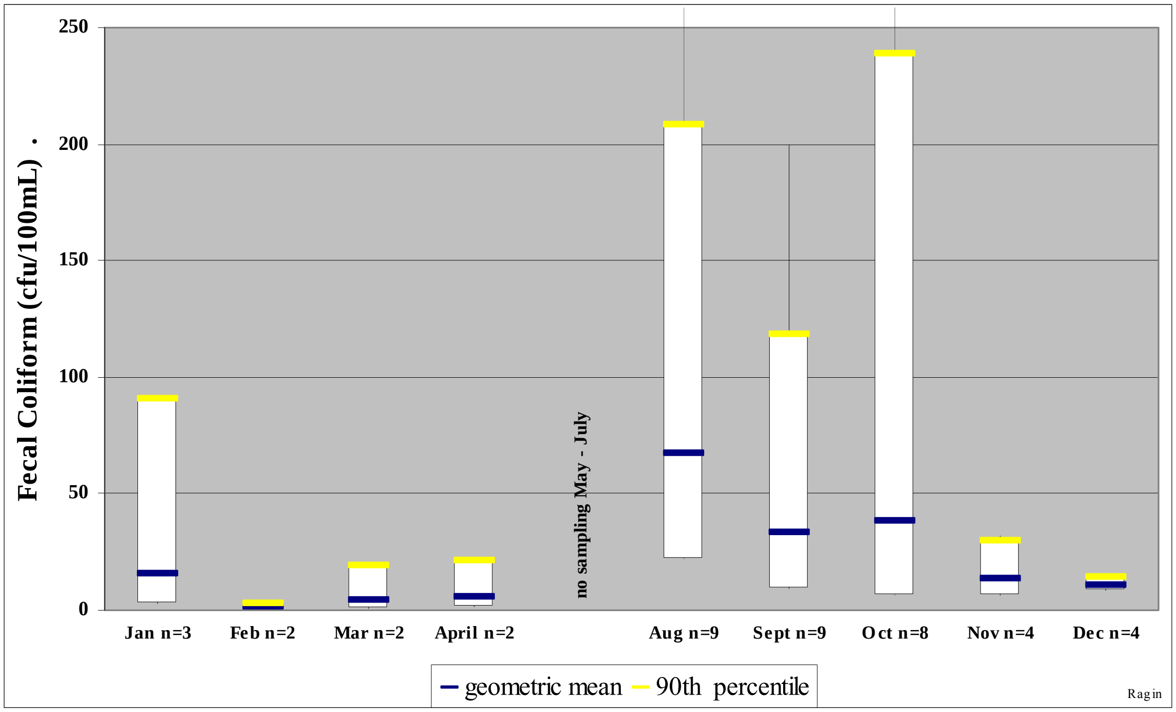

Figure 34. Raging River monthly fecal coliform statistics for August 2003 – February 2005.

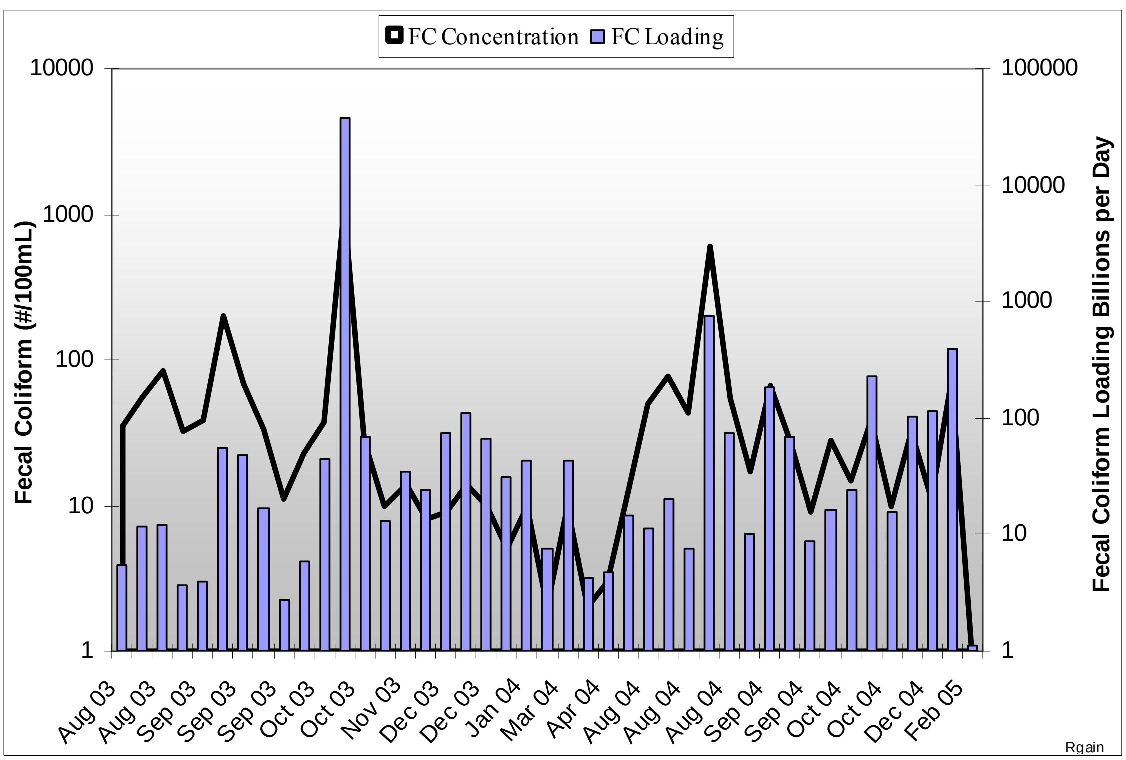

Figure 35. Raging River instantaneous fecal coliform concentrations and estimated daily loading.

Field Parameters

No continuous monitoring was conducted on the Raging River. During the synoptic surveys, the Raging River site met water quality standards for dissolved oxygen. Temperature did not meet the water quality standard with a maximum temperature of 24.4 °C in August 2004. There were numerous pH excursions during August and September, with pH levels as high as 9.7. The high pH values indicate that a low dissolved oxygen levels may be a problem in early morning hours due to respiration by excessive algal growth.

Intensive Monitoring Survey (August 30-31, 2005)

During the intensive survey, Raging River had low levels of nutrients and moderate bacteria levels as compared to the other sites. Water quality standards were met for temperature and dissolved oxygen. As with the synoptic surveys, pH did not meet standards. Intensive survey monitoring results are fully described in Appendix J.

Conclusions and Recommendations for the Raging River

Some elevated bacteria levels were seen in August and October at this site even though standards were met during the critical period. High pH levels during the critical period are of concern. This could indicate excessive periphyton growth (attached algae). Photosynthesis and respiration can affect pH and dissolved oxygen throughout the day. Periphyton consumes dissolved inorganic carbon during photosynthesis, leading to maximum pH values in the afternoon. Overnight, aquatic plant respiration increases dissolved inorganic carbon, causing minimum early morning pH values. Excessive amounts of respiration can cause dissolved oxygen depletion in the early morning hours.

While dissolved oxygen levels met standards at this site, monitoring generally occurred during the late afternoon when the highest levels of dissolved oxygen would be expected. During the day plants produce oxygen through photosynthesis. Dissolved oxygen levels likely drop below standards during the early morning hours. In addition, high temperatures were seen at this site.

The following actions are needed to improve water quality in the Raging River:

- Additional study on pH exceedances is needed, especially because of the potential for low dissolved oxygen levels during night and early morning hours. Ecology may eventually schedule a TMDL study; however, Tribes and King County are encouraged to investigate pH, temperature, and dissolved oxygen levels in more detail using the competitive Centennial Clean Water Fund grant process or other funding mechanisms. Projects that combine study with outreach and implementation are encouraged.
- High stream temperatures need to be investigated in the Raging River. Ecology is currently conducting a temperature TMDL for the Snoqualmie. That study will provide additional information and recommendations for action in all Snoqualmie tributaries. However, because of the importance of the Raging River for salmon spawning and rearing, additional investigation beyond Ecology’s basic temperature TMDL is warranted. Riparian conditions, stream hydrology, stream morphology, land use, and other relevant factors should be examined and evaluated as part of future detailed studies.

Snoqualmie River Fall City Transect Study, RM 36.0 – 35.3

A special diagnostic study was conducted on the mainstem Snoqualmie River around Fall City from September 2003 – September 2005. The results, conclusions, and recommendations for this study are presented in Appendix H. The tabular water quality data are presented in Appendix E.

Mainstem Snoqualmie River at RM 35.3

TMDL Implementation and Basin Changes, Mainstem Snoqualmie RM 35.3

The most significant change in the contributing watershed has been the growth in Snoqualmie Ridge in the town of Snoqualmie. About one square mile of the ridge has housing densities of 5 to 10 houses per acre. Stormwater from at least a portion of the development is discharged just downstream of Snoqualmie mainstem RM 40.7 and perhaps from some of the small tributaries discharging at various locations below the falls. Expansion of the residential housing on the ridge is expected to continue for a number of years. There is also a new PGA golf course that uses the reclaimed water from the Snoqualmie WWTP for dry weather irrigation. A new golf course was also constructed in the Fall City area that has at least 3000 feet of shoreline along the Snoqualmie, just across from a similarly sized golf facility that has been there for many years.

Some salmon restoration work and property acquisition has been done in the watershed between Snoqualmie Falls and RM 35.3. Along with habitat preservation, the acquired land may be used for trails and interpretive opportunities. Restoration work was also done on a 39.5 acre property adjacent to Neal Road. King County also purchased 31 acres along the Snoqualmie River near the confluence with the Raging River.

Restroom facilities are now available at the Puget Sound Energy access point just below Snoqualmie Falls where many summer recreational river users launch their canoes and rafts on trips down to Fall City. This likely has reduced the amount of fecal waste deposited during the recreational season.

Water Quality Results for Mainstem Snoqualmie at RM 35.3

Fecal Coliform Bacteria

Snoqualmie River at RM 35.3 met water quality standards for fecal coliform bacteria during the critical period, wet season, and all months (2003-05), with the exception of August and October. Fecal coliform results for the August 23 -24, 2004 sample events showed that many sites violated the second part of the fecal coliform bacteria standard for August (10% of all samples obtained for calculating the geometric mean shall not exceed 200 cfu/100 mL). A 0.76” rainfall event the day of sampling likely caused the October exceedance. Monthly fecal coliform statistics are presented in Figure 36.

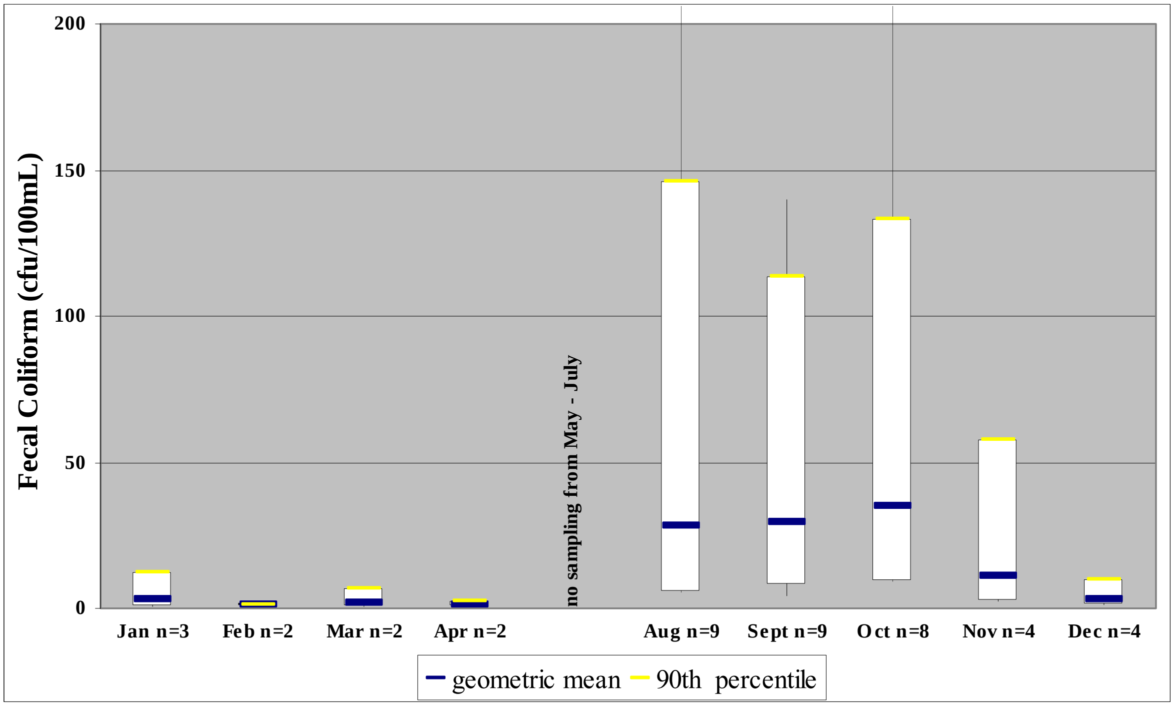

Figure 36. Mainstem Snoqualmie RM 35.3 monthly fecal coliform statistics for August 2003 – February 2005.

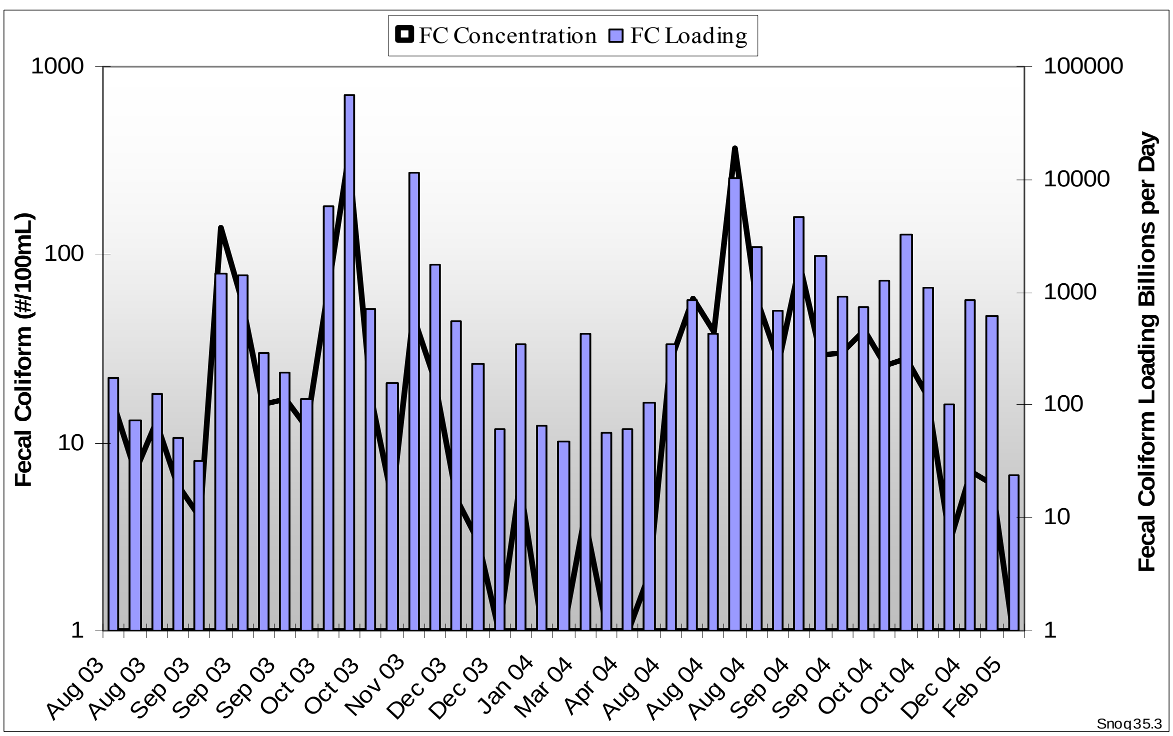

Figure 37. Mainstem Snoqualmie RM 35.3 instantaneous fecal coliform concentrations and estimated daily fecal coliform loading.

No statistically significant differences were seen in fecal coliform concentrations between the mainstem Snoqualmie stations at RM 40.7 and 35.3 (α=0.05) for the August-October critical period, the November-April wet season, or for both periods combined.

Estimated fecal coliform loading for the mainstem Snoqualmie River at RM 35.3 is presented in Figure 37. Flow discharge used to calculate loading for this site was estimated by adding flow discharge from the USGS gauging station 12145500, Raging River near Fall City at RM 2.6, and flow discharge from USGS station 12144500, Snoqualmie River near the city of Snoqualmie at RM 40.0. Raging River is the only significant tributary input between Snoqualmie RM 40.0 and RM 35.3.

No statistically significant differences were seen in fecal coliform loading between mainstem Snoqualmie stations at RM 40.7 and 35.3 (α=0.05) for the critical period, the wet season, or for both periods combined.

Nutrients

Minimal nutrient sampling was conducted at the Snoqualmie River site, RM 35.3. The mean orthophosphate level was 5 µg/L less than the mainstem TMDL limit of 10 µg/L. Ammonia-nitrogen levels were all below the detection limit, and other nitrogen parameters were generally low.

Field Parameters

No continuous monitoring was conducted at this site. During the synoptic surveys, this site met water quality standards for pH and dissolved oxygen. Water temperature did not meet the water quality standard with higher temperatures in August.

Intensive Monitoring Survey (August 30-31, 2005)

Intensive survey monitoring results are fully described in Appendix J. During the intensive survey, the mainstem Snoqualmie River site at RM 35.3 had the highest bacteria levels of the mainstem sites. In comparison to other sites, nutrient levels were moderate. Temperature, pH, and dissolved oxygen met water quality standards during the intensive survey.

Conclusions and Recommendations for Mainstem Snoqualmie RM 35.3

With the exception of high water temperatures, the mainstem Snoqualmie River site at RM 35.3 has good water quality for the parameters measured. This section of the river is among the most popular for summer recreational activities using small rafts (Svrjcek, personal observations). On a typical hot summer weekend, it would not be unusual for over 100 people to use the river, and this number can only be expected to grow in the future.

The following actions should be taken to control bacteria and nutrient pollution levels in the mainstem Snoqualmie between RM 40.7 and RM 35.3:

- Because the City of Snoqualmie is not receiving a Phase II municipal stormwater permit, the City will not be required to perform stormwater pollution control activities like most other urbanized areas in the Seattle/Tacoma/Everett corridor. For that reason, this report recommends the City examine the location of municipal and private stormwater conveyance systems discharging to the mainstem Snoqualmie and any tributaries to it, and perform illicit discharge detection and elimination (IDDE). Other aspects of the six minimum controls should be evaluated and implemented as resources allow.
- Examine small farm practices and require farm plans and implementation of best management practices as needed.
- Both human and pet waste management systems and educational signage are needed in the river beach area between the mouth of the Raging River and the beach below the Highway 202 crossing at Fall City. Both human and pet wastes have been observed on the beach or in the heavy growth of invasive plant species along the bank. Restroom facilities provided at the Puget Sound Energy and Washington Department of Fish & Wildlife (WDFW) access points are helpful. Good additions would be (1) additional facilities at the WDFW access point and the Fall City parking areas, and (2) additional educational signage at all sites for fisherman and others using tubes and rafts to float down river to Fall City.
- As noted in the Fall City Transect Study recommendations, more research is needed regarding the unknown bacteria source on the left bank Snoqualmie just upstream of the business district and public parking area. Although the overall mainstem river quality is very good, several high values were detected as part of the transect study. These values were only seen sporadically during two sampling events but are still a concern.

Patterson Creek: Snoqualmie RM 31.2

TMDL Implementation and Basin Changes in Patterson Creek

A number of significant changes have occurred in the Patterson Creek subbasin. In the lower watershed, one large dairy operation (158 acres, about 474 animals) in the floodplain went out of business and began conversion to an equestrian facility. At the time of the 2003-05 *Effectiveness Monitoring Study*, there was little or no livestock present on this property. The dairy located in the floodplain continues operation. In the past two years, there has been a great increase in the number of horses and cattle in the floodplain.

King County and King Conservation District staff worked with many landowners in the Patterson Creek subbasin. About 7,680 feet of fencing was installed to control animal access, and over 4 acres of riparian area was restored. Several composting and heavy use protection areas were also installed on private properties. A total of 34 farm plans were prepared throughout the subbasin, and one or more of those plans covered a significant portion of the floodplain area. In the past five years, several of these properties have changed ownership and/or land use, and there are many more livestock present. Apart from these plans, 111 acres of the floodplain in Patterson Creek are in the Farmland Preservation Program.

A golf course was developed upstream of the Snoqualmie mainstem floodplain in an area that was previously pasture. Large riparian areas were set aside and are being re-planted. Much of the stormwater is collected and used for golf course watering. Just upstream of the golf course is a significant input of new stormwater from a large development with housing densities ranging from about 2 to 4 houses per acre. Stormwater runoff from this area is controlled by a large detention pond that requires a dam permit.

Patterson Creek Park (495 acres) was also created, and an additional 10.5 acres of land with riparian and wetland areas was purchased.

Water Quality Results for Patterson Creek

Fecal Coliform Bacteria

Patterson Creek did not meet water quality standards for fecal coliform bacteria during the August-October critical period, but standards were met during the November-April wet season. Although the critical period geometric mean fell from 179 cfu/100 mL during the 1989-91 *TMDL Study* to 146 cfu/100 mL during the 2003-05 *Effectiveness Monitoring Study* (n=5, n=28, respectively), the 90th percentile value increased from 270 to 485 cfu/100 mL. The high bacteria levels were greatly influenced by data collected in association with two flood events.

Monthly fecal coliform statistics are presented in Figure 38. Highest fecal coliform levels were seen during the critical period. Based on the roll-back method, a 64% reduction in 90th percentile fecal coliform levels is needed during the critical period to meet water quality standards. Adequate flow data were not obtained at this site, so fecal coliform loading could not be calculated.

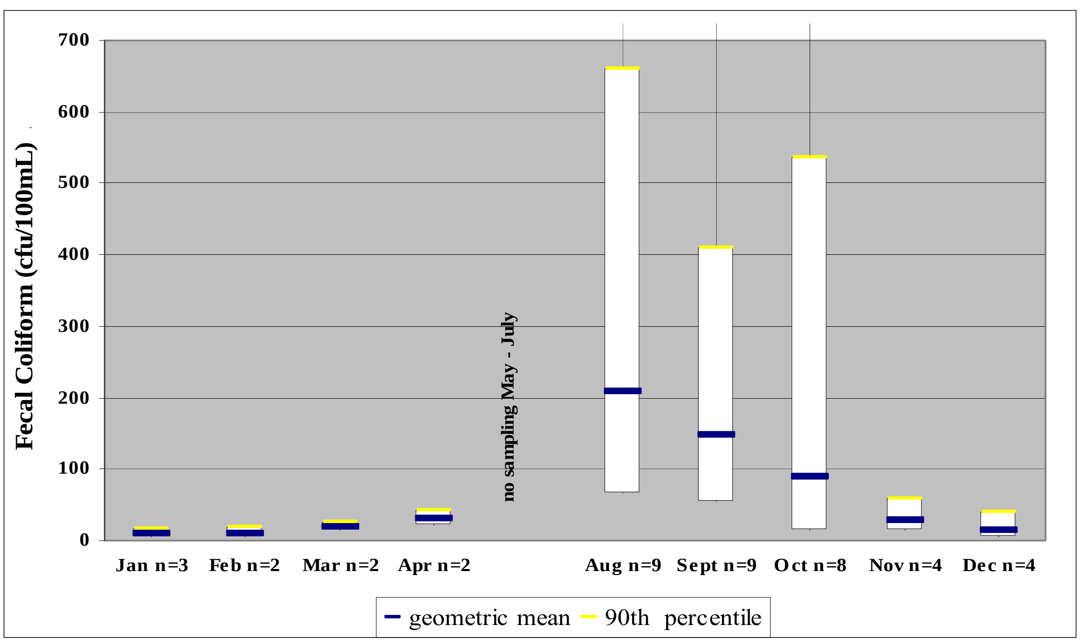

Figure 38. Patterson Creek monthly fecal coliform statistics for August 2003 – February 2005.

Nutrients

Minimal nutrient sampling was conducted on Patterson Creek. Two orthophosphate samples were obtained, and both results were greater than the TMDL guideline of ≤ 20 µg/L. Ammonia-nitrogen levels were low but above the detection limit.

Field Parameters

No continuous monitoring was conducted on Patterson Creek. During the synoptic surveys, Patterson Creek met water quality standards for pH. Dissolved oxygen levels did not meet water quality standards. The maximum spot temperature was 19.2°C, and minimum dissolved oxygen was 7.7 mg/L. Dissolved oxygen levels were lowest in August.

Intensive Monitoring Survey (August 30-31, 2005)

Compared to other sites, Patterson Creek had high nutrient levels (orthophosphate and total persulfate nitrogen). Moderately high bacteria levels were seen as well. During the intensive survey, temperature, dissolved oxygen, and pH met water quality standards. Intensive survey monitoring results are fully described in Appendix J.

Conclusions and Recommendations for Patterson Creek

Patterson Creek has poor water quality during the critical period with violations of the water quality standards for fecal coliform, dissolved oxygen, and temperature.

The following actions should be taken to control bacteria and nutrient pollution levels in Patterson Creek:

- Municipal and private stormwater conveyance systems discharging to Patterson Creek should be evaluated for the presence of illicit discharges.
- Compliance with the King County Livestock Ordinance should be evaluated throughout the watershed. Farm plans should be prepared and implemented wherever there is a potential for polluting surface waters. Properties with existing small farm plans should be revisited due to recent changes in ownership. Properties under Farmland Preservation should also be visited to encourage improved management of riparian areas and drainages to municipal stormwater conveyances.
- On-site sewage treatment systems in close proximity to surface water or drainage conveyances should be evaluated for proper operation.
- Regular inspections of existing dairy and any commercial livestock operations are needed.

Griffin Creek: Snoqualmie RM 27.2

TMDL Implementation and Basin changes in Griffin Creek

The majority of the Griffin Creek watershed is estimated to be under similar land uses as seen in 1996 (Curran et al., 1996). The first 2 miles of the watershed traveling from the mouth of the creek upstream are primarily a combination of agricultural, forestry, residential, and public open space uses. Beyond 2 miles, all of the watershed is managed as a forest production area. In the lower two miles, forestry and farming account for about 29% and 26% of land use, respectively. Rural residential and private youth camp activities make up about 10% and 19% of the lower 2 miles, respectively, and are located above Ecology's monitoring location where Griffin Creek crosses Highway 203. Most of the farming occurs adjacent to the last 0.5 miles of the creek, below Ecology's monitoring point. It is likely that residential land use has increased slightly.

Although no significant changes in land use are believed to have occurred in the Griffin Creek watershed, local government has worked on several important projects in the floodplain area. King County planted and maintained 3.5 acres of riparian restoration plantings along lower Griffin Creek at an existing farm and purchased 9.7 acres that included some riparian area. Approximately 20 acres of farmland adjacent to Griffin Creek in the floodplain are now part of the Farmland Preservation Program. About a quarter mile upstream of that farm, King County has established the Griffin Creek Natural Area, which is over 20 acres in size and covers 2,100 feet of the right bank of Griffin Creek. A farm plan was prepared for a private landowner located between the Natural Area and the Farmland Preservation Property. Also, a heavy use protection area was installed, which could help reduce bacteria and nutrient pollution inputs.

Water Quality Results for Griffin Creek

Fecal Coliform Bacteria

Bacteria levels in Griffin Creek have improved since the original 1989-91 *TMDL Study* (Joy, 1994). The critical period (August-October) geometric mean has decreased from 212 to 77 cfu/100 mL.

Griffin Creek did not meet water quality standards for fecal coliform bacteria during the critical period, but met standards during the wet season (November-April). Monthly fecal coliform statistical summaries for Griffin Creek are presented in Figure 39. The highest fecal coliform levels were seen during the critical period and are associated with storm or flood events. Compliance with bacteria standards will be greatly improved if pollution discharged during storm events is controlled. Based on the roll-back method, a 43% reduction in fecal coliform is needed during the critical period to meet water quality standards for fecal coliform bacteria.

Estimated fecal coliform loading for Griffin Creek is presented in Figure 40. Loading was estimated using flow discharge measurements from King County's gauging station Site 21A on Griffin Creek. The greatest loading occurred during the critical period.

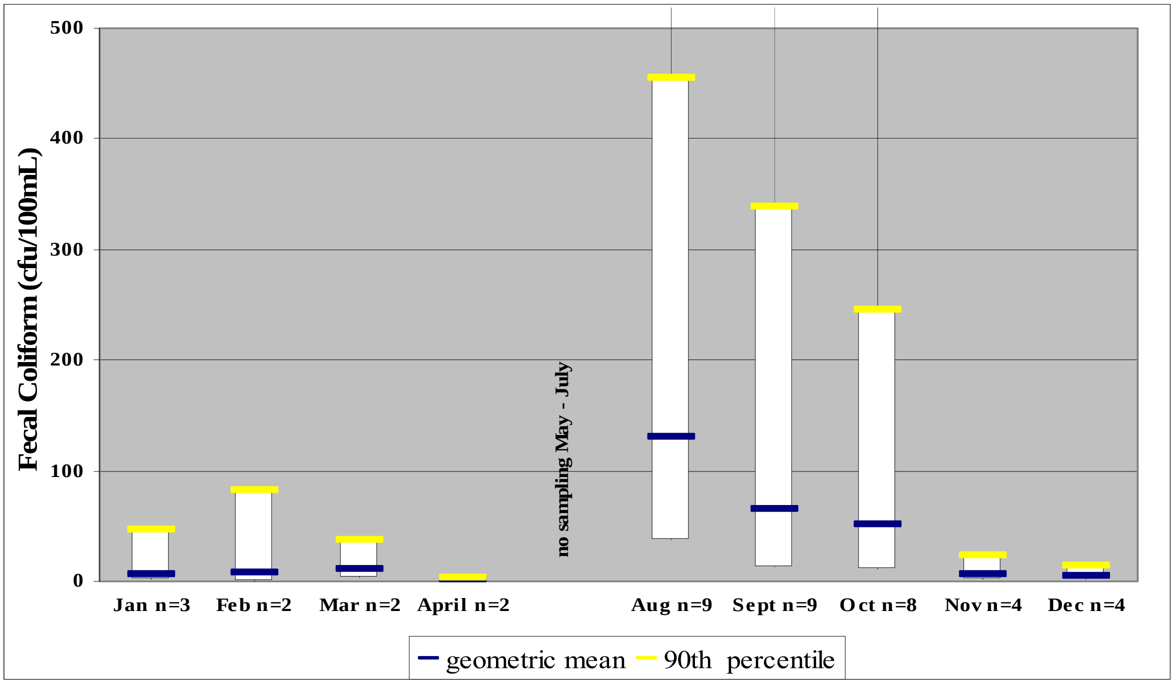

Figure 39. Griffin Creek monthly fecal coliform statistics for August 2003 – February 2005.

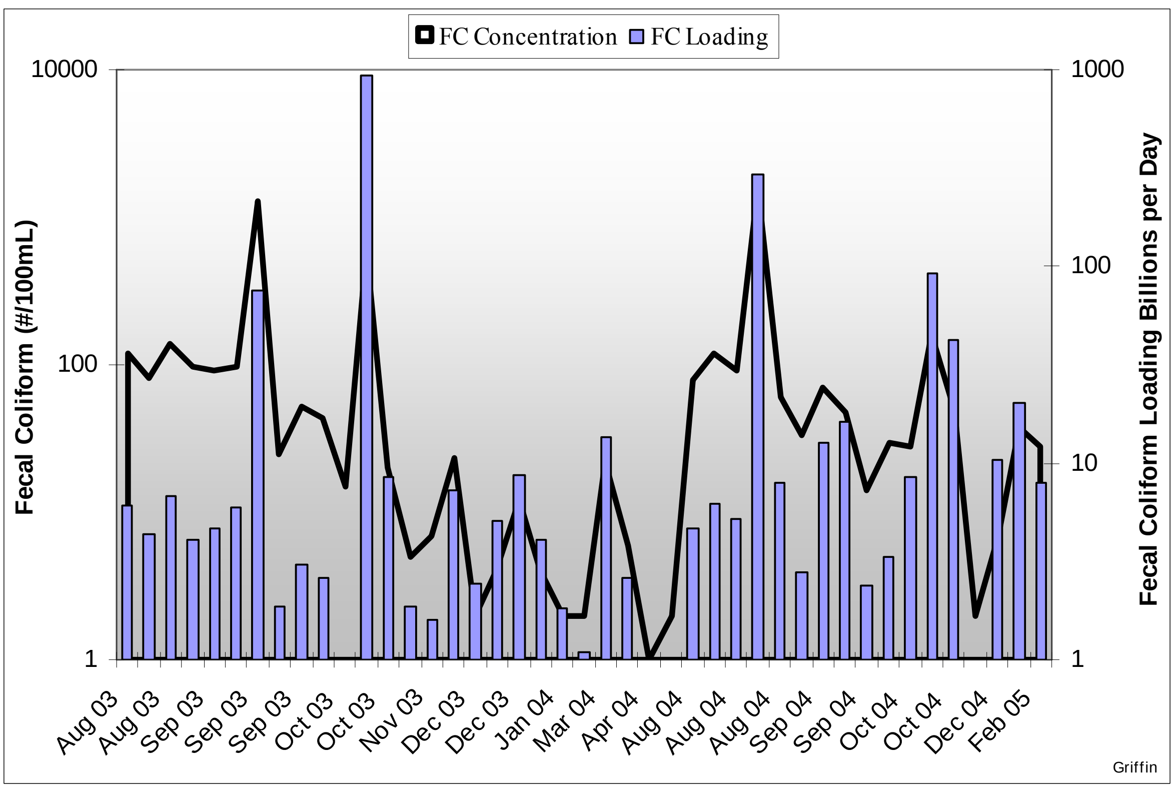

Figure 40. Griffin Creek instantaneous fecal coliform concentrations and estimated daily fecal coliform loading.

Nutrients

Minimal nutrient sampling was conducted on Griffin Creek. The one sample obtained for orthophosphate was less than the TMDL guideline for the tributaries. Ammonia-nitrogen levels were at or below the detection limit.

Field Parameters

No continuous monitoring was conducted on Griffin Creek. During the synoptic surveys, the Griffin Creek site met water quality standards for temperature, dissolved oxygen, and pH.

Intensive Monitoring Survey (August 30-31, 2005)

Compared to other sites, Griffin Creek had moderate levels of nutrients and bacteria. Water quality standards were met for temperature, dissolved oxygen, and pH. Intensive survey monitoring results are fully described in Appendix J.

Conclusions and Recommendations for Griffin Creek

Bacteria levels in Griffin Creek have improved since the original TMDL monitoring (1989-1991) was performed. Although Griffin Creek exceeded water quality standards for fecal coliform bacteria during the critical period, the creek met all standards for all other water quality parameters. During the 2003-05 *Effectiveness Monitoring Study* high bacteria levels were associated with flooding or storm events. Areas where nonpoint bacterial pollution could wash into Griffin Creek need to be evaluated. Because of the relatively small developable area and light development pressure in the Griffin Creek watershed, it should be considered a lower priority on a basin-wide scale. The following actions are recommended to improve bacteria levels in Griffin Creek:

- To address bacterial pollution associated with stormwater runoff, conduct outreach and assistance to rural residential landowners located above Highway 203 regarding small farm practices and proper septic system operation.
- Because water quality below Highway 203 was not evaluated, continue work with the agricultural community to reduce nonpoint runoff that could contain bacteria or nutrients. Install improved buffers or best management practices as needed.

Mainstem Snoqualmie River at RM 25.2

TMDL Implementation and Basin Changes, Snoqualmie River at RM 25.2

Ecology inspected an active dairy (approximately 587 animals, 660 acres) that straddles both the mainstem Snoqualmie River and Patterson Creek. Animals are confined and milked in the portion of the site near the mainstem Snoqualmie River. Dry manure is applied to the Patterson Creek area. Unlike many other dairies, this one has historically used a dry, sand-based process to manage its manure, so it does not generally employ the use of manure guns. Three smaller dairies, that included approximately 307 animals on 146 acres, went out of business in the area.

At least 13 farms were visited in the mainstem area between RM 35.3 and 25.2. Five farm plans were written and 700 feet of fencing was installed. There are also 12 properties totaling about 330 acres that are part of the Farmland Preservation Project. This portion of the mainstem receives stormwater from new development on the surrounding west ridge of the valley.

Water Quality Results for the Snoqualmie River at RM 25.2

Fecal Coliform Bacteria

The Snoqualmie River at RM 25.2 site met water quality standards for fecal coliform during the critical period, wet season, and most months (2003-05) (Figure 41). In August and October, fecal coliform standards were not met due to a single fecal coliform value > 200 cfu/100 mL. Fecal coliform results for the August 23 -24, 2004 sampling events showed that many sites violated the second part of the fecal coliform bacteria standard for August (10% of all samples obtained for calculating the geometric mean shall not exceed 200 cfu/100 mL). A 2.2″ rainfall event on the sampling day, and 0.76″ the previous day, likely caused the October exceedance.

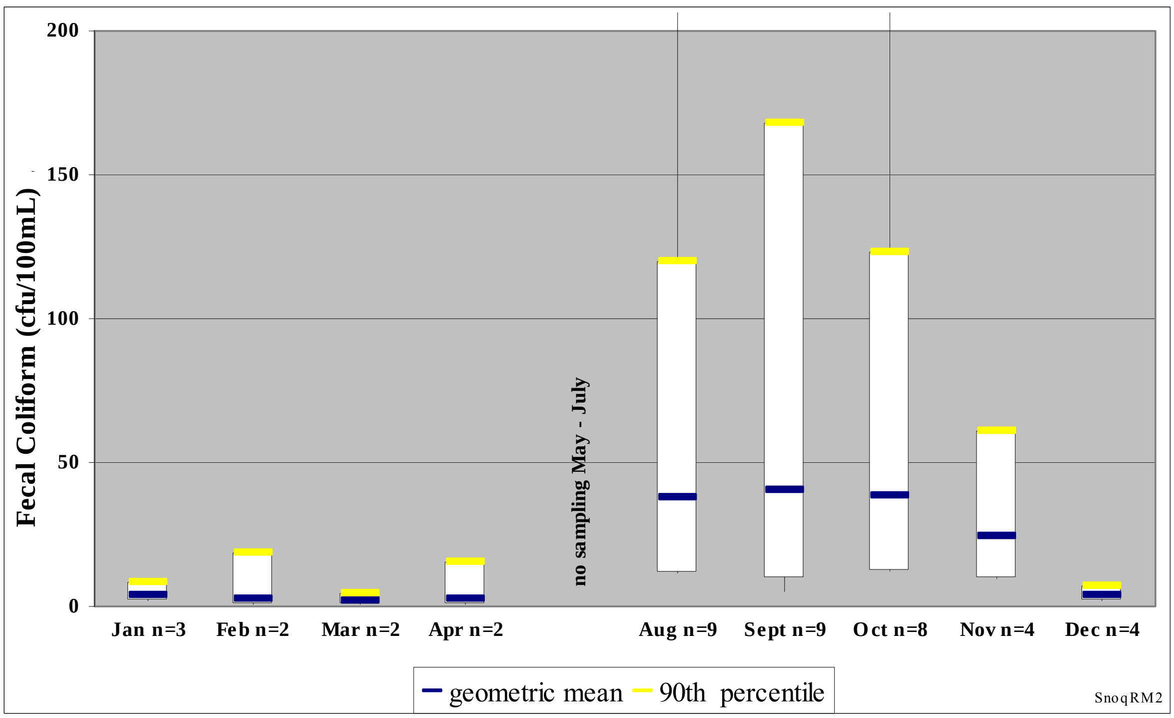

Figure 41. Mainstem Snoqualmie RM 25.2 monthly fecal coliform statistics for August 2003 – February 2005.

Fecal coliform levels have decreased since the 1989-91 *TMDL Study*. The geometric mean fecal coliform level has decreased from 50 to 39 cfu/100 mL. Estimated daily fecal coliform loading for the Snoqualmie River site at RM 25.2 is presented in Figure 42. Flows used to calculate loading were estimated for this site by subtracting flows at USGS gauging station 12148500 at the Tolt River near Carnation (Snoqualmie RM 24.9) from flows at the USGS gauging station 12149000, Snoqualmie River near Carnation at Snoqualmie RM 23.0.

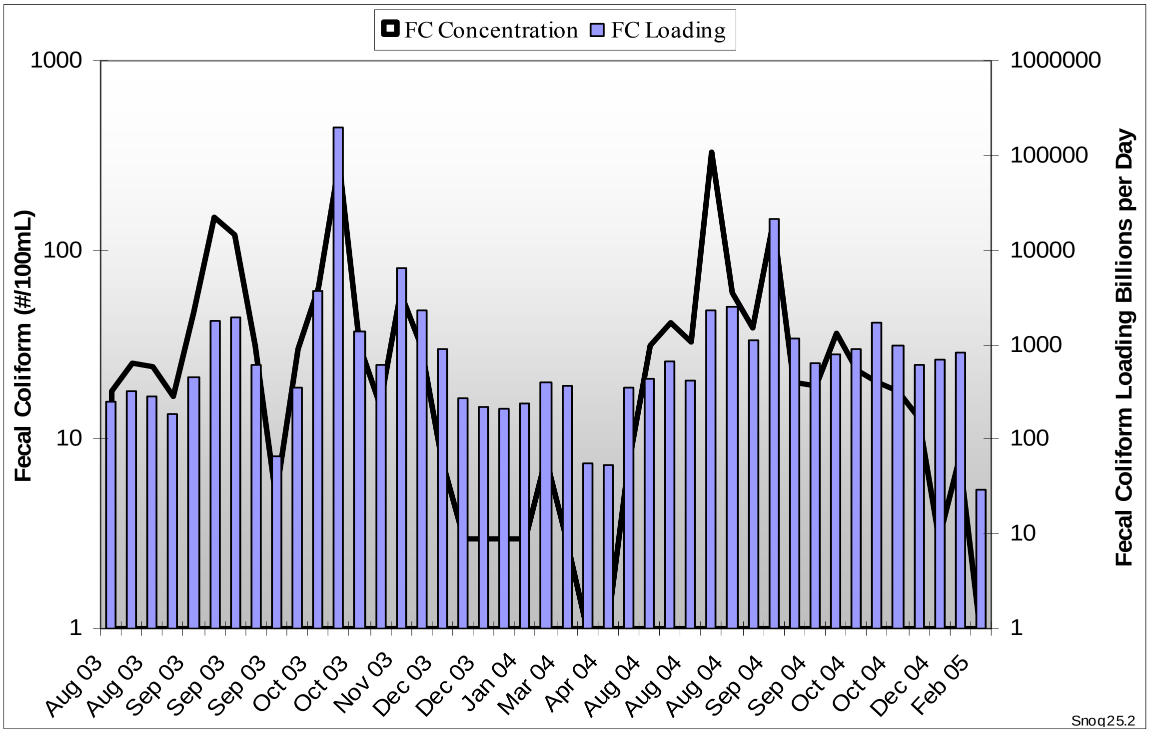

Figure 42. Mainstem Snoqualmie RM 25.2 instantaneous fecal coliform concentrations and estimated daily loading.

Nutrients

More nutrient sampling was done at Snoqualmie RM 25.2 than at other sites. Table 14 presents mean nutrient concentrations for each sampling period. Orthophosphate levels at this site met the mainstem TMDL target limit of 10 µg/L. Nitrogen parameters were generally low.

Table 14. Snoqualmie RM 25.2 mean nutrient concentrations for both sample periods.

Sample Period	Ortho-Phosphate (µg/L)	No. of samples	Nitrite-Nitrate Nitrogen (mg/L)	No. of samples	Ammonia-Nitrogen (mg/L)	No. of samples	Total Persulfate Nitrogen (mg/L)	No. of samples
Aug-Oct: critical period	4	14	0.182	13	0.011	14	0.247	13
Nov-Apr: wet season	5	6	0.261	7	0.011	10	0.315	7

Field Parameters

During the synoptic surveys, this site met water quality standards for dissolved oxygen. Stream temperatures did not meet the water quality standard with higher temperatures obtained during August. There was one pH excursion below the standard at 6.3 SU.

A continuous in-situ meter was deployed at Snoqualmie RM 25.2 during the critical period in 2003, 2004, and 2005. Data from 2004 were rejected because meter accuracy could not be determined; no quality control data were available. Data from 2003 and 2005 met data quality objectives, and data are presented in Figures 43 and 44, respectively.

During the 2003 continuous monitoring period, the lowest dissolved oxygen level was 9.1 mg/L, with a maximum diurnal variation of 0.6 mg/L. The 2005 results were the same, with the lowest dissolved oxygen level at 9.1 mg/L, and a maximum diurnal variation of 0.6 mg/L.

During both years of continuous monitoring, temperature did not meet the water quality standard, with a high of 18.2°C.

Intensive Monitoring Survey (August 30-31, 2005)

Compared to other sites, the mainstem Snoqualmie River site at RM 25.2 had low levels of nutrients and bacteria during the intensive monitoring survey. Water quality standards were met for temperature, dissolved oxygen, and pH. Intensive survey monitoring results are fully described in Appendix J.

Conclusions and Recommendations for Snoqualmie River at RM 25.2

With the exception of high stream temperatures, the mainstem Snoqualmie River site at RM 25.2 had good water quality for the parameters measured. Bacteria levels have improved, likely due to improved management of dairies and participation of local landowners along the mainstem and tributaries in the area. The following actions should be taken to protect and enhance water quality between RM 35.3 and 25.2.

- Continue to provide outreach and assistance to farms in the floodplain. Farm plans are needed for all locations with a potential to discharge stormwater to surface waters or drainage conveyances to surface waters.
- Refer also to the recommendations for Patterson Creek and Griffin Creek.

Tolt River: Snoqualmie RM 24.9

TMDL Implementation and Basin Changes in the Tolt River watershed

There is no dairy activity in the Tolt subbasin, and the land use has stayed relatively constant. Some new residential development has occurred at the eastern edge of the city of Carnation, but the impact of stormwater and on-site sewage treatment systems has not been evaluated. In the upper basin, the Wild Trout Conservancy (formerly Washington Trout) and the University of Washington performed sedimentation and temperature control work above the reservoir on the South Fork Tolt. The work performed included stabilizing hill slopes through road improvements and riparian restoration. King County purchased 37 acres of riparian habitat along the Tolt River. King County also is preparing to set back an existing levee at the confluence with the Snoqualmie to improve water quality and salmon habitat.

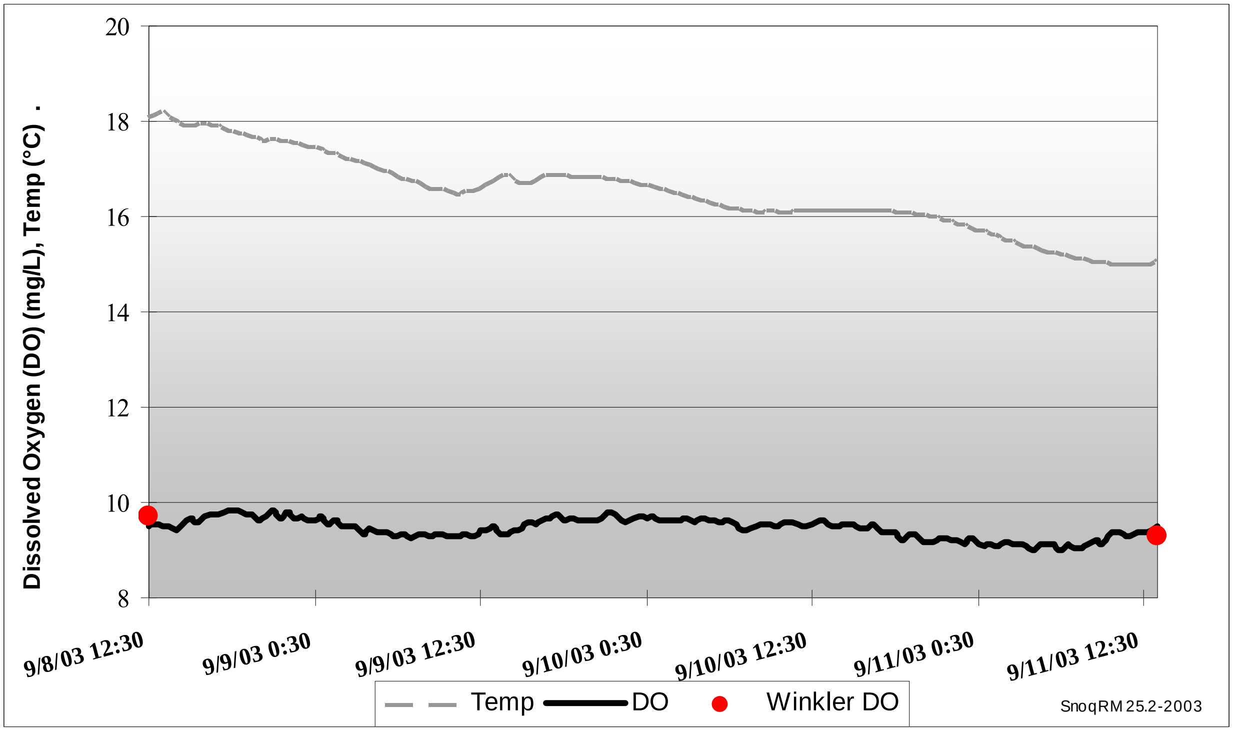

Figure 43. Snoqualmie RM 25.2 continuous temperature, dissolved oxygen, and conductivity readings for September 8-11, 2003.

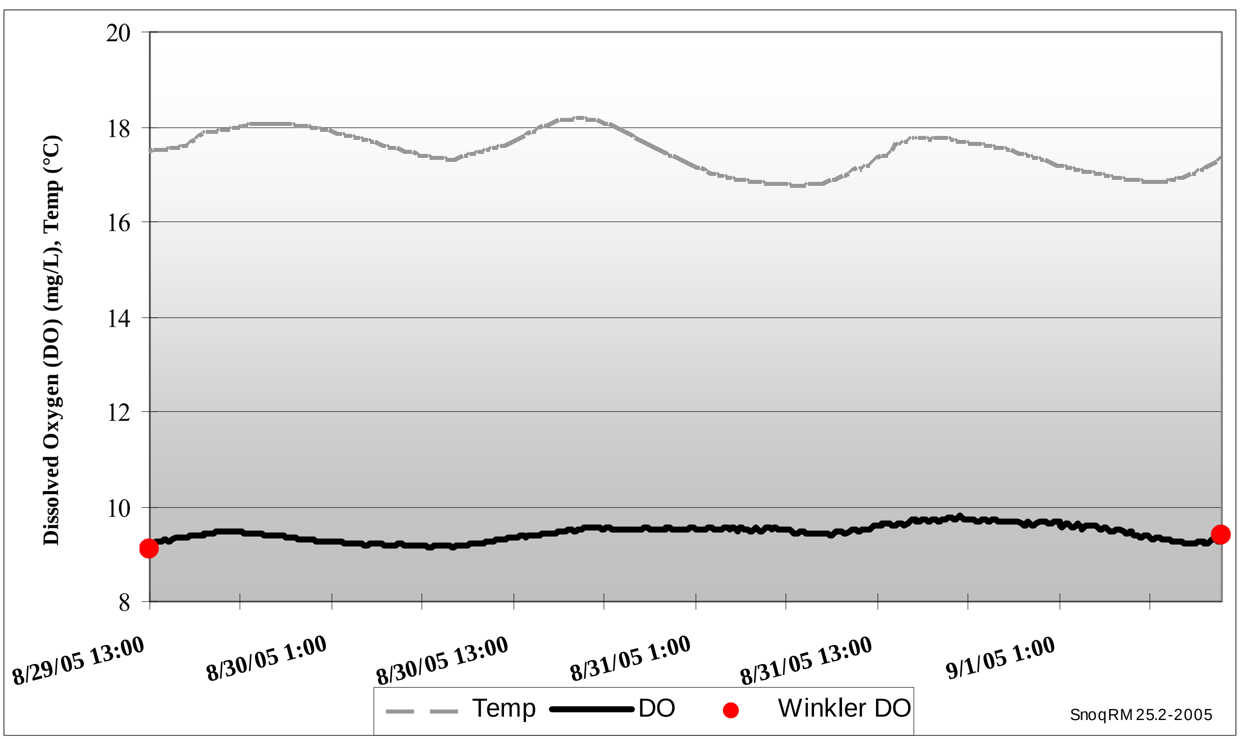

Figure 44. Snoqualmie RM 25.2 continuous temperature, pH, dissolved oxygen, and conductivity readings for August 29 – September 1, 2005.

Two farm plans were prepared in the Tolt watershed and 450 feet of fencing was installed. Seattle Public Utilities manages much of the upper watershed as part of the Tolt Reservoir water supply system and has been purchasing riparian salmon habitat along the lower Tolt River.

Water Quality Results for the Tolt River

Fecal Coliform Bacteria

The Tolt River met water quality standards for fecal coliform bacteria during the August-October critical period and the November-April wet season. Due to one value being > 200 cfu/100 mL in August, the Tolt River did not meet water quality standards for bacteria for that month. Monthly fecal coliform statistics for the Tolt River are presented in Figure 45.

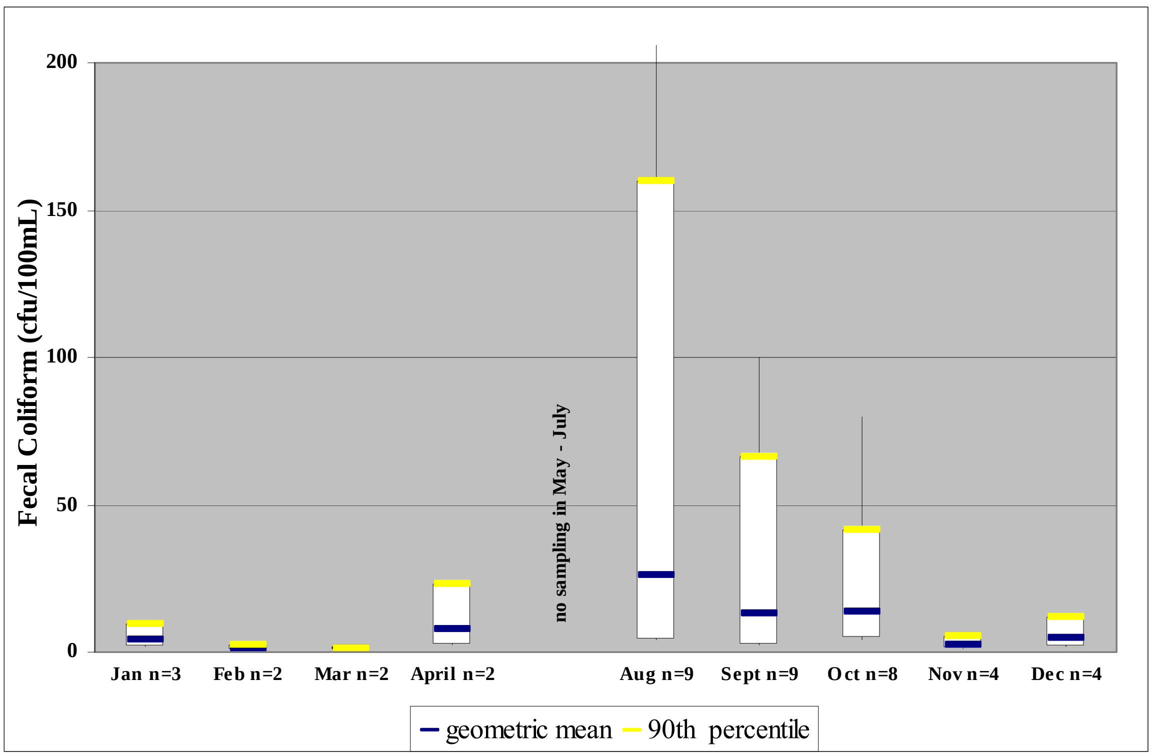

Figure 45. Tolt River monthly fecal coliform statistics for August 2003 – February 2005.

Estimated fecal coliform loading for the Tolt River is presented in Figure 46. Loading was estimated by developing a flow curve relationship with flow at USGS gauging station 12148500 at the Tolt River near Carnation (RM 8.7). Highest fecal coliform loading is seen during the critical period.

Nutrients

Minimal nutrient sampling was conducted on the Tolt River. The one sample obtained for orthophosphate had levels less than the TMDL guideline for the tributaries. Ammonia-nitrogen levels were at or below the detection limit.

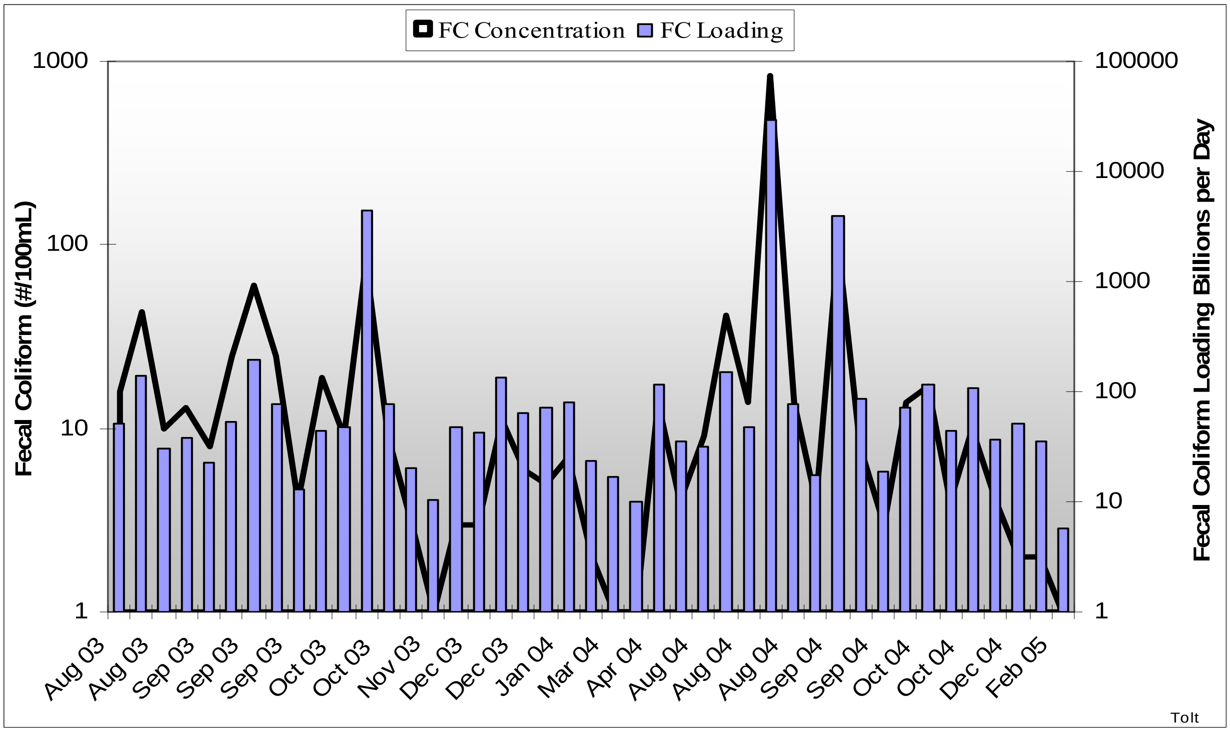

Figure 46. Tolt River instantaneous fecal coliform concentrations and estimated daily loading.

Field Parameters

No continuous monitoring was conducted on the Tolt River. During the synoptic surveys, the Tolt River met water quality standards for temperature and dissolved oxygen. One pH value fell slightly below the standard at 6.4 SU.

Intensive Monitoring Survey (August 30-31, 2005)

Compared to other sites, the Tolt River had some of the lowest bacteria and nutrient levels. Water quality standards were met for temperature, dissolved oxygen, and pH. Intensive survey monitoring results are fully described in Appendix J.

Conclusions and Recommendations for the Tolt River

The Tolt River has good water quality for the parameters measured. The following action is recommended to protect water quality in the Tolt River.

- Properly manage stormwater in all development in the watershed. Use low impact development techniques in new construction projects and in redevelopment to more closely mimic natural hydrologic patterns.

Harris Creek: Snoqualmie RM 21.3

TMDL Implementation and Basin Changes in the Harris Creek Watershed

It is likely that there has been increased rural development (more small farms) in the north fork of Harris Creek. The south fork remained relatively undeveloped. There was fish and wildlife restoration work on 153 acres of private property along Harris Creek and the Snoqualmie River. At least 15 visits were made to local farms resulting in 8 farm plans. About 1,600 feet of fencing, two roof runoff systems, and one heavy protection area was installed in the upper watershed. The entire watershed is served by on-site sewage treatment systems. Within the floodplain area, about 120 acres of farmland is enrolled in the Farmland Preservation Program.

Water Quality Results for Harris Creek

Fecal Coliform Bacteria

Harris Creek did not meet water quality standards for fecal coliform bacteria during the critical period or during the months of August, September, and October. The high values observed were associated with storm events. The original 1989-91 *TMDL Study* reported geometric mean bacteria levels at 43 cfu/100 mL (n=4) compared with 45 cfu/100 mL under recent conditions. Monthly fecal coliform statistics are presented in Figure 47. Harris Creek met fecal coliform standards during the November-April wet season. Based on the roll-back method, a 10% reduction in fecal coliform bacteria levels is needed during the critical period to meet water quality standards.

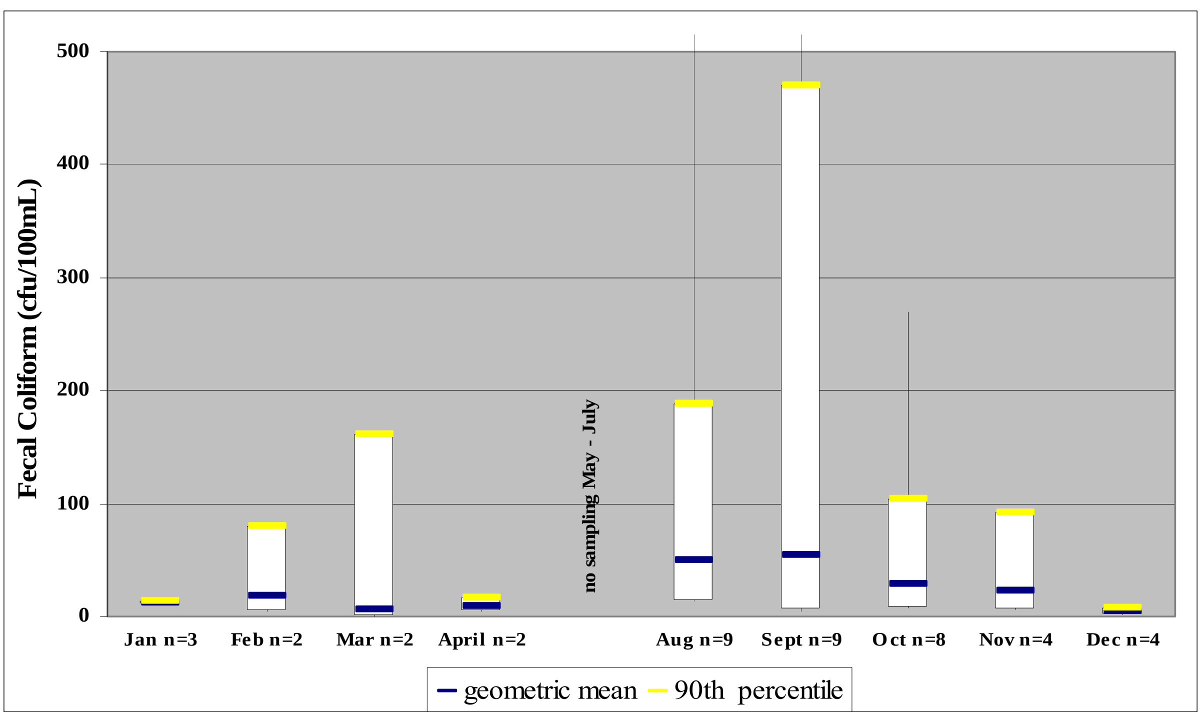

Figure 47. Harris Creek monthly fecal coliform statistics for August 2003 – February 2005.

Estimated fecal coliform loading for Harris Creek is presented in Figure 48. Loading was estimated by developing a flow curve relationship with flow at the Harris Creek King County gauging station 22A. The highest fecal coliform loading was seen during the critical period.

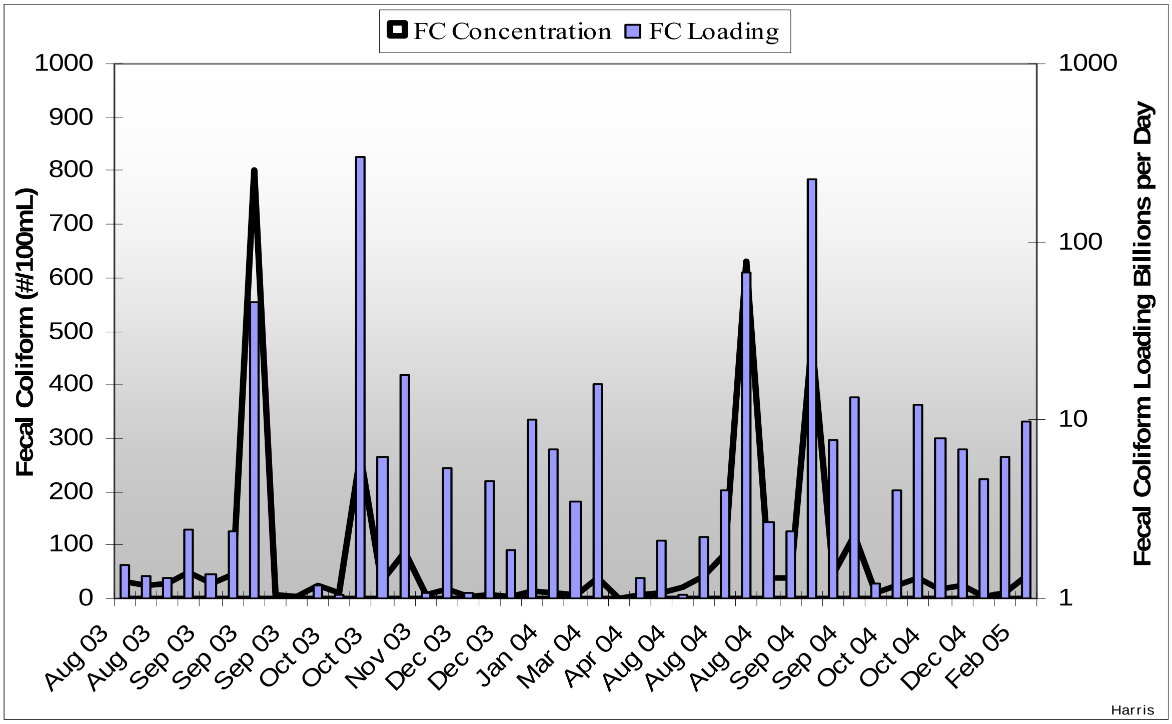

Figure 48. Harris Creek instantaneous fecal coliform concentrations and estimated daily loading.

Nutrients

Minimal nutrient sampling was conducted on Harris Creek. The one sample obtained for orthophosphate was 21 µg/L, slightly exceeding the TMDL guideline of ≤ 20µg/L. Ammonia-nitrogen levels were generally below the detection limit or slightly higher. Nitrite-nitrate levels were elevated, with a mean of 0.732 mg/L (n=3) during the critical period.

Field Parameters

No continuous monitoring was conducted on Harris Creek. During the synoptic surveys, Harris Creek met water quality standards for temperature, dissolved oxygen, and pH.

Intensive Monitoring Survey (August 30-31, 2005)

Compared to other sites, Harris Creek had lower bacteria levels during the intensive survey. Nutrient, especially nitrite-nitrate nitrogen, levels were higher than other sites. Total organic carbon levels were also higher. Water quality standards were met for temperature, dissolved oxygen, and pH. Intensive survey monitoring results are fully described in Appendix J.

Conclusions and Recommendations for Harris Creek

Geometric mean bacteria levels in Harris Creek have remained about the same since the original 1989-1991 TMDL monitoring. However, Harris Creek did not meet fecal coliform water quality standards during the critical period due to high bacteria levels associated with storm events. Areas where nonpoint pollution could wash into Harris Creek need to be evaluated.

The following actions are recommended to improve bacteria levels in Harris Creek:

- Continue to work with the agricultural community and small farms to reduce nonpoint runoff that could contain bacteria or nutrients. Install improved buffers or best management practices as needed. Provide regular outreach to the small farm community.
- Conduct regular inspections or targeted outreach and education to landowners so that on-site sewage treatment systems located near surface waters or drainages are functioning properly.
- Control stormwater management in new development to prevent the introduction of stormwater pollutants into Harris Creek. Use low impact development techniques wherever applicable.

Ames Creek: Snoqualmie RM 17.5

TMDL Implementation and Basin Changes in the Ames Creek Watershed

Four or more dairies ceased operations in the Ames Creek subbasin between 1994 and 2003. First was the Nestle Regional Training Center (approximately 115 mature animals and 250 immature animals on 330 acres). The Chinook Bend planting area near Carnation was donated to King County by Nestle Corporation for salmon habitat restoration. There were many animals grazing this land in the past; now there are trees planted. At least three other dairies totaling approximately 750 animals on 630 acres also went out of business. At least one heifer-raising operation was observed to be in operation during the 2003-05 *Effectiveness Monitoring Study.*

Nine farm plans were prepared in the Ames Creek watershed resulting in the installation of 2,100 feet of fencing, 1 roof runoff management system, and 2 heavy use areas. Eleven parcels of land totally 280 acres have been enrolled in the Farmland Preservation Program.

Ames Creek receives stormwater discharges from residential areas on the west valley plateau. Recently, the 818-acre Nestle Carnation Farm was purchased by Camp Korey, a nonprofit organization that will engage seriously ill children in programs and camp experiences in a medically supportive environment. Activities will have an agricultural theme, and local grounds are expected to support some level of livestock-rearing activities.

Fecal Coliform Bacteria

Ames Creek did not meet water quality standards for fecal coliform bacteria during the August-October critical period or during the months of August, September, October, November, and April. However, since the 1989-91 *TMDL Study* (Joy, 1994), fecal coliform levels have improved greatly (during the critical period) decreasing from a geometric mean of 3291 cfu/100 mL (n=7) to 311 cfu/100 mL (n=26). Wet season (November-April) fecal coliform levels met standards. Monthly fecal coliform statistics are presented in Figure 49. While Ames Creek had high bacteria levels during various months, the highest levels were seen during the critical period. Many, but not all, of the high values were observed in association with rain events. Based on the roll-back method, an 86% reduction in fecal coliform levels is needed during the critical period to meet water quality standards.

Adequate flow data were not obtained for Ames Creek, so fecal coliform loading could not be calculated.

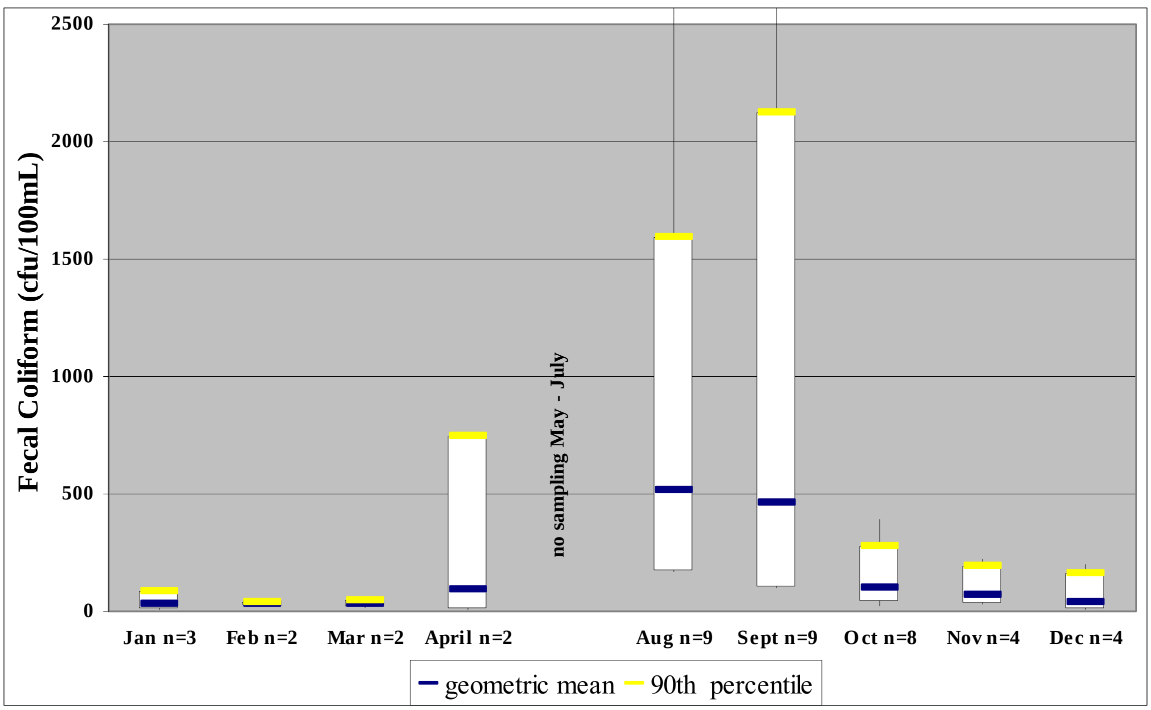

Figure 49. Ames Creek monthly fecal coliform statistics for August 2003 – February 2005.

Nutrients

Minimal nutrient sampling was conducted on Ames Creek. The one sample obtained for orthophosphate was 43 µg/L, higher than the TMDL guideline of ≤ 20 µg/L. Ammonia-nitrogen levels in Ames Creek were higher than at most sites and did not meet the TMDL guideline of ≤ 0.030 mg/L, with a critical period mean of 0.074 mg/L (n=14). The wet season mean was higher at 0.190 mg/L (n=10). Minimal nitrite-nitrate nitrogen sampling was conducted (n=4), but levels were higher than other sites, with a mean of 0.876 mg/L.

Field Parameters

No continuous monitoring was conducted on Ames Creek. During the synoptic surveys, Ames Creek met water quality standard for temperature. Dissolved oxygen and pH levels were below standards. Minimum dissolved oxygen and pH levels occurred in October 2003 with values of 4.6 mg/L and 5.8 SU, respectively.

Intensive Monitoring Survey (August 30-31, 2005)

Ames Creek had the highest fecal coliform bacteria levels of any site sampled. Ames Creek also had some of the highest nutrient and total organic carbon levels. Water quality standards were met for temperature and pH, but, as with the synoptic surveys, dissolved oxygen levels did not meet the standard. Intensive survey monitoring results are fully described in Appendix J.

Conclusions and Recommendations for Ames Creek

While Ames Creek bacteria levels have improved since the original 1989-91 *TMDL Study* (Joy, 1994), water quality is still very poor. The loss of four dairies in the subbasin is likely a factor in bacteria reductions.

Some of the highest bacteria and nutrient levels measured during the study were observed in the Ames subbasin. Higher nutrient levels at this site may account for the low dissolved oxygen levels observed. Excessive nutrients (especially phosphorus in freshwater) can cause excessive algal growth. When those aquatic plants decay or respire at night, low dissolved oxygen levels can occur in the creek. High nutrient and bacteria levels are likely due to animal access to the creek or failing on-site sewage treatment systems.

The following actions should be taken to control bacteria and nutrient pollution levels in Ames Creek:

- Pollution source tracking activities are needed in the Ames Creek subbasin. This includes more intensive water quality monitoring, an examination of municipal and private stormwater conveyance systems for the presence of illicit discharges, and inspection of farms.
- A study of diurnal dissolved oxygen and temperature levels during the critical period should be conducted.
- Compliance with the King County Livestock Ordinance should be evaluated throughout the watershed. Farm plans should be prepared and implemented wherever there is a potential for polluting surface waters. Properties with existing farm plans should be revisited. Properties under Farmland Preservation should also be visited to encourage improved management of riparian areas and drainages to municipal stormwater conveyances.
- On-site sewage treatment systems in close proximity to surface water or drainage conveyances should be evaluated.
- Regular inspections of commercial livestock operations are needed with technical assistance provided to staff at Camp Corey which begins operations in 2008.

Duvall Wastewater Treatment Plant at Snoqualmie RM 11.0

TMDL Implementation and Changes at the Duvall WWTP

During most of the 2003-05 study period (through May 2005), the City of Duvall WWTP provided secondary treatment using an oxidation ditch, followed by traditional clarification and ultraviolet disinfection. As shown in Figure 50, discharges during the study, and afterwards are generally well below the maximum TMDL allocations during the August-October critical period. Seasonal changes in flows suggest considerable inflow and infiltration and reduced plant performance during the winter months. Because the Snoqualmie TMDL focuses on the critical period when plant performance is more stable, inflow and infiltration should not affect the City's ability to meet discharge limits based on TMDL allocations.

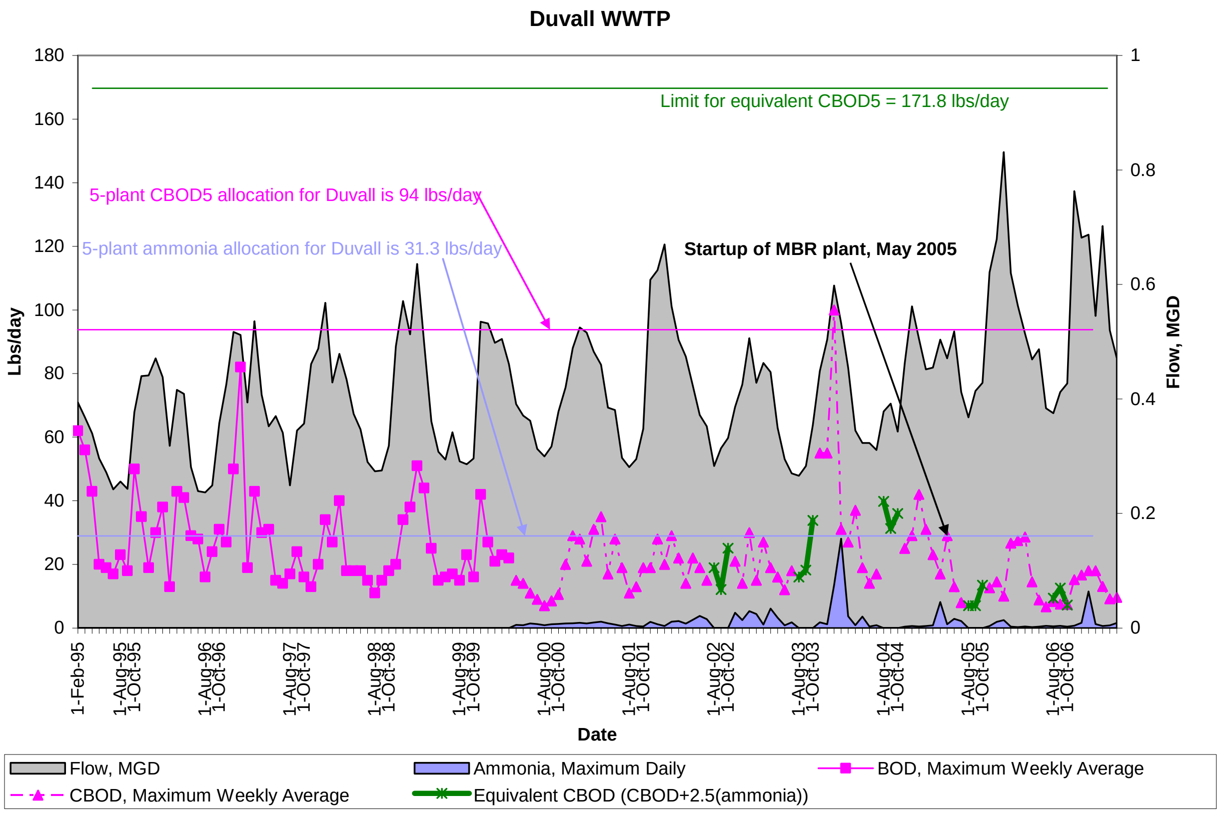

Figure 50. Duvall WWTP compliance with TMDL-required permits.

Duvall completed its WWTP upgrade to a membrane filter bioreactor in May 2005. This change will allow the City an additional measure of confidence that it can meet TMDL-based limits in the future with modest additional growth. The membrane filter treatment facility produces Class A water that is intended for discharge to the river.

Water Quality Results for the Duvall WWTP

In the *TMDL Study* (Joy, 1994), WWTP controls for biochemical oxygen demand (BOD) and ammonia-nitrogen were required the Duvall WWTP (five municipal WWTP scenario including WWTP and nonpoint source controls). Required and recommended controls included:

- BOD5 ≤ 15 mg/L (required)
- Ammonia-nitrogen ≤ 8 mg/L (required)
- Orthophosphate ≤ 2.00 mg/L = 2000 µg/L (recommended)
- Fecal coliform geometric mean ≤ 400/100 mL (recommended)

Discharge monitoring report (DMR) and split sample review: A review of the Duvall WWTP compliance history from 2000 to 2007 showed excellent compliance with NPDES permit limits for ammonia, CBOD, and bacteria levels (Figure 50). No violations were noted.

Ecology conducted minimal sampling of the Duvall WWTP as part of this 2003-05 study. Sampling was not conducted the same day as the mainstem Snoqualmie sites so data could not be compared.

During the 2003-05 *Effectiveness Monitoring* synoptic surveys, fecal coliform levels in the Duvall WWTP discharge were high with levels ranging from 1 to 80,000 cfu/100 mL. Five of the ten samples obtained had bacteria counts greater than 800 cfu/100 mL. In November 2004, the City of Duvall responded to Ecology concerns and replaced the UV bulbs and wipers to improve disinfection levels. On three occasions there were large discrepancies between bacteria sampling results obtained by Ecology and the City.

The one orthophosphate sample obtained was 3,860 µg/L, greater than the TMDL control target of 2,000 µg/L. The one ammonia-nitrogen sample obtained was 17.1 mg/L, also higher than the TMDL control target. Nitrite-nitrate nitrogen varied from 0.092 to 16.5 mg/L (n=8). Water quality criteria and permit requirements for pH were met.

Intensive Monitoring Survey (August 30-31, 2005)

As with the other WWTP discharges, Duvall's had high levels of nutrients and total organic carbon. Fecal coliform bacteria levels were low. Water quality standards were met for pH. No other field parameters were measured. Intensive survey monitoring results are fully described in Appendix J.

Conclusions and Recommendations for the Duvall WWTP

Ecology established permit conditions to control ammonia and carbonaceous biochemical oxygen demand (CBOD) discharges in accordance with the original 1989-91 *TMDL Study*. Compliance with TMDL-related NPDES permit conditions to protect river oxygen levels was good from 2000 to 2007 with no violations reported. Definitive conclusions regarding the water quality discharge from the Duvall WWTP could not be verified by this 2003-05 study due to limited sampling during the critical period. Because permit compliance has been good, no major changes in the operation or permitting of the Duvall WWTP are recommended at this time. A closer evaluation of the laboratory protocols for enumerating bacteria levels is needed to ensure accurate bacteria counts are being provided.

Tuck Creek: Snoqualmie RM 10.3

TMDL Implementation and Basin Changes in the Tuck Creek Watershed

A large rural residential area in located at the headwaters of Tuck Creek. The lower portion of the Tuck Creek subbasin is in agricultural production. It is assumed that there has been at least modest growth in the rural residential area and that a number of small farms exist there. No farm plans appear to have been prepared prior to the 2003-05 monitoring study, although some plans have been created in recently. It is assumed that domestic wastewater is treated solely by on-site sewage treatment systems.

In the floodplain, there was one active dairy in the Tuck Creek subbasin with approximately 300 animals on 200 acres of land. This dairy was still using spray gun technology to distribute manure on land and had made a number of improvements to the facility over the course of the study. However, the dairy is no longer in operation and the site is being used to grow organic herbs. Nearly the entire agricultural production district is enrolled in the Farmland Preservation Program.

What appeared to be dry manure piles were observed by Ecology staff in several fields within the Tuck Creek watershed outside of the growing season. The piles were not located near surface water or drainage ditches; however, assuming it was manure, it was not being applied at agronomic rates.

Water Quality Results for Tuck Creek

Fecal Coliform Bacteria

Bacteria levels in Tuck Creek have increased and now exceed the water quality standards. Tuck Creek did not meet water quality standards for fecal coliform bacteria during the August-October critical period or the months of August, September, October, November, and January. Monthly fecal coliform statistics are presented in Figure 51. The highest bacteria levels in Tuck Creek are seen during the critical period. Based on the roll-back method, a 39% reduction in fecal coliform levels is needed during the critical period to meet water quality standards.

Estimated fecal coliform loading for Tuck Creek is presented in Figure 52. Loading was estimated by developing a flow curve relationship with flow at the Harris Creek King County gauging station 22A. Tuck Creek had very low flow and thus did not contribute much fecal coliform loading to the Snoqualmie River.

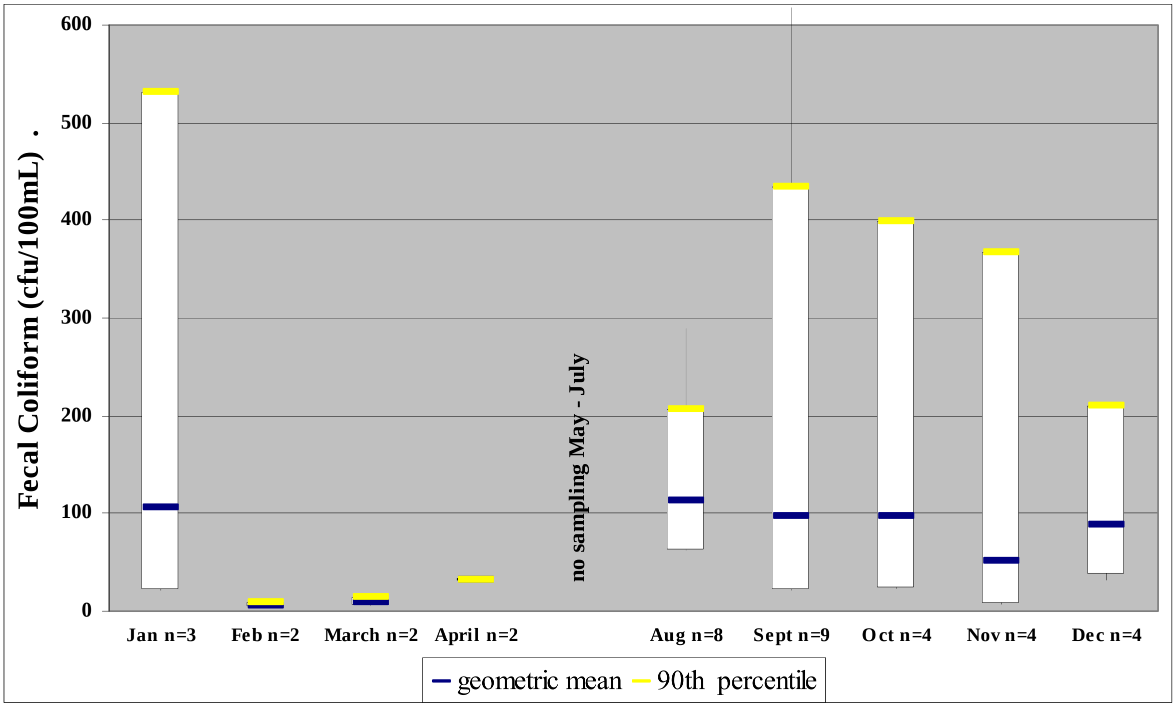

Figure 51. Tuck Creek monthly fecal coliform statistics for August 2003 – February 2005.

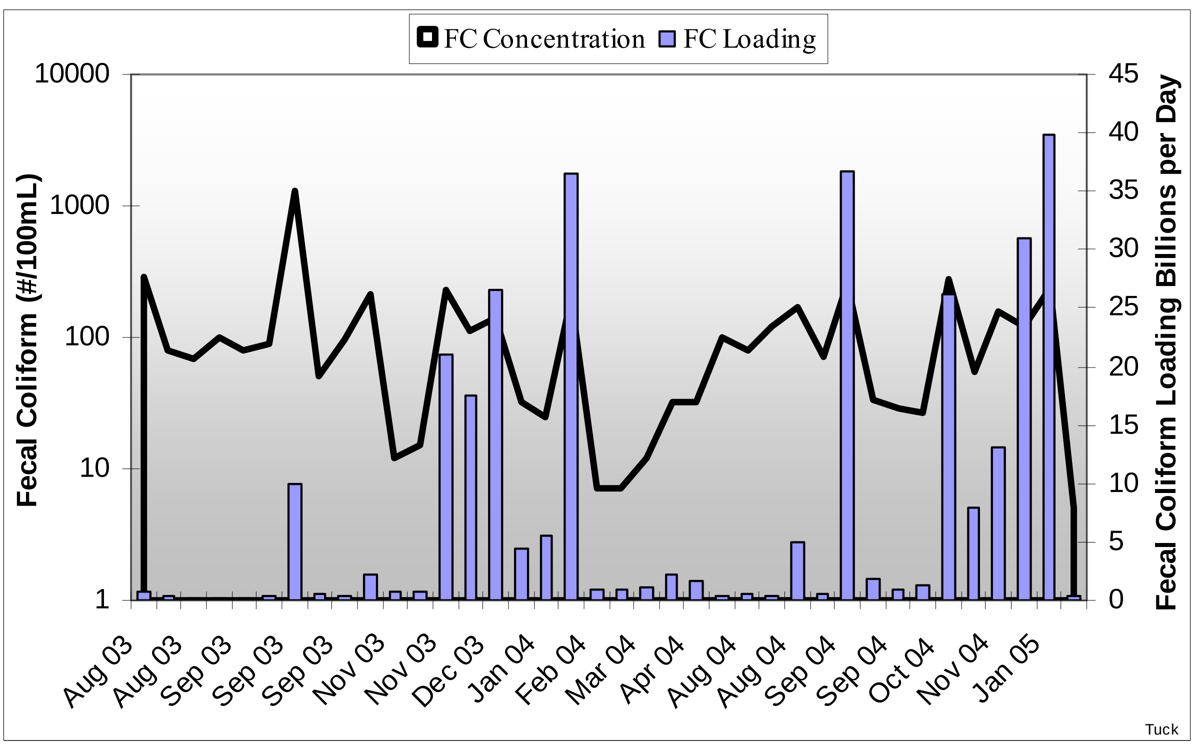

Figure 52. Tuck Creek instantaneous fecal coliform concentrations and estimated daily loading for August 2003 – February 2005.

Nutrients

Minimal nutrient sampling was conducted on Tuck Creek. The one sample obtained for orthophosphate was 38 µg/L, greater than the TMDL guideline of ≤ 20 µg/L. Ammonia-nitrogen levels met the standard but were higher than at other sites, with a critical period mean of 0.028 mg/L (n=10) and a November-April wet season mean of 0.113 mg/L (n=10). Minimal nitrite-nitrate nitrogen sampling was conducted (n=3) but, with a mean of 0.072 mg/L, levels were not high compared to other sites.

Field Parameters

No continuous monitoring was conducted on Tuck Creek. During the synoptic surveys, Tuck Creek met water quality standards for dissolved oxygen. Temperature did not meet standards during August. pH levels fell below standards during December and January.

Intensive Monitoring Survey (August 30-31, 2005)

Tuck Creek had moderately high fecal coliform levels. As with the synoptic surveys, orthophosphate and total organic carbon levels were higher than at most sites. While total nitrogen levels were moderate, a large fraction occurred as ammonia-nitrogen. Water quality standards were met for pH and temperature. Dissolved oxygen levels dropped below the standard. Intensive survey monitoring results are fully described in Appendix J.

Conclusions and Recommendations for Tuck Creek

Tuck Creek has poor water quality that has degraded since the original 1989-91 *TMDL Study*. High bacteria and ammonia-nitrogen levels were seen. Dissolved oxygen, pH, and temperature did not meet water quality standards. Bacteria loading levels were very high during winter months, suggesting improper manure management practices or poor control of stormwater runoff.

The following actions should be taken to control bacteria and nutrient pollution levels in Tuck Creek:

- Because of significant changes in the land use in the floodplain area of Tuck Creek, a reevaluation of the agricultural practices should be made. New landowners should develop farm plans and implement best management practices to control bacteria and nutrient levels.
- A reevaluation of ambient (environmental) water quality should be performed after all farms are visited and farm plans are in place. A diurnal examination of dissolved oxygen levels should be included. Water quality from outside the agricultural production district should be evaluated.
- Compliance with the King County Livestock Ordinance should be evaluated throughout the watershed. Farm plans should be prepared and implemented wherever there is a potential for polluting surface waters. Properties with existing farm plans should be revisited.
- The high winter loadings could be affected by municipal stormwater discharges. Municipal stormwater conveyances should be surveyed for runoff from small farms and illicit discharges.

- On-site sewage treatment systems in close proximity to surface water or drainage conveyances should be evaluated for proper operation.
- To reduce temperature problems, riparian areas without trees should be planted to reduce solar radiation inputs to the creek, and, optimally, to improve riparian microclimates.

Cherry Creek: Snoqualmie RM 6.7

TMDL Implementation and Basin Changes in the Cherry Creek Watershed

The upper half of the Cherry Creek subbasin is forested with little development. Traveling from these headwaters down to the floodplain, there has been considerable rural residential growth. Based on a quick comparison of orthophotography from the 1990s to photos in 2006, the number of developed rural lots in the watershed areas has increased. The King Conservation District made at least 19 visits to local farms, resulting in the development of 12 farm plans. Approximately 2.5 miles (13,700 feet) of fencing was installed along with one composting facility at one farm. About 290 acres of property is enrolled in the Farmland Preservation Program.

In the agricultural production district in the floodplain, there is one dairy with approximately 200 mature and 15 immature animals on 150 acres. At least two inspections were conducted by Ecology staff. The facility uses the injection method instead of spraying for distributing manure. This is more expensive but it controls odors, is better for crops, and greatly minimizes the risk of manure reaching surface waters where drain tiles do not present a problem. The dairy has applied for and received money to put a liner in its undersized manure lagoon.

During the course of this 2003-05 study, a large equestrian boarding facility was being constructed just above the Highway 203 crossing where sampling was occurring. No obvious pollution problems were observed at the farm during the study period. Since the close of the study, ownership and land use at the farm have changed (Higgins, 2007).

In 2006, the Wild Fish Conservancy conducted a study of juvenile salmonid survival in Lateral A, a tributary to Cherry Creek. Fish placed in Lateral A as experimental controls died during the research project. A brief examination of water quality revealed that portions of lateral A had dissolved oxygen levels less that 5.0 mg/L.

Water Quality Results for Cherry Creek

Fecal Coliform Bacteria

Since the 1989-91 *TMDL Study*, Cherry Creek bacteria levels have improved during the August-October critical period. Cherry Creek fecal coliform levels have decreased from a TMDL geometric mean of 307 to 136 cfu/100 mL during the 2003-05 *Effectiveness Monitoring Study*.

Cherry Creek did not meet water quality standards for fecal coliform bacteria during the critical period, but met standards for the November-April wet season. Monthly fecal coliform statistics are presented in Figure 53. Based on the roll-back method, a 63% reduction in fecal coliform levels is needed during the critical period to meet water quality standards. Adequate flow data were not obtained for this site, so fecal coliform loading information is not available.

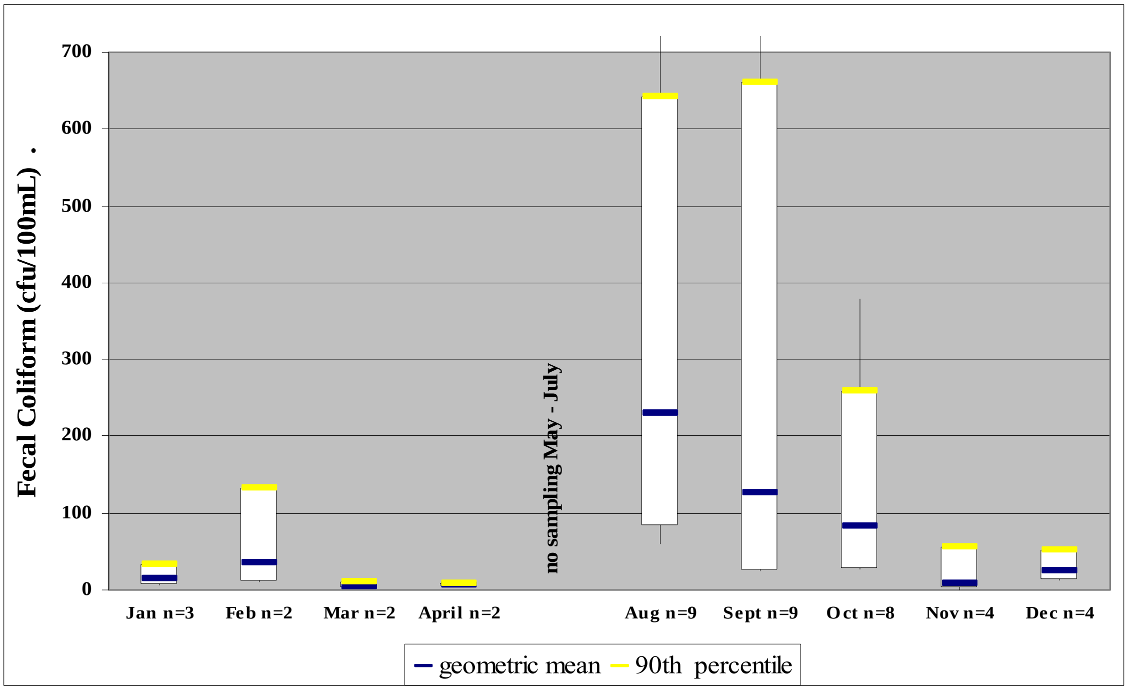

Figure 53. Cherry Creek monthly fecal coliform statistics for August 2003 – February 2005.

Nutrients

Minimal nutrient sampling was conducted on Cherry Creek. The one sample obtained for orthophosphate was 13 µg/L below the TMDL guideline of ≤ 20 µg/L. Both the 2003 and 2004 sampling periods had similar ammonia-nitrogen levels, with a yearly mean of 0.029 mg/L (n=24), just below the TMDL guideline of 0.030 mg/L. Minimal nitrite-nitrate nitrogen sampling was conducted and, with a mean of 0.404 mg/L (n=3), levels were higher than most sites.

Field Parameters

No continuous monitoring was conducted on Cherry Creek. During the synoptic surveys, Cherry Creek did not meet water quality standards for temperature, dissolved oxygen, or pH. Higher stream temperatures were observed in August. Low dissolved oxygen values were accompanied by low pH levels during the October 28, 2003 and August 31, 2004 sampling events

Intensive Monitoring Survey (August 30-31, 2005)

Compared to other sites, Cherry Creek had high fecal coliform levels and moderately high nitrogen and total organic carbon levels. Temperature and pH met water quality standards during the intensive survey. Dissolved oxygen levels were below the standard. Intensive survey monitoring results are fully described in Appendix J.

Conclusions and Recommendations for Cherry Creek

While Cherry Creek bacteria levels have improved since the 1989-91 *TMDL Study* (Joy, 1994), this site continues to have poor water quality. Fecal coliform standards are not met during the critical period. Dissolved oxygen, pH, and temperature levels did not meet standards.

Ecology recommends the following actions to control bacteria and nutrient pollution levels in Cherry Creek:

- The local dairy and any commercial livestock operations in Cherry Creek should be inspected regularly. New landowners should develop farm plans and implement best management practices to control bacteria and nutrient levels.
- Compliance with the King County Livestock Ordinance should be evaluated throughout the watershed. Additional farm plans should be prepared and implemented wherever there is a potential for polluting surface waters. Properties with existing farm plans should be revisited.
- An evaluation of ambient water quality should be performed. A diurnal examination of dissolved oxygen levels should be included. Water quality from outside the agricultural production district should be evaluated. A special study on pollution sources and environmental characteristics of Lateral A is needed.
- The high loadings during wet weather events could be partially due to contaminated municipal stormwater discharges. Illicit discharge detection and elimination should be conducted on municipal stormwater conveyances for runoff from small farms and illicit discharges.
- On-site sewage treatment systems in close proximity to surface water or drainage conveyances should be evaluated for proper operation.
- To reduce temperature problems, riparian areas without trees should be planted to reduce solar radiation inputs to the creek, and, optimally, to improve riparian microclimates.

Mainstem Snoqualmie River at RM 2.7

TMDL Implementation and Basin Changes, Snoqualmie Mainstem RM 2.7

Pollution discharges reaching RM 2.7 are a combination of all upstream sources and a number of dairies. Land in the floodplain is used primarily for agriculture. Outside the floodplain, there has been significant residential growth, especially in the Duvall area. There are numerous small streams that discharge into the mainstem Snoqualmie River below RM 25.3. It is expected that stormwater discharges through these tributaries have increased significantly since the original 1989-91 *TMDL Study*. The original study modeled a number of unknown nonpoint pollution sources to account for high bacteria loading in this part of the watershed.

Eight dairies with about 1,500 animals on over 720 acres (acreage data not available for some facilities) ceased operation prior to the beginning of this 2003-05 *Effectiveness Monitoring Study*, thus removing a number of potential pollution sources. Six dairies were still in operation during this 2003-05 study with an estimated 2450 mature and immature animals on about 2000 acres. During the 1994-2004 TMDL implementation period, Ecology performed at least 26 inspections and issued at least 17 warning letters and Notices of Noncompliance. Two facilities received citations for continued noncompliance problems. Land use remains agricultural, and some facilities are raising beef cattle now. One dairy facility was converted to a commercial composting operation.

At least 24 visits have been made to local farms resulting in ten farm plans. About 1800 feet of fencing, 2 heavy-use protection areas, and 1 roof-runoff management system was installed as part of farm plan implementation. Over 3,000 acres of land in the agricultural production district was enrolled in the Farmland Preservation Program.

In recent years, the Tulalip Tribe has worked closely with the local dairy community and, as a result, formed the Qualco Energy Cooperative. The Cooperative has researched and obtained funds to construct a methane digester on the land donated to the Tulalip Tribe by the state government (former Monroe Correctional Facility). Baseline characterization of local stream and ditch water quality is being evaluated now by Washington State University Extension Service. This evaluation is part of a project to examine how the use of digested manure products reduces animal pathogens and otherwise affect agricultural operations.

Water Quality Results for the Snoqualmie River at RM 2.7

Fecal Coliform Bacteria

The Snoqualmie River at RM 2.7 meets water quality standards for fecal coliform bacteria during the critical period, wet season, and all months with the exception of August and September (2003-05). During these months, a single value > 200 cfu/100 mL caused the standard to be exceeded. Fecal coliform results for the August 23 -24, 2004 sampling events showed many sites violated the second part of the fecal coliform bacteria standard for August (10% of all samples obtained for calculating the geometric mean shall not exceed 200 cfu/100 mL). Rainfall amounts preceding the September sampling event were not particularly high. Monthly fecal coliform statistics are presented in Figure 54.

Fecal coliform loading was not calculated for the Snoqualmie River site at RM 2.7 due to lack of flow discharge data.

No statistically significant differences were seen in fecal coliform concentrations between the mainstem Snoqualmie River sites at RM 25.2 and 2.7 (α=0.05) for the August-October critical period, the November-April wet season, or for both periods combined.

Nutrients

More nutrient sampling was conducted at this site compared to other sites. Table 15 presents mean nutrient concentrations for each sampling period. Mean orthophosphate levels at this site did not exceed the mainstem TMDL limit of 10 µg/L. But on two dates, October 28, 2003 and September 14, 2004, orthophosphate levels were greater than 10 µg/L, at 13 and 19 µg/L respectively. Nitrogen parameters were not high.

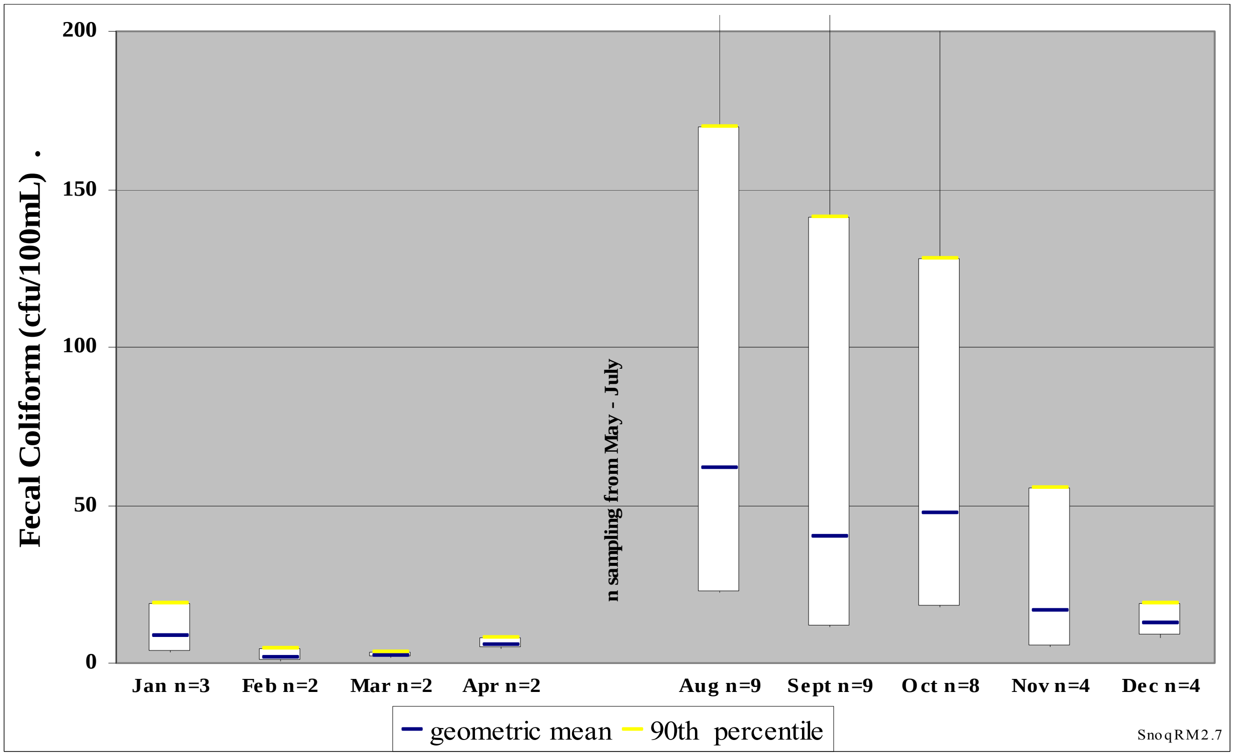

Figure 54. Mainstem Snoqualmie RM 2.7 monthly fecal coliform statistics for August 2003 – February 2005.

Table 15. Snoqualmie RM 2.7 mean nutrient concentrations for both sample periods.

Sample Period	Ortho-phosphate (µg/L)	No. of samples	Nitrite-Nitrate Nitrogen (mg/L)	No. of samples	Ammonia-Nitrogen (mg/L)	No. of samples	Total Persulfate Nitrogen (mg/L)	No. of samples
Aug-Oct: critical period	7	14	0.215	13	0.014	13	0.310	13
Nov-Apr: wet season	6	6	0.300	7	0.013	10	0.367	7

Field Parameters

During the synoptic surveys, this site met the water quality standard for dissolved oxygen. Temperature did not meet the water quality standard with elevated stream temperatures in August and September. One pH value was below the standard at 6.2 SU.

Continuous in-situ field monitors were deployed at the Snoqualmie River site at RM 2.7 during the critical period in 2003, 2004, and 2005. Data from all years met data quality objectives (Figures 55, 56 and 57).

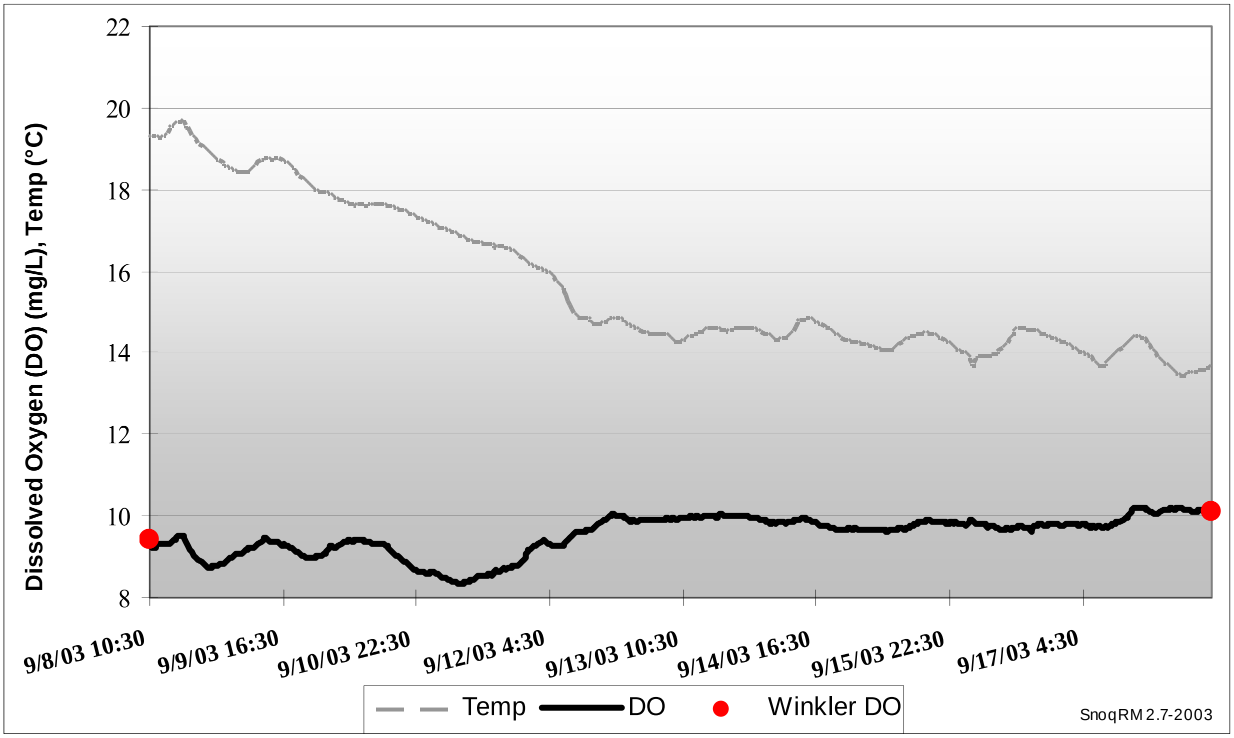

Figure 55. Mainstem Snoqualmie RM 2.7 continuous temperature and dissolved oxygen readings for September 8 – 18, 2003.

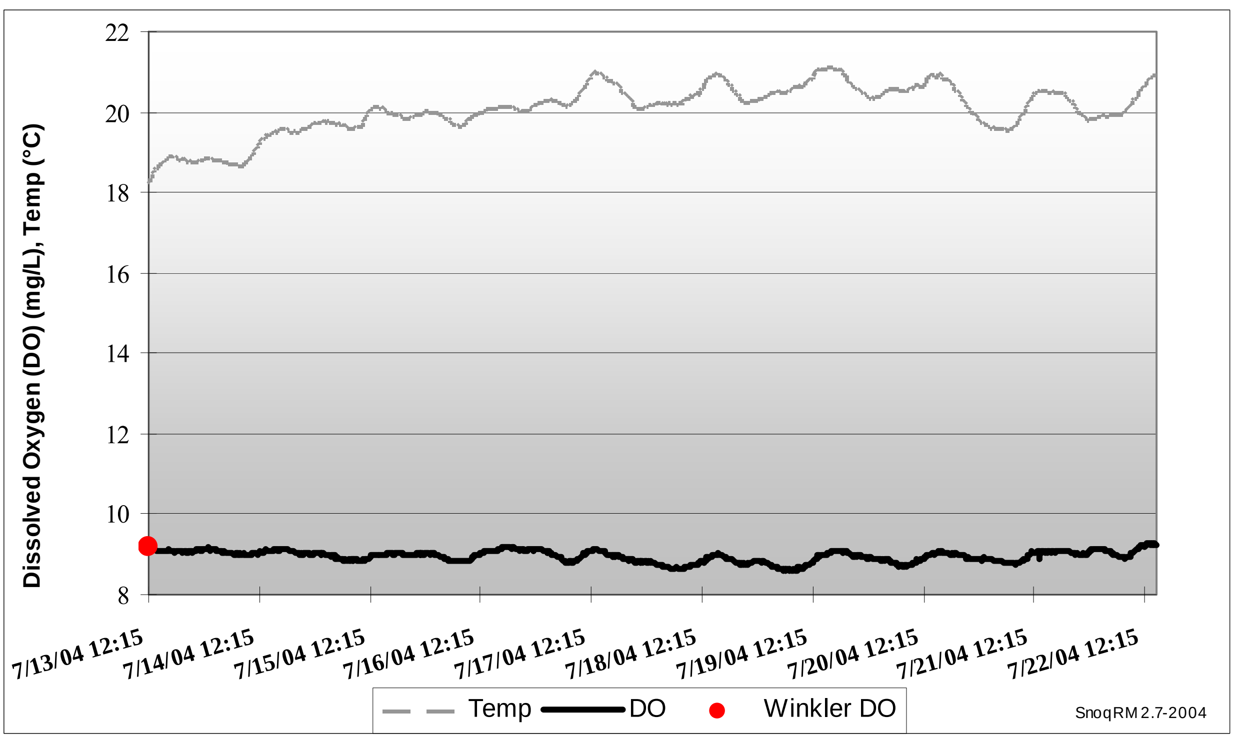

Figure 56. Mainstem Snoqualmie RM 2.7 continuous temperature and dissolved oxygen readings for July 13 – 22, 2004.

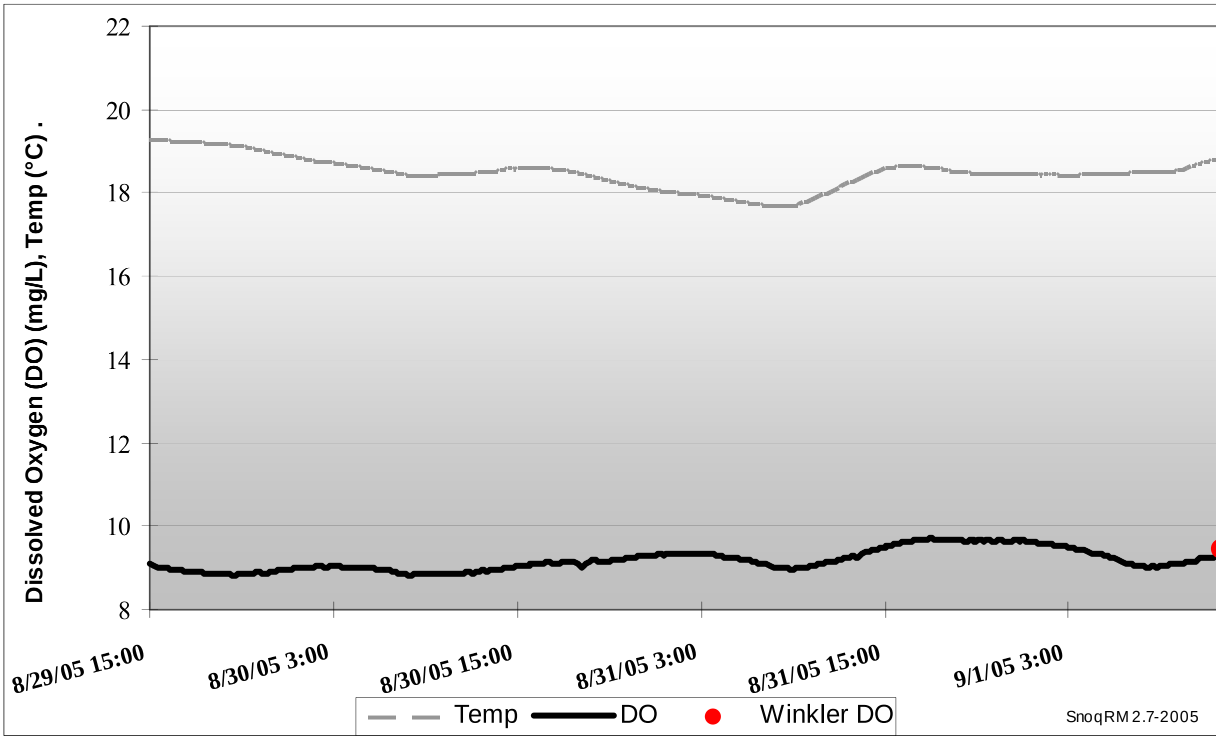

Figure 57. Mainstem Snoqualmie RM 2.7 continuous temperature and dissolved oxygen readings for August 29 – September 1, 2005.

During the 2003 continuous monitoring period, the lowest dissolved oxygen level was 8.3 mg/L, with a maximum diurnal variation of 0.8 mg/L, and an average daily minimum value of 9.2 mg/L. With a high of 19.7°C, temperature did not meet water quality standard (Figure 55).

During the 2004 continuous monitoring period, the lowest dissolved oxygen level was 8.6 mg/L, with a maximum diurnal variation of 0.5 mg/L, and an average daily minimum value of 8.8 mg/L. With a high of 21.1°C, temperature did not meet water quality standard (Figure 56).

During the 2005 continuous monitoring period, the lowest dissolved oxygen level was 8.8 mg/L, with a maximum diurnal variation of 0.7 mg/L, and an average daily minimum value of 8.9 mg/L. With a high of 19.3°C, temperature did not meet water quality standards (Figure 57).

The dissolved oxygen results met TMDL targets, but monitoring did not occur during the 7Q20 critical period. Lowest flows during continuous monitoring occurred in 2005.

Intensive Monitoring Survey (August 30-31, 2005)

Compared to other sites, the mainstem Snoqualmie River site at RM 2.7 had low levels of nutrients and bacteria during the intensive monitoring survey. Water quality standards were met for dissolved oxygen and pH, but the water quality temperature standard was not met. Intensive survey monitoring results are fully described in Appendix J.

Conclusions and Recommendations for the Snoqualmie River RM 2.7

With the exception of high stream temperatures, the mainstem Snoqualmie River site at RM 2.7 has good water quality for the parameters measured. The following recommendations are made to maintain good water quality in the lower mainstem Snoqualmie River.

- The local dairy and commercial livestock operations should be inspected regularly. New landowners should develop farm plans and implement best management practices to control bacteria and nutrient levels.
- Compliance with the King County Livestock Ordinance should be evaluated throughout the portion of the watershed located in King County.
- In lieu of developing and enforcing a livestock ordinance, Snohomish County should work with the Snohomish Conservation District to (1) periodically assess the status of water quality in the Snohomish County portion of the watershed, and (2) help to ensure that best management practices are in place at local farms.
- Additional farm plans should be prepared and implemented wherever there is a potential for polluting surface waters. Properties with existing farm plans should be revisited.
- On-site sewage treatment systems in close proximity to surface water or drainage conveyances should be evaluated for proper operation.
- Illicit discharge detection and elimination should be conducted on municipal stormwater conveyances to ensure they are not contributing excessive nutrients or bacteria to the watershed.
- To reduce temperature problems, riparian areas on small tributary streams should be evaluated. Streams without trees should be planted to reduce solar radiation inputs to the creek, and optimally, to improve riparian microclimates.
- Continuous diurnal dissolved oxygen and temperature monitoring should be conducted during the 7Q20 low-flow critical period to determine compliance with TMDL targets for dissolved oxygen.

This page is purposely left blank

Recommended Actions to Improve Water Quality in the Snoqualmie River Basin

Ecology, local tribes, local governments and agencies, private organizations, businesses, and citizens in the Snoqualmie watershed have made good progress in protecting and improving water quality in the Snoqualmie River and its tributaries. Water quality has improved, or is at acceptable levels, at many locations tested during this 2003-05 *Effectiveness Monitoring Study*. The broad scope of this study gives us good confidence that we know what to do, and where to do it, to return the remaining polluted areas to good health.

Ecology has high expectations for reaching many of its water quality goals over the next five or more years. Although the effects of individual actions could not be measured, a number of programs were essential to the progress made to date. These programs should continue, and in some cases, expand their activities. Following is a discussion of these programs:

- **Ecology NPDES Permitting Program.** Ecology should continue to monitor the performance of wastewater treatment plants (WWTPs) in the Snoqualmie basin. To protect dissolved oxygen levels, this program has been very effective in controlling WWTP discharges of oxygen-consuming substances. Issuing permits to the three existing and one future WWTP is critical to protecting dissolved oxygen levels in the Snoqualmie River.

  The municipal stormwater permit activities of King County and the City of Duvall will also contribute to reducing bacteria and nutrient problems to the watershed. Low impact development (LID) practices should be considered in both new construction and retrofit situations to prevent new sources of stormwater and reduce the impact of existing ones. Because this 2003-05 *TMDL Effectiveness Monitoring Study* did not quantify the contribution of municipal stormwater pollution to bacterial and nutrient problems, no additional requirements are being added to those permits at this time.

- **Washington State Department of Agriculture (WSDA)/Ecology.** Continued, regular inspections of dairies by the WSDA are needed. Changes in dairy management practices, as well as reductions in the number of dairies, are believed to have contributed to the improvement in water quality in the Snoqualmie River watershed. Many problems were documented and resolved, resulting in reduced discharges of manure.

- **King Conservation District (KCD)/Natural Resource Conservation Service (NRCS).** Ecology recommends continued vigorous activities by the KCD, including program augmentations such as targeted educational efforts and door-to-door visits, increased number of follow-up visits to existing farms, and visits to farms when ownership changes hands. Continued support of dairy farm plan development and funding by the NRCS for watershed best management practices are needed. The NRCS should consider including TMDL impairment/implementation as a criteria for selection in its grant-funding activities.

Educational and technical assistance programs offered by the KCD and NRCS were valuable based on the large number of farm plans written and the number of best management practices installed. Because KCD actions are based on voluntary compliance by landowners or referrals by the King County Livestock Program, KCD's ability to prepare plans is dependant on the quality of enforcement and outreach to the community. Ecology anticipates that the new KCD-Snoqualmie Forum Opportunity Fund will be valuable in improving and maintaining water quality in the future.

- **King County.** King County should continue its comprehensive approach to improve watershed health through technical and financial assistance to the agricultural community, timely revisions to Growth Management Act requirements, salmon recovery efforts, and enforcement of existing regulations. The County is encouraged to maintain its existing level of effort in the basin and to explore the use of Ecology's Centennial Grant Funds to perform additional studies and pollution correction activities in the Snoqualmie River watershed. Ecology also encourages the County to work with the Snoqualmie Tribe, other local jurisdictions, and Ecology to develop and participate in a long-term water quality monitoring network that provides representative data for all key tributaries.

- **Snoqualmie Watershed Forum.** This report recommends that the Forum integrate water cleanup activities into its present watershed enhancement priorities. The Forum's past efforts have focused largely on chinook salmon recovery. Improving water quality, especially temperature problems, is expected to have an important effect on the health of the overall salmonid fishery in the Snoqualmie River watershed.

- **Public Health District.** Ecology believes that the proper regulation and management of on-site sewage treatment systems is critical to improving and maintaining the health of the Snoqualmie River watershed.

  Both the Public Health of Seattle and King County (PHSKC) and the Snohomish Health District should continue to respond promptly to reports of on-site sewage treatment system failures, provide technical assistance, and require corrective actions where necessary. Continuing education of private homeowners on system maintenance is needed. This report highly recommends establishing adequate staffing and resources to meet the need for sanitary surveys and other direct investigative strategies to locate and resolve the problem of failing on-site sewage treatment systems.

  If the collaborative project between the Snohomish Health District and Snohomish County to identify and address areas with failing on-site sewage treatment systems is shown to be effective, the project should be replicated in the Snoqualmie watershed to address areas needing investigation and possible correction.

The major activities to improve water quality in the Snoqualmie River basin during 1994 through 2003, and their effect on local water quality, have been discussed above. In recent years, more groups and activities are in place to improve water quality in the basin. A discussion of those organizations is provided earlier in this report under the heading, *What Was Done to Improve Water Quality?* More detailed recommendations for future action are provided following the review of water quality data in the upper and lower watersheds earlier in this document. Table 16 provides a summary of the major activities needed, listed by subbasin.

Finally, regular monitoring of water quality is needed in the Snoqualmie River watershed. Other than the two sites monitored by Ecology, and limited monitoring by King County at selected road crossings, no long-term monitoring plan exists for the watershed. In order to understand and track changes in water quality over time, long-term (monthly) sampling and special studies are needed (Table 16).

Table 16. Summary of major water quality cleanup activities and monitoring needed in the Snoqualmie basin.

Subbasin location	Best Management Practices						Monitoring		
	Improve riparian shading*	Illicit discharge detection & elimination	Investigate agricultural practices	Prevent future stormwater impacts	Survey on-site sewage systems	Reduce phosphorus discharges	Additional study	Long-term	Periodic
Upper Snoqualmie basin									
Middle Fork	X								X
North Fork	X								X
South Fork at RM 2.0									X
North Bend WWTP						X			
South Fork at RM 1.5		X	X	X			X	X	
Snoqualmie RM 42.3				X				X**	
Kimball Creek	X	X	X	X	X		X	X	
Lower Snoqualmie basin									
Snoqualmie RM 40.7							X		X
Tokul Creek							X		X
Raging River	X						X	X	
Snoqualmie RM 35.3		X	X	X			X	X	
Patterson Creek	X	X	X	X	X		X	X	
Griffin Creek			X		X				X
Snoqualmie RM 25.2			X						X
Tolt River				X					X
Harris Creek			X	X	X			X	
Ames Creek		X	X	X	X		X	X	
Tuck Creek	X	X	X	X	X		X	X	
Cherry Creek	X	X	X	X	X		X	X	
Snoqualmie RM 2.7	X	X	X	X	X			X**	

* Due to downstream temperature problems, investigation of additional shading opportunities is recommended for all tributaries.
** Currently performed by the Washington State Department of Ecology (Ecology).

References

APHA, AWWA and WEF, 1998. Standard Methods for the Examination of Water and Wastewater 20th Edition. American Public Health Association, Washington, D.C.

Aroner, E.R., 2002. WQHYDRO: Water Quality/Hydrology Graphics/Analysis System (Version 2040). Portland, OR.

Atwill, R., 2006. Rangeland cattle and the risk of waterborne Cryptosporidium parvum infection in humans. Department of Population Health & Reproduction and Veterinary Medicine Extension, Veterinary Medicine Teaching and Research Center, School of Veterinary Medicine, University of California, Davis, 18830 Road 112, Tulare, CA 93274. From UC Davis website @ www.vetmed.ucdavis.edu/vetext/INF-EC_Nev98C.html

Callahan, Cindy, 2003. Personal communication, Salmon Recovery Inspector, Washington State Department of Ecology, Northwest Regional Office, 31890 SE 160th Ave SE, Bellevue, WA 98008.

Center for Watershed Protection, 1999. Microbes in Urban Watersheds. Feature article II. Watershed Protection Techniques, Vol 3, No. 1, April 1999. Ellicott City, MD.

Chang, G. 1999. Personal communication. Austin TX Environmental and Conservation Services Dept. City of Austin, TX. Cited from Feature Article II, Watershed Protection Techniques, Vol. 3, No. 1, April 1999. Center for Watershed Protection, Ellicott City, MD.

Curran, R., U. Gigler, T. Kutzmark, S. Ogier, and D. Pflugh, 1996. Griffin Creek Watershed Study. University of Washington. Document prepared for Studio urbpb-508, University of Washington Department of Urban Design and Planning, Fall Quarter 1996 under the guidance of Professors Dennis Ryan and Hilda Blanco.

Das, T., 1992. Snoqualmie River Basin Class II Inspections at North Bend, Snoqualmie, and Duvall Wastewater Treatment Plants. Washington State Department of Ecology, Olympia, WA. 9 p. Publication No. 92-e21. www.ecy.wa.gov/biblio/92e21.html

Doran, J.W., J.S. Schepers, and N.P. Swanson, 1981. Chemical and bacteriological quality of pasture runoff. Journal of Soil and Water Conservation, May-June: 166-171.

EarthInfo, 1992. Hydrodata. Compact disk read only memory. USGS discharge information of the western United States. EarthInfo, Inc.

Ecology, 1988. Statewide Water Quality Assessment 305(B) Report. Washington State Department of Ecology, Water Quality Program, Olympia, WA.

Ecology, 1994. Snoqualmie River TMDL Nonpoint Action Plan, Phased Approach, July 1994. Nonpoint Source Unity, Water Quality Section, Ecology Northwest Regional Office, Bellevue, WA., 98008.

Ecology, 1997. Infiltration/Inflow: I/I Analysis and Project Certification. EPA brochure. Washington State Department of Ecology, Olympia, WA. Ecology Publication No. 97-03. www.ecy.wa.gov/biblio/9703.html

Faries, F.C. Jr, J.M Sweeten, and J. Reagor, 1998. Water Quality: Its relationship to livestock. Texas Agricultural Extension Service, Publication L-2374. From p2pays website @ www.p2pays.org/ref/12/11608.pdf.

Fleming, R. and P. Eng, 2004. Cryptosporidium: Could it be in Your Water? Ontario Ministry of Agriculture, Food, and Rural Affairs, Factsheet # 04-015, Ontario, Canada. From website @ www.omafra.gov.on.ca/english/engineer/facts/04-015.htm.

Herrera Environmental Consultants, Inc., 2001. Water Quality Inventory and Assessment. Prepared for City of Snoqualmie, PO Box 987, Snoqualmie, WA.

Herrera Environmental Consultants, Inc., 2004. Monitoring Report Kimball Creek Water Quality Monitoring and Microbial Source Tracking Study. Prepared for City of Snoqualmie, PO Box 987, Snoqualmie, WA.

Higgins, Kollin, 2007. Personal communication, Fisheries Biologist, King County Natural Resources and Parks, Water and Land Resources Division.

Hopkins, B., 1992. Upper Snoqualmie River special study. Memorandum to D. Wright, January 30. Washington State Department of Ecology, Environmental Investigations and Laboratory Services Program, Olympia, WA. 7 p.

Hovde, Belinda, 2001. Personal communication. Ecology Dairy Inspector. Email April 10, 2001. Washington State Department of Ecology.

Joy, J., Pelletier, G., Williams, R., Heffner, M., and Aroner, E., 1991. Snoqualmie River Low Flow Water Quality Assessment, July - September 1989. Washington State Department of Ecology, Olympia, WA. 117 p. Publication No. 91-e30. www.ecy.wa.gov/biblio/91e30.html

Joy, J., 1993. Project proposal for lotic waters nutrient and eutrophication criteria development. Memorandum to W. Kendra, May 26. Washington State Department of Ecology, Olympia, WA. 19 p.

Joy, J., 1994. Snoqualmie River Total Maximum Daily Load Study. Washington State Department of Ecology, Olympia, WA. 42 p. Publication No. 94-71. www.ecy.wa.gov/biblio/9471.html

Joy, J., 2000. Lower Nooksack River Basin Bacteria Total Maximum Daily Load Evaluation. Washington State Department of Ecology, Olympia, WA. Publication No. 00-03-006. www.ecy.wa.gov/biblio/0003006.html

Kardouni, J. and N. Cristea, 2006. Quality Assurance Project Plan: Snoqualmie River Temperature Total Maximum Daily Load Study. Washington State Department of Ecology, Olympia, WA. Publication No. 06-03-106. www.ecy.wa.gov/biblio/0603106.html

Lembi, C. 2000. Aquatic Plant Management. Cooperative Extension Service Fact Sheet. Purdue University, Cooperative Extension Service, West Lafayette, IN 47907.

Mathieu, N., 2006. Replicate Precision for Twelve Total Maximum Daily Load (TMDL) Studies and Recommendations for Precision Measurement Quality Objectives for Water Quality Parameters. Washington State Department of Ecology, Olympia, WA. Publication No. 06-03-044. www.ecy.wa.gov/biblio/0603044.html

MEL, 2001. Quality Assurance Manual for the Washington State Department of Ecology, Environmental Assessment Program, Washington State Department of Ecology, Manchester, WA.

Meyers, J.M., R.G. Kope, G.J. Bryant, D. Teel, L.J. Lierheimer, T.C. Wainwright, W.S. Grand, F.W. Waknitz, k. Neely, S.T. Lindley, and R.S. Waples, 1998. Status review of Chinook salmon from Washington, Idaho, and California, U.S. Dept. Commerce, NOAA Tech. Memo. NMFS-NWFSC-35, 443 p.

Microsoft, 2001. Microsoft Office XP Professional, Version 10.0. Microsoft Corporation.

Nelson, Eric, 2004. Personal communication. Manager King County Agricultural Assistance Program, Feb-March 2004.

Onwumere, G. and D. Batts, 2004. Snoqualmie River Total Maximum Daily Load Effectiveness Evaluation: Quality Assurance Project Plan. Washington State Department of Ecology, Olympia, WA. Publication No. 04-03-201. www.ecy.wa.gov/biblio/0403201.html

Ott, W., 1995. Environmental Statistics and Data Analysis. Lewis Publishers, New York, NY.

Patterson, B. and B. Dickes, 1993. Snoqualmie River Bacteria Study. Washington State Department of Ecology, Olympia, WA. 13 p. Publication No. 93-e46. www.ecy.wa.gov/biblio/93e46.html

PEI Consultants, 1987. Field Data for City of Snoqualmie Wastewater Treatment Plant Outfall: September 10, 1987. Reported by R.T. Tyree, PEI Consultants, Inc., Seattle, WA. 8 p.

Pfost, D.L., C. Fulhage, and S. Casteel, 2006. Water Quality for Livestock Drinking. University of Missouri Extension publication EQ381. From website at http://muextension.missouri.edu/xplor/envqual/eq0381.

Pitt, R. 1998. Epidemiology and stormwater management. In Stormwater Quality Management. CRC/Lewis publishers. New York, NY.

Roberts, Mindy, 2003. South Prairie Creek Bacteria and Temperature Total Maximum Daily Load Study. Washington State Department of Ecology, Olympia, WA. Publication No. 03-03-021. www.ecy.wa.gov/biblio/0303021.html

STORET, 1993. Data retrieval from the STORET water quality database system, Washington Department of Ecology, Environmental Investigations and Laboratory Services Program, Olympia, WA.

URS, 1977. SNOMET King County 208 Area wide Water Quality Plan: Technical Appendix II. Prepared by URS Company for Snohomish County, King County, and the City of Everett. November 1977. 167 p.

Varner, P., 1995. Characterization and source control of urban stormwater quality. City of Bellevue Utilities Department, Bellevue, WA.

WAC 173-201A. Water Quality Standards for Surface Waters in the State of Washington Washington State Department of Ecology, Olympia, WA. www.ecy.wa.gov/laws-rules/ecywac.html

Washington State Department of Transportation, 2005. 2005 NPDES Progress Report for the Cedar-Green, Island, Snohomish, and South Puget Sound Water Quality Management Areas, September 2005. Washington State Department of Transportation, Olympia, WA. www.wsdot.wa.gov/Environment/waterquality/#reports

Washington State Department of Transportation, 2006. 2006 Stormwater Report, September 2006. Washington State Department of Transportation, Olympia, WA. www.wsdot.wa.gov/Environment/waterquality/#reports

Yurchak, T, and B. Buchanan, 1995. Linking Water Quality and Livestock Productivity. Alberta Agriculture, Food and Rural Development, Box 4560, Barrhead, AB T7N 1A4. From Prairie Water News Website @ www.prairiewaternews.ca/back/vol5no2/story6.html

Appendices

This page is purposely left blank

Appendix A. Glossary, Acronyms, and Abbreviations

Following are terms, acronyms, and abbreviations used frequently in this report. Those used infrequently are not listed here.

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.

7Q20 flow: A critical low-flow condition. The 7Q20 is a statistical estimate of the lowest 7-day average flow that can be expected to occur once every 20 years on average. The 7Q20 flow is commonly used to represent the critical flow condition in a waterbody and is typically calculated from long-term flow data collected in each basin.

90th percentile: A statistical number obtained from a distribution of a data set, above which 10% of the data exists and below which 90% of the data exists.

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

BOD: Biological oxygen demand

cfs: Cubic feet per second

cfu: Colony forming unit

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

Critical condition: When the physical, chemical, and biological characteristics of the receiving water environment interact with the effluent to produce the greatest potential adverse impact on aquatic biota and existing or designated water uses. For steady-state discharges to riverine systems, the critical condition may be assumed to be equal to the 7Q10 flow event unless determined otherwise by the department.

Critical period: August through October in this 2003-05 *Effectiveness Monitoring Study.*

Designated uses: Those uses specified in Chapter 173-201A WAC (Water Quality Standards for Surface Waters of the State of Washington) for each waterbody or segment, regardless of whether or not the uses are currently attained.

Diurnal: Of, or pertaining to, a day or each day; daily. (1) Occurring during the daytime only, as different from nocturnal or crepuscular, or (2) Daily; related to actions which are completed in the course of a calendar day, and which typically recur every calendar day (e.g., diurnal temperature rises during the day, and falls during the night).

Ecology: Washington State Department of Ecology

Effectiveness monitoring: Monitoring to determine whether the recommended *Detailed Implementation Plan*, after a significant portion of the recommendations or prescriptions have been implemented, is adequate in meeting (1) the goals and objectives for the TMDL project or (2) other desired outcomes over long temporal scales.

Effectiveness monitoring period: 2003-05 in this study.

Effective shade: The fraction of incoming solar shortwave radiation that is blocked from reaching the surface of a stream or other defined area.

Enterococci: A subgroup of the fecal streptococci that includes *S. faecalis*, *S. faecium*, *S. gallinarum* and *S. avium*. The enterococci are differentiated from other streptococci by their ability to grow in 6.5% sodium chloride, at pH 9.6, and at 10 degrees C and 45 degrees C.

Extraordinary primary contact: Waters providing extraordinary protection against waterborne disease or that serve as tributaries to extraordinary quality shellfish harvesting areas.

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 degrees 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.

Intensive survey: August 30-31, 2005 in this *Effectiveness Monitoring Study.*

Load allocation: 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.

Loading capacity: The greatest amount of a substance that a waterbody can receive and still meet water quality standards.

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

MGD: Million gallons per day.

Municipal separate storm sewer systems: A conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, manmade channels, or storm drains): (i) owned or operated by a state, city, town, borough, county, parish, district, association, or other public body having jurisdiction over disposal of wastes, stormwater, or other wastes and (ii) designed or used for collecting or conveying stormwater; (iii) which is not a combined sewer; and (iv) which is not part of a Publicly Owned Treatment Works (POTW) as defined in the Code of Federal Regulations at 40 CFR 122.2.

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 NPDES. 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, 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: Sources of pollution that discharge 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 5 acres of land.

Pollution: Such contamination, or other alteration of the physical, chemical, or biological properties, of any waters of the state. This includes change in temperature, taste, color, turbidity, or odor of the waters. It also includes discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state. This definition assumes that these changes will, or is likely to, create a nuisance or render such waters harmful, detrimental, or injurious to (1) public health, safety, or welfare, or (2) domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or (3) livestock, wild animals, birds, fish, or other aquatic life.

Primary contact recreation: Activities where a person would have direct contact with water to the point of complete submergence including, but not limited to, skin diving, swimming, and water skiing.

Riparian: Relating to the banks along a natural course of water.

RM: River mile

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 snow melt. Stormwater can also come from hard or saturated grass surfaces such as lawns, pastures, playfields, and from gravel roads and parking lots.

SU: Standard unit

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 surveys: Comprehensive water quality surveys designed to provide a water quality snapshot in a specific watershed. The surveys typically collect surface water grab samples under a variety of environmental conditions at a number of sites in the watershed.

TMDL study period: 1989-91 for this study.

Total Maximum Daily Load (TMDL): A distribution of a substance in a waterbody designed to protect it from exceeding water quality standards. A TMDL is equal to the sum of all of the following: (1) individual wasteload allocations for point sources, (2) the 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.

USGS: U.S. Geological Survey

Wasteload allocation: The portion of a receiving water's loading capacity allocated to existing or future point sources of pollution. Wasteload allocation constitutes one type of water quality-based effluent limitation.

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.

Wet season: November through April, in this *Effectiveness Monitoring Study.*

WWTP: Wastewater treatment plant

Appendix B. Overview of Potential Pollution Sources Overview

Many pollution sources have the potential of degrading water quality in the Snoqualmie River watershed. Each of these sources is discussed in general terms below

Municipal Wastewater Treatment Plant Discharges

All municipal wastewater treatment plants (WWTPs) in Washington State are regulated by the Department of Ecology. Ecology issues permits to these facilities and specifies the concentration and volume of treated water that can be discharged into state waters.

Treated municipal wastewater typically contains several pollutants that are addressed by the Snoqualmie TMDL Study: fecal coliform bacteria, ammonia, and biological oxygen demand (BOD). Ammonia and BOD decrease oxygen levels downstream from where they are discharged; this is called a “far-field” effect. Ecology’s TMDLs, and thus our permits, have taken this into account to protect oxygen levels at critical times (summer dry period) and locations (pools located above Snoqualmie Falls, Tolt River, and confluence with the Skykomish River). Because disinfection is required at all WWTPs, bacteria levels are low and not considered a cause for concern unless there is a problem at the WWTP.

Municipal WWTPs for the cities of North Bend, Snoqualmie, and Duvall currently discharge directly to the Snoqualmie River. The Echo Glen Children’s Center operated a WWTP that discharged to Icicle Creek, a tributary to the Raging River, until 2007. During summer months Icicle creek dries up, and discharges from the plant did not flow directly into the Raging. Echo Glen now discharges to the Snoqualmie WWTP. You can learn more about Ecology’s wastewater permitting program at the following website:
www.ecy.wa.gov/programs/wq/permits/index.html#wastewater_individual_permits

Urban and Suburban Stormwater

As the communities of North Bend, Snoqualmie, Fall City, Carnation, and Duvall have grown and shifted away from being solely agricultural and logging economies, there has been a shift from rural land uses to residential, commercial, and industrial land uses. The associated increased demand for municipal wastewater treatment services was a major reason that Ecology performed the 1989-1991 Snoqualmie *TMDL Study*. Stormwater is another wastewater byproduct of most modern urban and suburban areas that affects local water quality.

Urban stormwater runoff can carry a variety of pollutants from urban areas including bacteria from pet wastes, surface wastewater from failing septic tank systems, excess nutrients from lawns and gardens, metals, oil and grease, and other pollutants associated with activities such as car washing and sidewalk cleaning. Stormwater can be a significant source of bacterial and nutrient inputs to local waterbodies. In this document, stormwater is defined very broadly and includes (1) rainwater that hits the ground and does not infiltrate at that location and (2) other discharges that are collected in stormwater collection systems (pipes or ditches) and is conveyed to local surface waters. (See the

Ecology website @ www.ecy.wa.gov/programs/wq/stormwater for more information.) Sources of stormwater pollution that are not conveyed in regulated stormwater systems (runoff from private properties for example) are discussed individually elsewhere in this section.

In urban areas around Puget Sound and elsewhere across the country, bacteria concentrations in stormwater range from approximately 1,000 to over 100,000 organisms/100 mL (Chang, 1999; Doran et al., 1981; Pitt, 1998; Varner, 1995). In a recent study by the Center for Watershed Protection, mean fecal coliform concentrations in urban stormwater were 15,000 cfu/100 mL (Center for Watershed Protection, 1999). That same study showed that nearly every individual stormwater runoff sample exceeded bacterial standards, usually by a factor of 75 to 100.

Recent data collected by the Washington State Department of Transportation shows that bacteria levels in untreated highway runoff had concentrations of 307 and 2,179 cfu/100 mL, geometric mean and 90th percentile, respectively (WSDOT, 2005, 2006).

Municipal Stormwater Permits

To control stormwater in urban areas in accordance with the Clean Water Act, Ecology has developed municipal stormwater National Pollution Discharge Elimination System (NPDES) permits for certain counties and cities. King County was issued a Phase I municipal stormwater permit in 1995. That permit was recently revised and reissued in early 2007. Duvall is the only city within the Snoqualmie watershed that received the new Phase II municipal stormwater permit that was issued to many cities and several smaller counties across the state of Washington.

Ecology is required to address TMDL conditions as part of any applicable NPDES permit. Because stormwater was not identified as a pollution source in the original 1994 *TMDL Study*, and because the TMDL originally focused on dry weather conditions, Ecology has not imposed any special municipal stormwater permit requirements as a result of this TMDL.

We now know that stormwater is a major pollution source across Puget Sound. For that reason, this TMDL promotes many activities to control stormwater pollution. To learn more about the activities the King County and Duvall will be taking to reduce stormwater pollution, you can visit King County's website @ http://dnr.metrokc.gov/wlr/stormwater or Ecology @ www.ecy.wa.gov/programs/wq/stormwater/municipal/index.html.
Beginning in March 2008, the city of Duvall will have web-based information available on their website.

Important portions of the stormwater management plans that address nutrient and bacterial pollution include the public education and outreach, and illicit discharge detection and elimination (IDDE), programs. Both permits will increase the level of activity in both these areas. This report recommends that the cities of North Bend, Snoqualmie, and Carnation strongly consider these activities as part of their TMDL implementation responsibilities.

Agriculture and Livestock

Rural livestock maintenance and poor agricultural practices are a potential source of bacterial pollution and nutrients. At the time that the Snoqualmie TMDL was prepared, livestock pollution from dairies and unrestricted cattle grazing had not yet been systematically assessed for their potential water quality impacts. This is still the case as of the writing of this report.

The development of farm plans is a key element of managing agricultural practices that can affect water quality. Farm plans detail the best management practices (BMPs) that are needed to make a farm healthy for animals and the environment. Among the most basic and important BMPs are the installation of fencing, use of heavy use protection areas, roof runoff management systems, and the establishment of trees and shrubs where needed.

Figure B-1. Heifer at a Snoqualmie Valley Farm.

King County's Livestock Ordinance (King County Code 21A.30) sets forth a number of important minimum standards for the management of livestock and other animals in rural areas.

Dairies

In 1998, Class A dairies became regulated by the Dairy Nutrient Management Act, RCW 90.64. Each dairy was required to develop and implement a Dairy Nutrient Management Plan (DNMP). The DNMP describes how to manage nutrient-rich byproducts of the dairy operation. All DNMP plans were to be implemented by December 31, 2003. Both financial and technical assistance is available to dairies and other commercial animal husbandry organizations through the National Resource Conservation Service (NRCS), the King Conservation District, and King County's Agricultural Assistance Program.

Ecology administered the Dairy Nutrient Management Act until July 1, 2003, when those duties were transferred to the Washington State Department of Agriculture. The WSDA inspects dairies about once every 18 months.

The average dairy has about 250 cows plus replacement stock, as well as milking facilities, cattle housing and confinement areas, food storage areas, and waste handling collection and storage facilities. In most cases, manure from cattle is stored in the winter and applied as fertilizer in the summer when plants are actively growing. In this way, the manure is a valuable nutrient for the farmer. Many dairies are located on a floodplain or adjacent to surface water. Manure cannot be applied in winter months when groundwater tables are high and plants are unable to utilize the waste as a source of nutrients.

Feed waste, silage leachate, milk-house drainage, and manure from the confinement area or manure storage facility have been found to contaminate runoff at some dairies. Contaminated runoff and overspray from the field application of manure can contribute to bacterial and nutrient pollution. Injection of manure is a more expensive, but preferred method of direct manure application that provides plant nutrients, maximizes irrigation benefits, and minimizes odor production.

Nutrient pollution causes decreased levels of dissolved oxygen in downstream waters, which can impair the health of fish and other aquatic organisms. To prevent bank erosion and direct deposition of fecal matter by the animals, dairy cattle should not be allowed unrestricted access to streams and ditches. These best management practices are needed for all livestock operations located in the immediate proximity of a watercourse. In addition, vegetated buffers are highly recommended to protect streams and ditches by (1) providing habitat for support species, (2) reducing nutrient, bacteria, and organic matter input, and (3) providing shading to control stream temperatures by reducing the effect of direct solar radiation.

Dairies have less cost-share money available to them now since the state of Washington stopped providing these funds. Federal Environmental Quality Incentives Program (EQUIP) money is still available annually from the federal Natural Resources Conservation Service (NRCS), and a number of farmers are still applying for funds.

Heifer Operations and Cattle Grazing

No historical assessment of cattle grazing has been performed as part of this *TMDL Study*, but the increase in cattle and heifer raising is suspected to have increased with the loss of many dairies and the renewed interest in organic beef. During the present TMDL study, cattle herds were located in the Patterson, Ames, and South Fork subbasins and along the mainstem Snoqualmie. Some of the former dairies have converted from milking operations to raising heifers, or calves, for other dairies. Heifer facilities generate considerable manure wastes, but the volume is much smaller and it is generally a dry product. For these reasons, heifer operations are potentially lower risk operations. A potential water quality problem from a heifer operation was observed during the study and was adjacent to the mainstem Snoqualmie just south of the city of Duvall along
263rd Avenue NE.

Small Farms and Equestrian Facilities

No historical assessment of small farms was performed as a part of this study, but the number of small farms has likely increased with rural development throughout the watershed. Patterson, Cherry, Harris, and Kimball Creeks are known to have significant numbers of small farms. During the 1989-91 *TMDL Study* to 2003, two large equestrian facilities were built in the Patterson Creek watershed.

Miscellaneous NPDES Permitted Dischargers

At the time this TMDL was finalized, there were eight NPDES permitted wastewater discharges in the initial TMDL study area (Joy, 1994). They include the three municipal WWTPs mentioned above; a log pond stormwater discharge from Lake Borst; two for a single fish hatchery; and two others that allow manure application to spray fields from one facility. The three municipal plants and the log pond discharge directly to the mainstem Snoqualmie River. The hatchery and rearing pond discharges to Tokul Creek, and the spray field permits do not allow direct discharge to surface water.

The state Department of Corrections runs a WWTP at Echo Glen Corrections Center. This facility discharged a relatively low flow of about 20,000 gallons per day to Icicle Creek, a tributary to the Raging River (Callahan 2003). The discharge is most if not all of the flow of the creek at that point. During the dry summer months, most of the effluent discharges to ground through the streambed within a few hundred feet of the outfall. The Department of Corrections began discharging directly to the Snoqualmie WWTP in 2006.

In addition to the dairy, municipal stormwater, and WWTP permits mentioned earlier, there were approximately 55 active NPDES permits at the time the 2003-05 *Effectiveness Monitoring Study* began. As of the spring of 2003, all industrial discharges from the Weyerhaeuser Mill have ceased. The facility has been inactive for many years, with only boiler blow down and surface water discharges entering Borst Lake. Monitoring from the stormwater pond outlet has continued and can be found with the Discharge Monitoring Reports (DMRs) for the Weyerhaeuser facility at Ecology's Northwest Regional Office. There are two permitted fish hatcheries. Ecology's permit manager overseeing the facility says there are no DMR issues that would affect water quality in the Snoqualmie (Callahan, 2003).

There are 12 sand and gravel pits. One pit, Fiorito Bros. in North Bend, has the potential to affect the Snoqualmie River receiving water with excess sediment discharge; an enforcement action was brought against them within the past ten years. There is also a relatively new gravel pit in North Bend called Grouse Ridge, which will be discharging stormwater to the Snoqualmie. Ecology permitting requirements will protect the Snoqualmie River from improper discharges to the it.

Development activities on Snoqualmie Ridge initially had a significant impact on the Snoqualmie River causing discharges of excessively turbid water. As a result of this problem, Ecology created the first individual construction stormwater permit to resolve the problem. Snoqualmie Ridge had an individual stormwater permit and was required to monitor the local streams receiving their construction stormwater discharges. This permit has expired and new development is proceeding on the Ridge. The new development has employed several low impact development (LID) tools to reduce the volume of stormwater that needs to be treated and discharged to the river during rain events.

Composting Facilities

Composting facilities with a potential to discharge stormwater to surface waters need an NPDES permit. Several dairies in the Snohomish River basin have converted to composting facilities, combining animal manure with other organic waste products to produce compost. The DeJong Dairy has been converted to a Pacific Topsoils facility south of Duvall on West Valley Road. During the 2003-05 *Effectiveness Monitoring Study*, the Tulalip Tribe was working closely with local dairy farmers located between Duvall and Monroe to process dairy manure into electricity and compost by constructing a methane generating plant at the former Monroe Correctional Facility (inactive dairy). That project has passed the planning and design stages and is now procuring funding for the project.

Washington State University has received funding to study pathogen and nutrient changes in the processed manure and local waterways. Baseline data collection by the Snohomish Conservation District is expected to start in late 2007.

Other Potential Pollution Sources

Failing on-site septic systems

Local health departments are usually the lead agencies for addressing failing on-site septic systems. Some departments are active in locating and resolving problems from failing septic tanks, others are not budgeted to do so. In King County, health district staff were actively working on finding and correcting failing systems over a decade ago; however, due to budget cuts, this service is no longer provided. Public Health of Seattle and King County (PHSKC) has been providing general education and outreach on septic tank maintenance.

No areas in the watershed were investigated in detail as part of this 2003-05 study to identify failing septic tanks. In 2001, the City of Snoqualmie performed a water quality monitoring on Kimball Creek. Their dataset was too small to fully characterize the Kimball Creek watershed. In general, the creek was determined to have poorer water quality than average compared to other King County streams. One area called the SE North Street slough had particularly high bacteria, conductivity, phosphorus, and ammonia-nitrogen levels, which could indicate septic tank problems in the area (Herrera, 2004).

Illegal sewage dumping

There have been two documented cases of illegal septic dumping in the Snoqualmie Valley during fall of 2003. One case was near Carnation; the other case was in Duvall (King County 2003). This raises the possibility of undocumented illegal dumping occurring. There are no programs in place at the county or state levels to address illegal dumping, other than complaint response.

Appendix C. Historical data evaluation and TMDL Conclusions

One objective of this 2003-05 *Effectiveness Monitoring Study* is to review historical data and collect additional information to determine the changes in water quality characteristics of the Snoqualmie River.

Data from the following studies were used in the historical evaluation:

- USGS study (EarthInfo, 1992).
- Ecology's two long-term studies (Hopkins, 1992).
- Ecology's 1989 intensive surveys (Patterson and Dickes, 1993).
- Ecology's 1990-92 study (Joy, 1993).
- Ecology's bacterial study in lower-valley swimming areas and eutrophication criteria study (STORET, 1993).

However, emphasis is limited to temperature, DO, fecal coliform, and ammonia.

TMDL Conclusions

Although, the TMDL was developed for ammonia-nitrogen, biochemical oxygen demand (BOD), and fecal coliform, historical water quality data in the basin had indicated potential violations of water quality standards for other parameters such as pH and aesthetic values (e.g., nutrient enrichment) (URS, 1977; PEI Consultants, 1987; Ecology, 1988; Thornburg et al, 1991; STORET, 1993). The development of ammonia limits for municipal WWTP discharges was essential to control downstream nitrogenous BOD (NBOD) impacts, and for the prevention of un-ionized ammonia toxicity beyond the point source discharge mixing zone. Similarly, carbonaceous BOD (CBOD) limits were needed to protect aquatic life in several critical areas of the Snoqualmie River.

Pollutant allocations were also necessary for fecal coliform bacteria in order to restore and preserve the recreational uses of the river and its tributaries. For the *TMDL Study*, Ecology focused on ammonia, BOD, fecal coliform bacteria, and some conventional pollutants, due to their relationship to pH and aesthetic problems. Only limited efforts are put towards evaluating other potential pollutants directly.

Dissolved Oxygen

High water temperatures and minimum dissolved oxygen (DO) concentrations occurred in the months of July and August (EarthInfo, 1992; STORET, 1993). Naturally, these high water temperatures can create lower DO concentrations due to lesser gas solubility. On the other hand, algal primary productivity also increases in summer. Photosynthetic activity can create DO super-saturation during daylight hours, and respiration processes can cause depressed DO concentrations at night in some reaches. Similarly, reaction rates affecting oxygen-demanding substances increase with temperature, thereby affecting the DO levels. Furthermore, critical conditions for DO can occur when velocities and re-aeration rates are reduced in pool areas at lower flows. According to Joy (1994), instream temperatures and DO levels in several areas of the Snoqualmie River basin do not meet Class A or Class AA criteria.

Several DO sensitive environments were identified from the surveys (Joy et al., 1991; Joy, 1994) and historical data sources. These include pools on the mainstem of the Snoqualmie River at the following locations:

- The pools above Snoqualmie Falls.
- Above the Tolt River.
- On the last three miles of the diked river channel.

The reasons for these conditions are slower water velocities, low re-aeration rates, high sediment oxygen demand potentials, and higher temperatures. For example, the pool above Snoqualmie Falls recorded DO concentrations below 8.0 mg/L (PEI, 1987; PP&L, 1991) and therefore does not always meet the Class A criterion. Ecology monitoring at RM 2.7, near the confluence of the Skykomish River, recorded a mid-day DO concentration of 8.4 mg/L at a temperature of 21° C (STORET 1993).

Fecal Coliform Bacteria

Fecal coliform bacteria counts exceeding Class A and AA standards occurred at various times of the year in the Snoqualmie River basin. There is less dilution during dry periods (July through September); hence direct discharges of fecal wastes to the water column can lead to violations. On the other hand, fecal wastes can be washed into water courses directly from land surfaces or through the soils during extended rainstorms or flood conditions.

Joy et al. (1991) found both nonpoint and point sources contributing to the bacterial problems in the mainstem Snoqualmie River. Fecal coliform, water-quality-limited tributaries are Ames Creek, Cherry Creek, Kimball Creek, Patterson Creek, and the Raging River. Although Das (1992) reported significant improvements in effluent disinfection at the three main sewage treatment plants, nonpoint sources were still creating localized bacterial contamination problems (Patterson and Dickes, 1993).

Ammonia Toxicity

Critical conditions for ammonia toxicity occur near wastewater sources. According to Joy et al. (1991) and Das (1992), the highest ammonia concentrations were reported from Duvall WWTP effluent samples. These critical conditions occur during low-flow months when high pH (usually related to biomass productivity), elevated background ammonia concentrations (from the WWTP), low dilution, and high temperatures are present. Also, elevated ammonia concentrations were observed at Ames Creek in comparison to characteristically low concentrations throughout most of the Snoqualmie River system.

Appendix D. Water Quality Standards and Beneficial Uses

Relationship of this Report with Ecology's new Water Quality Standards

Ecology finished revisions to the Washington State Water Quality Standards (WAC 173-201A) in December 2006. The revisions completed the transition from a "class-based" to a "use-based" system. In the older, class-based system, waterbodies were listed as being either Class AA, A, B, or Lake Class. Each class had a specific set of expectations for water quality.

In the new use-based system, Ecology now sets water quality expectations based on the type of designated use expected for a particular waterbody. Although the criteria for most water quality parameters stayed the same, there were significant changes to temperature criteria based on the needs of fish species during their life stages. The new standards establish six categories for aquatic life uses. Three of the uses are found in the Stillaguamish watershed: (1) Char spawning and rearing, (2) Core summer salmonids habitat, and (3) Salmon spawning and rearing. In addition, Ecology has established standards for salmonid spawning and incubation protection (Ecology 2006).

The original TMDL studies on the Snoqualmie River watershed relied on the old water quality criteria. In most cases, the uses and numeric standards for quality have remained the same. Temperature standards, however, have changed significantly. Because temperature levels in the watershed are not a focus of this report, the changes in the standards do not significantly affect the major conclusions of this document.

Water Quality Standards and Beneficial Uses

Fecal Coliform Bacteria

Fresh Waters

Bacteria criteria are set to protect people who work and play in and on the water from waterborne illnesses. In the Washington State water quality standards, fecal coliform is used as an "indicator bacteria" for the state's freshwaters (e.g., lakes and streams). Fecal coliform in water "indicates" the presence of waste from humans and/or other warm-blooded animals. Waste from warm-blooded animals is more likely to contain pathogens that will cause illness in humans than waste from cold-blooded animals. The fecal coliform criteria are set at levels that have been shown to maintain low rates of serious intestinal illness (gastroenteritis) in people.

(1) The *Extraordinary Primary Contact* use is intended for waters capable of "providing extraordinary protection against waterborne disease or that serve as tributaries to extraordinary quality shellfish harvesting areas." To protect this use category: Fecal coliform organism levels must not exceed a geometric mean value of 50 colonies/100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 100/colonies mL" [WAC 173-201A-200(2)(b), 2003 edition].

(2) The *Primary Contact* use is intended for waters "where a person would have direct contact with water to the point of complete submergence including, but not limited to, skin diving, swimming, and waterskiing." More to the point, however, the use is to be designated to any waters where human exposure is likely to include exposure of the eyes, ears, nose, and throat. Since children are the most sensitive group for many of the waterborne pathogens of concern, even shallow waters may warrant primary contact protection. To protect this use category: "Fecal coliform organism levels must not exceed a geometric mean value of 100 colonies/ 100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 200/colonies mL" [WAC 173-201A-200(2)(b), 2003 edition].

Compliance is based on meeting both the geometric mean criterion and the 10% of samples (or single sample if less than ten total samples) limit. These two measures used in combination ensure that bacterial pollution in a waterbody will be maintained at levels that will not cause a greater risk to human health than intended. While some discretion exists for selecting sample averaging periods, compliance will be evaluated for both monthly (if five or more samples exist) and seasonal (summer versus winter) data sets.

The criteria for fecal coliform are based on allowing no more than the pre-determined risk of illness to humans who work or recreate in a waterbody. The criteria used in the state standards are designed to allow seven or fewer illnesses out of every 1,000 people engaged in primary contact activities. Once the concentration of fecal coliform in the water reaches the numeric criterion, human activities that would increase the concentration above the criteria are not allowed. If the criterion is exceeded, the state will require that human activities be conducted in a manner that will bring fecal coliform concentrations back into compliance with the standard.

If natural levels of fecal coliform (from wildlife) cause criteria to be exceeded, no allowance exists for human sources to measurably increase bacterial pollution further. While the specific level of illness rates caused by animal-versus-human sources has not been quantitatively determined, warm-blooded animals are a common source of serious waterborne illness for humans. This is particularly the case for warm-blooded animals managed by humans and thus exposed to human-derived pathogens as well as pathogens of animal origin.

Dissolved Oxygen

Aquatic organisms are very sensitive to reductions in the level of dissolved oxygen in the water. The health of fish and other aquatic species depends on maintaining an adequate supply of oxygen dissolved in the water. Growth rates, swimming ability, susceptibility to disease, and the relative ability to endure other environmental stressors and pollutants are all affected by oxygen levels. While direct mortality due to inadequate oxygen can occur, the Washington State's criteria are designed to maintain conditions that support healthy populations of fish and other aquatic life.

Oxygen levels can fluctuate over the day and night in response to changes in climatic conditions as well as the respiratory requirements of aquatic plants and algae. Since the health of aquatic species is tied predominantly to the pattern of daily minimum oxygen concentrations, the criteria are expressed as the lowest 1-day minimum oxygen concentration that occurs in a waterbody.

Fresh Waters

In Washington State water quality standards, freshwater aquatic life use categories are described using key species (salmonid versus warm-water species) and life-stage conditions (spawning versus rearing). Minimum concentrations of dissolved oxygen are used as criteria to protect different categories of aquatic communities [WAC 173-201A-200; 2003 edition]. In this TMDL, the following designated aquatic life use(s) and criteria is(are) to be protected:

(2) To protect the designated aquatic life use of "Salmon and Trout Spawning, Core Rearing, and Migration," the lowest 1-day minimum oxygen level must not fall below 9.5 mg/l more than once every ten years on average.

(3) To protect the designated aquatic life use of "Salmon and Trout Spawning and Noncore Rearing," the lowest 1-day minimum oxygen level must not fall below 8.0 mg/l more than once every ten years on average.

(4) To protect the designated aquatic life use of "Non-anadromous Interior Redband Trout," the lowest 1-day minimum oxygen level must not fall below 8.0 mg/l more than once every ten years on average.

The criteria described above are used to ensure that where a waterbody is naturally capable of providing full support for its designated aquatic life uses, that condition will be maintained. The standards recognize, however, that not all waters are naturally capable of staying above the fully protective dissolved oxygen criteria. When a waterbody is naturally lower in oxygen than the criteria, an additional allowance is provided for further depression of oxygen conditions due to human activities. In this case, the combined effects of all human activities must not cause more than a 0.2 mg/l decrease below that naturally lower (inferior) oxygen condition.

While the numeric criteria generally apply throughout a waterbody, the criteria are not intended to apply to discretely anomalous areas such as in shallow stagnant eddy pools where natural features unrelated to human influences are the cause of not meeting the criteria. For this reason the standards direct that measurements be taken from well-mixed portions of rivers and streams. For similar reasons, samples should not be taken from anomalously oxygen rich areas. For example, in a slow moving stream, focusing sampling on surface areas within a uniquely turbulent area would provide data that is erroneous for comparing to the criteria.

Temperature

Fresh Waters

Temperature affects the physiology and behavior of fish and other aquatic life. Temperature may be the most influential factor limiting the distribution and health of aquatic life. Temperature can be greatly influenced by human activities.

Temperature levels fluctuate over the day and night in response to changes in climatic conditions and river flows. Since the health of aquatic species is tied predominantly to the pattern of maximum temperatures, the criteria are expressed as the highest 7-day average of the daily maximum temperatures (7-DADMax) occurring in a waterbody.

In the state water quality standards, aquatic life use categories are described using key species (salmon versus warm-water species) and life-stage conditions (spawning versus rearing) [WAC 173-201A-200; 2003 edition].

(1) To protect the designated aquatic life uses of "Salmon and Trout Spawning, Core Rearing, and Migration," the highest 7-DADMax temperature must not exceed 16°C (60.8°F) more than once every ten years on average.

(2) To protect the designated aquatic life uses of "Salmon and Trout Spawning and Noncore Rearing," the highest 7-DADMax temperature must not exceed 17.5°C (63.5°F) more than once every ten years on average.

(3) To protect the designated aquatic life uses of "Salmon and Trout Migration Only," the highest 7-DADMax temperature must not exceed 17.5°C (63.5°F) more than once every ten years on average.

(4) To protect the designated aquatic life uses of "Non-anadromous Interior Redband Trout," the highest 7-DADMax temperature must not exceed 18°C (64.4°F) more than once every ten years on average.

The criteria described above are used to ensure that where a waterbody is naturally capable of providing full support for its designated aquatic life uses, that condition will be maintained. The standards recognize, however, that not all waters are naturally capable of staying below the fully protective temperature criteria. When a waterbody is naturally warmer than the above-described criteria, an additional allowance is provided for warming due to human activities. In this case, the combined effects of all human activities must also not cause more than a 0.3°C (0.54°F) increase above the naturally higher (inferior) temperature condition.

In addition to the maximum criteria noted above, compliance must also be assessed against criteria that limit the incremental amount of warming of otherwise cool waters due to human activities. When water is cooler than the criteria noted above, the allowable rate of warming up to, but not exceeding, the numeric criteria from human actions is restricted to:

- Incremental temperature increases resulting from individual point source activities must not, at any time, exceed 28/T+7 as measured at the edge of a mixing zone boundary (where "T" represents the background temperature as measured at a point or points unaffected by the discharge).
- Incremental temperature increases resulting from the combined effect of all nonpoint source activities in the waterbody must not at any time exceed 2.8°C (5.04°F).

Special consideration is also required to protect spawning and incubation of salmonid species. Where the Department of Ecology determines the temperature criteria established for a waterbody would likely not result in protective spawning and incubation temperatures, the following criteria apply:

- Maximum 7-DADMax temperatures of 9°C (48.2°F) at the initiation of spawning and at fry emergence for char.
- Maximum 7-DADMax temperatures of 13°C (55.4°F) at the initiation of spawning for salmon and at fry emergence for salmon and trout.

pH

The pH of natural waters is a measure of acid-base equilibrium achieved by the various dissolved compounds, salts, and gases. pH is an important factor in the chemical and biological systems of natural waters. pH both directly and indirectly affects the ability of waters to have healthy populations of fish and other aquatic species. The degree of dissociation of weak acids or bases is affected by changes in pH. This effect is important because the toxicity of many compounds is affected by the degree of dissociation. While some compounds (e.g., cyanide) increase in toxicity at lower pH, others (e.g., ammonia) increase in toxicity at higher pH.

While there is no definite pH range within which aquatic life is unharmed and outside which it is damaged, there is a gradual deterioration as the pH values are further removed from the normal range. However, at the extremes of pH lethal conditions can develop. For example, extremely low pH values (<5.0) may liberate sufficient carbon dioxide from bicarbonate in the water to be directly lethal to fish.

While the pH criteria in the state water quality standards are primarily established to protect aquatic life, the criteria also serve to protect waters as a source for domestic water supply. Water supplies with either extreme pH, or that experience significant changes of pH even within otherwise acceptable ranges, are more difficult and costly to treat for domestic water purposes. pH also directly affects the longevity of water collection and treatment systems. Low pH waters may cause compounds of human health concern to be released from the metal pipes of the distribution system.

In the state's water quality standards, two pH criteria are established to protect six different categories of aquatic communities [WAC 173-201A-200; 2003 edition].

To protect the designated aquatic life uses of "Salmon and Trout Spawning and Noncore Rearing," Salmon and Trout Rearing and Migration Only," "Non-anadromous Interior Redband Trout," and "Indigenous Warm Water Species," pH must be kept within the range of 6.5 to 8.5, with a human-caused variation within the above range of less than 0.5 units.

This page is purposely left blank

Appendix E. Raw Laboratory and Field Data

Table E-1. Laboratory results for the mainstem Snoqualmie.

Date	Fecal Coliform (cfu/100mL)		*E-coli* (cfu/100mL)		Orthophosphate (mg/L)		Ammonia-Nitrogen (mg/L)		Nitrite-nitrate nitrogen (mg/L)		Total Persulfate Nitrogen (mg/L)		BOD5 (mg/L)	Inhibited BOD (mg/L)
Snoqualmie mainstem at River Mile 42.3														
08/05/2003	10		19		0.0055		0.013		0.156		0.273			
08/11/2003	24		29											
08/18/2003	13		17				0.010 U							
08/25/2003	8		10											
09/02/2003	30		18		0.0038		0.010 U		0.176		0.220			
09/09/2003	57		88											
09/15/2003	44	50	54	47									2 U	
09/22/2003	16		10											
09/29/2003	36 J		36 J		0.0037		0.010		0.172		0.275			
10/06/2003	4		4											
10/13/2003	35		31				0.010 U							
10/20/2003	73 J		73 J											
10/27/2003	8		4				0.010 U							
11/03/2003	3		2											
11/11/2003	43		40				0.010 U							
11/17/2003	11		9											
12/01/2003	4		3				0.010 U							
12/08/2003	5		2											
12/15/2003	8		6											
01/12/2004	1		1				0.010 U							
01/20/2004	1		1 U											
02/17/2004	1		1				0.010 U							
03/08/2004	1		1				0.010 U							
03/15/2004	5		3				0.010 U							
04/05/2004	2		1 U											
04/20/2004	6		5											
08/02/2004	20		20				0.010 U							
08/09/2004	30		28											
08/16/2004	37		28				0.011							
08/23/2004	380		360											
08/30/2004	62		46		0.0050		0.010 U	0.010 U						

Date	Fecal Coliform (cfu/100mL)		*E-coli* (cfu/100mL)		Orthophosphate (mg/L)		Ammonia-Nitrogen (mg/L)		Nitrite-nitrate nitrogen (mg/L)		Total Persulfate Nitrogen (mg/L)		BOD5 (mg/L)	Inhibited BOD (mg/L)
09/07/2004	27		23											
09/13/2004	38		37				0.010 U							
09/20/2004	9		5											
09/27/2004	38		19				0.011							
10/05/2004	20		17											
10/11/2004	22		17				0.010 U							
10/18/2004	19		22											
10/25/2004	10		9				0.010 U							
11/15/2004	2		2				0.010 U							
12/13/2004	6		5				0.010 U							
01/24/2005	2						0.010 U							
02/22/2005	1						0.010 U							
Snoqualmie mainstem at River Mile 40.7														
08/05/2003	17		18		0.0042		0.011		0.160		0.250			
08/11/2003	28		34											
08/18/2003	9		19		0.0034	0.0033	0.013		0.163		0.283			3.5 U
08/25/2003	14		14											
09/02/2003	23		16		0.0042		0.010 U		0.168		0.220			
09/09/2003	100		110											
09/17/2003	80		88		0.0034	0.0032	0.010 U		0.194		0.266		2 U	
09/22/2003	12		11											
09/29/2003	33	35	43	55	0.0046		0.010 U		0.165		0.278			
10/06/2003	24		15											
10/13/2003	33		31		0.003U		0.010 U							2 U
10/20/2003	110 J	130 J	100 J	110 J										
10/27/2003	3		3		0.0051		0.010 U		0.240		0.290			
11/03/2003	6		3											
11/11/2003	60		52		0.0033		0.010 U		0.170		0.230			2 U
11/17/2003	14		7											
12/01/2003	2		1		0.0040		0.010 U		0.234		0.272			
12/08/2003	8		7											
12/15/2003	8		7											
01/12/2004	1		1		0.0035		0.010 U		0.232		0.271			

Date	Fecal Coliform (cfu/100mL)		*E-coli* (cfu/100mL)		Orthophosphate (mg/L)		Ammonia-Nitrogen (mg/L)		Nitrite-nitrate nitrogen (mg/L)		Total Persulfate Nitrogen (mg/L)		BOD5 (mg/L)	Inhibited BOD (mg/L)
01/20/2004	1 U		NAF											
02/17/2004	3		2		0.0079		0.010 U		0.251	0.250	0.290			
03/08/2004	2		1		0.003U		0.010 U				0.212			
03/15/2004	1		1											
04/05/2004	5		2		0.003U		0.010 U		0.141		0.210			
04/20/2004	6		4											
08/02/2004	13		11		0.0031		0.010 U		0.156		0.230			
08/09/2004	38		35											
08/16/2004	43		38		0.0039		0.013		0.157		0.250			2 U
08/23/2004	840		770											
08/30/2004	15		15		0.0042		0.010 U		0.179		0.210	0.210		
09/07/2004	18		13											
09/13/2004	55		52		0.0041		0.010 U		0.152		0.200			2 U
09/20/2004	6		5											
09/27/2004	35		18		0.0035	0.0036	0.010 U		0.159		0.200			
10/05/2004	24		19											
10/11/2004	17		15		0.0031	0.0034	0.010 U		0.163		0.214			2 U
10/18/2004	25		20											
10/25/2004	4		4		0.003U		0.010 U		0.178		0.210			
11/15/2004	8		4				0.010 U	0.010 U						
12/13/2004	7		6				0.010 U							
01/24/2005	1 U						0.010 U							
02/22/2005	1 U						0.011							
Snoqualmie mainstem at River Mile 35.3														
08/05/2003	15	16	21	16	0.0060	0.0059	0.010 U		0.139		0.250			
08/11/2003	7		15											
08/18/2003	13		2				0.010 U							
08/25/2003	6		13											
09/02/2003	4		7				0.010 U		0.159		0.200			
09/09/2003	140		150											
09/17/2003	57		84				0.010 U		0.208		0.281		2U	
09/22/2003	16		11											
09/29/2003	17		27		0.0041		0.010 U		0.154		0.248			

Date	Fecal Coliform (cfu/100mL)		*E-coli* (cfu/100mL)		Orthophosphate (mg/L)		Ammonia-Nitrogen (mg/L)		Nitrite-nitrate nitrogen (mg/L)		Total Persulfate Nitrogen (mg/L)		BOD5 (mg/L)	Inhibited BOD (mg/L)
10/06/2003	12		10											
10/13/2003	63		63				0.010 U							
10/20/2003	330 J		320 J											
10/27/2003	17		14				0.010 U							
11/03/2003	5		5											
11/11/2003	47		44				0.010 U							
11/17/2003	22		19											
12/01/2003	5		3				0.010 U							
12/08/2003	3		1											
12/15/2003	1		1											
01/12/2004	6		6				0.010 U							
01/20/2004	1 U		NAF											
02/17/2004	1		1				0.010 U							
03/08/2004	4		3				0.010 U							
03/15/2004	1		1											
04/05/2004	1		1 U				0.010 U	0.010U						
04/20/2004	2		2											
08/02/2004	27		24				0.010 U							
08/09/2004	58		52											
08/16/2004	39		37				0.010 U							
08/23/2004	370		340											
08/30/2004	60		54				0.010 U	0.010U						
09/07/2004	27		23											
09/13/2004	89		80				0.010 U							
09/20/2004	29		21											
09/27/2004	30		17				0.010 U	0.010U						
10/05/2004	40		37											
10/11/2004	26		21				0.010 U							
10/18/2004	28		28											
10/25/2004	18		16				0.010 U	0.010U						
11/15/2004	3		3				0.010 U							
12/13/2004	7		5				0.010 U							
01/24/2005	6						0.010 U							

Date	Fecal Coliform (cfu/100mL)		*E-coli* (cfu/100mL)		Orthophosphate (mg/L)		Ammonia-Nitrogen (mg/L)			Nitrite-nitrate nitrogen (mg/L)		Total Persulfate Nitrogen (mg/L)		BOD5 (mg/L)	Inhibited BOD (mg/L)
Snoqualmie mainstem at River Mile 25.2															
08/06/2003	18		24		0.0031		0.010			0.151		0.220			
08/12/2003	25		22												
08/19/2003	24		18		0.003U		0.010	U		0.138		0.210			
08/26/2003	17		10												
09/03/2003	47		52		0.0040		0.010	U		0.144		0.210			
09/10/2003	150		140												
09/16/2003	120		96		0.0047	0.0044	0.014			0.211		0.324		2 U	
09/23/2003	31		37												
09/30/2003	5		25		0.0035		0.010	U		0.149		0.255			
10/07/2003	30		26												
10/14/2003	63		61		0.0030		0.010	U		0.246		0.322			
10/21/2003	290		280												
10/28/2003	31		24		0.0053		0.013			0.304		0.371	0.378		
11/03/2003	15		13												
11/12/2003	60		60		0.0045		0.010	U		0.253		0.333			
11/17/2003	31		28												
12/02/2003	8		7		0.0057	0.0052	0.016			0.325		0.387			
12/08/2003	3		3												
12/15/2003	3		1												
01/13/2004	3		3		0.0044		0.010	U		0.318		0.397			
01/20/2004	3		2												
02/18/2004	8		8		0.0079	0.0079	0.010	U		0.339		0.375			
03/09/2004	3		3		0.0037		0.010	U		0.187		0.230			
03/15/2004	1	U	NAF												
04/06/2004	1	U	NAF		0.0035	0.0033	0.010	U		0.179		0.220			
04/20/2004	7		4												
08/03/2004	31		31		0.0031		0.011			0.142		0.210			
08/10/2004	41		38												
08/17/2004	33		28		0.0044		0.010	U		0.157		0.210			
08/24/2004	330		300												
08/31/2004	60	J	53	J	0.0054		0.010	U		0.202		0.230			
09/08/2004	39		29												

Date	Fecal Coliform (cfu/100mL)		*E-coli* (cfu/100mL)		Orthophosphate (mg/L)		Ammonia-Nitrogen (mg/L)		Nitrite-nitrate nitrogen (mg/L)		Total Persulfate Nitrogen (mg/L)		BOD5 (mg/L)	Inhibited BOD (mg/L)
09/14/2004	140		130		0.0068		0.010 U		0.158		0.200			
09/21/2004	20		14											
09/28/2004	19		17		0.0050		0.010 U	0.010U	0.177		0.230			
10/06/2004	36		29											
10/12/2004	23		19		0.0068		0.010 U							2 U
10/19/2004	20 J		16 J											
10/26/2004	18		12		0.0039		0.010 U	0.010U	0.192		0.220			
11/16/2004	13		12				0.010 U							
12/15/2004	3		2				0.010 U	0.010U	0.231	0.227	0.250	0.273		
01/25/2005	8						0.010 U							
02/23/2005	1 U						0.010 U							
Snoqualmie mainstem at River Mile 2.7														
08/06/2003	39		39		0.0049									
08/12/2003	41		41											
08/19/2003	53		61		0.0077		0.010 U		0.127		0.210			
08/26/2003	29		21											
09/03/2003	14		22		0.0052	0.0045	0.010 U		0.111		0.190			
09/10/2003	65		40											
09/16/2003	100		110		0.0067		0.018		0.256		0.408		2 U	
09/23/2003	64		69											
09/30/2003	14		22		0.0056		0.037		0.173		0.307			
10/07/2003	18		17											
10/14/2003	75		70		0.0041		0.010 U		0.273		0.365			
10/21/2003	200		190											
10/28/2003	41		33		0.0120	0.0130	0.030		0.401		0.566			
11/03/2003	8		7											
11/12/2003	48		43		0.0041		0.010 U		0.211	0.21	0.277			
11/17/2003	28		23											
12/02/2003	8		3		0.0072		0.012		0.375	0.374	0.445	0.450		
12/08/2003	14		12											
12/15/2003	14		12											
01/13/2004	12		10		0.0057	0.0060	0.010 U		0.435		0.534			
01/20/2004	4		3											

Date	Fecal Coliform (cfu/100mL)		*E-coli* (cfu/100mL)		Orthophosphate (mg/L)		Ammonia-Nitrogen (mg/L)		Nitrite-nitrate nitrogen (mg/L)		Total Persulfate Nitrogen (mg/L)		BOD5 (mg/L)	Inhibited BOD (mg/L)
02/18/2004	1 U		NAF		0.0088		0.011		0.399		0.486			
03/09/2004	2		1		0.0049	0.0049	0.010 U		0.217		0.269			
03/15/2004	3		2											
04/06/2004	7		7		0.0041		0.010 U		0.190		0.250			
04/20/2004	5		4											
08/03/2004	32		30		0.0047		0.010 U		0.160		0.240			
08/10/2004	110		100											
08/17/2004	43		36		0.0063		0.010 U		0.170		0.258			
08/24/2004	340		320											
08/31/2004	100		76		0.0070	0.0073	0.010 U		0.210	0.209	0.278	0.268		
09/08/2004	39		31											
09/14/2004	230		210		0.0190		0.010 U		0.257	0.248	0.311			2 U
09/21/2004	22		15											
09/28/2004	16		14		0.0056		0.010 U		0.196	0.195	0.250			
10/06/2004	53		42											
10/12/2004	43		28		0.0045		0.010 U		0.204	0.203	0.274	0.282		2 U
10/19/2004	55		49											
10/26/2004	18		17		0.0060		0.010 U		0.267	0.267	0.381	0.362		
11/16/2004	7		7				0.010 U							
12/15/2004	16		13				0.010 U		0.277		0.305			
01/25/2005	12						0.026							
02/23/2005	3						0.017							

U – The analyte was not detected at or above the reported sample quantitation limit.
NAF – Not analyzed for.
J – The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.
For bacteria, this indicates estimated count; samples are analyzed over 24 hours after collection.

Table E-2. Field results for the Snoqualmie mainstem.

Date	Time	Temperature (°C)	Winkler Dissolved Oxygen (mg/L)	Winkler Meter (mg/L)	pH (SU)	Conductivity (μmhos)	Flow Discharge (cfs)
Snoqualmie mainstem at River Mile 42.3							
08/05/2003	15:07	16.2	9.7		6.9	59	nd
08/11/2003	13:59	15.3					nd
08/18/2003	15:30	16.6	10.0		6.7X	62	nd
08/25/2003	15:12	15.3			7.6	65	nd
09/02/2003	13:40	14.6	9.9		7.3	65	nd
09/09/2003	14:13	14.0 X					nd
09/15/2003	11:45	13.4	10.0		7.3	195	nd
09/22/2003	14:10	11.9					nd
09/29/2003	11:25	12.9	9.7 X		7.4	56	nd
10/06/2003	15:15	12.4	11.1	11.1			nd
10/13/2003	13:35	9.9	11.3		7.0	24	nd
10/20/2003	14:49	12.2	10.6				nd
10/27/2003	12:43	10.1	10.7		6.8	38	nd
11/03/2003	11:16	4.9					nd
11/11/2003	13:00	7.8			6.6	17	nd
11/17/2003	10:48	6.5 X					nd
12/01/2003	11:53	5.5			6.9X	27	nd
12/08/2003	11:21	5.8					nd
12/15/2003	11:13	5.3					nd
01/12/2004	13:25	5.7			7.2	36	nd
02/17/2004	12:40	7.5			7.1	43	nd
03/08/2004	10:54	8.2			6.9	24	nd
04/05/2004	11:09	8.7			7.0X	30	nd
04/20/2004	11:18	8.4					nd
08/02/2004	15:32	17.9	9.6		7.3	57	nd
08/09/2004	13:41	16.7					nd
08/16/2004	13:48	17.2	9.1		7.0	57	nd
08/23/2004	10:45	14.7					nd
08/30/2004	13:31	15.0	9.8		7.0	33	nd
09/07/2004	13:07	12.9					nd
09/13/2004	13:45	11.9	10.4		7.0	29	nd
09/20/2004	13:44	10.9					nd
09/27/2004	11:50	11.8			7.1	41	nd
10/05/2004	12:56	10.3					nd
10/11/2004	13:25	10.3	11.1		7.3 X	32	nd
10/18/2004	12:28	9.4					nd
10/25/2004	12:49	7.4	11.7		7.2		nd
11/15/2004	12:55	7.7			7.2	44	nd
12/13/2004	12:30	5.7			7.0	27	nd
01/24/2005	14:52	6.0			7.1	27	nd
02/22/2005	12:09	3.4			7.1	50	nd

Date	Time	Temperature (°C)	Winkler Dissolved Oxygen (mg/L)	Winkler Meter (mg/L)	pH (SU)	Conductivity (μmhos)	Flow Discharge (cfs)
Snoqualmie mainstem at River Mile 40.7							
08/05/2003	16:06	16.5	8.9		6.9	60	444 x_1
08/11/2003	14:59	16.8					420 x_1
08/18/2003	16:55	17.8	9.1		7.1X	63	384 x_1
08/25/2003	16:38	16.3			7.5	66	337 x_1
09/02/2003	14:25	16.2	8.9		7.3	67	314 x_1
09/09/2003	15:40	14.6					417 x_1
09/17/2003	10:10	12.1X	10.1		7.4	43	973 x_1
09/22/2003	15:25	12.2					723 x_1
09/29/2003	11:57	13.8	9.1 X		7.2	58	444 x_1
10/06/2003	15:55	13.2					371 x_1
10/13/2003	14:26	9.9	11.2		7.3	24	3660 x_1
10/20/2003	16:06	12.2	10.6				5943 x_1
10/27/2003	13:19	10.4	10.7		6.9	39	1594 x_1
11/03/2003	11:53	4.9					1247 x_1
11/11/2003	13:40	7.4			7.0	18	9752 x_1
11/17/2003	11:14	6.7 X					3126 x_1
12/01/2003	13:15	5.6			6.8X	28	4246 x_1
12/08/2003	12:00	5.8					2866 x_1
12/15/2003	11:35	5.4					2274 x_1
01/12/2004	14:20	5.6			6.9	37	2117 x_1
01/20/2004	13:45						2501 x_1
02/17/2004	13:10	6.0			6.9	43	1805 x_1
03/08/2004	11:28	7.3			6.9	27	4246 x_1
03/15/2004	09:27						2264 x_1
04/05/2004	11:35	8.4			7.0X	31	2437 x_1
04/20/2004	11:55	8.8					2117 x_1
08/02/2004	16:48	17.8	9.0		7.2	58	510 x_1
08/09/2004	15:40	17.3					584 x_1
08/16/2004	14:48	18.1	8.6		7.1	58	434 x_1
08/23/2004	11:57	15.0					1060 x_1
08/30/2004	14:30	15.3	9.8		7.0	33	1668 x_1
09/07/2004	13:50	13.2					1010 x_1
09/13/2004	14:50	12.1	10.4		7.0	30	2069 x_1
09/20/2004	15:46	11.3					2808 x_1
09/27/2004	12:30	11.9			7.2	41	1212 x_1
10/05/2004	14:12	10.8					723 x_1
10/11/2004	14:20	10.4	11.0		7.0 X	32	1939 x_1
10/18/2004	14:11	9.6					4604 x_1

Date	Time	Temperature (°C)	Winkler Dissolved Oxygen (mg/L)	Winkler Meter (mg/L)	pH (SU)	Conductivity (µmhos)	Flow Discharge (cfs)
10/25/2004	13:29	7.4	11.6		7.1		2469 x_1
11/15/2004	13:35	7.9			7.0	39	1268 x_1
12/13/2004	13:20	5.9			6.6	28	4604 x_1
01/24/2005	15:28	6.4			6.9	28	4030 x_1
02/22/2005	13:38	3.6			7.0	50	920 x_1
Snoqualmie mainstem at River Mile 35.3							
08/05/2003	17:50	18.8	10.0		6.8	67	454 x_2
08/11/2003	17:30	18.4					430 x_2
08/18/2003	19:20	20.4	10.0		7.3X	69	393 x_2
08/25/2003	17:54	18.2			8.3	72	345 x_2
09/02/2003	15:50	17.7	10.8		7.9	73	322 x_2
09/09/2003	16:00	16.1					428 x_2
09/17/2003	11:05	13.1X	10.6		7.7	54	999 x_2
09/22/2003	16:30	13.6					744 x_2
09/29/2003	13:00	14.4	10.8X		7.8	62	456 x_2
10/06/2003	17:05	14.0					382 x_2
10/13/2003	15:40	12.4	11.4		8.2	61	3,701 x_2
10/20/2003	17:17	12.7	10.7				7,003 x_2
10/27/2003	14:14	10.8	10.8		7.4	43	1,673 x_2
11/03/2003	12:38	5.3					1,291 x_2
11/11/2003	14:30	7.6			7.2	26	9,831 x_2
11/17/2003	11:52	6.7X					3,221 x_2
12/01/2003	14:00	5.7			7.5X	31	4,501 x_2
12/08/2003	12:47	5.9					3,106 x_2
12/15/2003	12:00	5.5					2,481 x_2
01/12/2004	15:12	5.2			7.5	46	2,309 x_2
01/20/2004	12:45						2,634 x_2
02/17/2004	13:45	6.2			7.4	47	1,925 x_2
03/08/2004	11:59	8.3			7.7	33	4,381 x_2
03/15/2004	09:54						2,334 x_2
04/05/2004	12:15	9.0			7.8X	34	2,490 x_2
04/20/2004	12:27	10.6					2,158 x_2
08/02/2004	18:32	22.4	9.7		7.8	63	521 x_2
08/09/2004	16:57	20.0					594 x_2
08/16/2004	15:37	20.5			8.0	60	444 x_2
08/23/2004	14:20	17.6					1,112 x_2
08/30/2004	15:20	16.5	10.0		7.3	36	1,714 x_2
09/07/2004	15:30	14.6					1,034 x_2
09/13/2004	15:46	12.6			7.6	33	2,158 x_2

Date	Time	Temperature (°C)	Winkler Dissolved Oxygen (mg/L)	Winkler Meter (mg/L)	pH (SU)	Conductivity (µmhos)	Flow Discharge (cfs)
09/20/2004	17:03	11.6					2,911 x_2
09/27/2004	13:25	12.4	10.6		7.7	45	1,246 x_2
10/05/2004	16:05	12.1					747 x_2
10/11/2004	15:25	11.0	11.5		7.6	35	1,991 x_2
10/18/2004	15:21	9.8					4,784 x_2
10/25/2004	14:20	7.8			7.7		2,522 x_2
11/15/2004	14:02	8.1			7.6	44	1,369 x_2
12/13/2004	14:05	6.2			7.3	31	4,919 x_2
01/24/2005	16:13	6.8			7.6	31	4,201 x_2
02/22/2005	14:12	4.3			7.4	57	958 x_2
Snoqualmie mainstem at River Mile 25.2							
08/06/2003	10:47	18.0			7.1	69	559 x_3
08/12/2003	09:30	18.2					525 x_3
08/19/2003	11:43	19.0	9.3		6.9	72X	483 x_3
08/26/2003	11:46	12.8			7.5	73	438 x_3
09/03/2003	09:40	17.7	9.5		7.7	74	395 x_3
09/10/2003	09:32	16.0					492 x_3
09/16/2003	10:20	13.1	10.0		7.5	69	654 x_3
09/23/2003	09:25	13.6					785 x_3
09/30/2003	12:04	14.8	10.1		7.7	66	544 x_3
10/07/2003	12:40	14.0					480 x_3
10/14/2003	10:06	10.4	10.7		7.3	28	2349 x_3
10/21/2003	17:34	12.5					27742 x_3
10/28/2003	12:40	11.4	10.1		6.3	48	1778 x_3
11/03/2003	13:53	5.9					1670 x_3
11/12/2003	09:50	6.9			7.4	33	4400 x_3
11/17/2003	13:05	7.2X					3026 x_3
12/02/2003	09:57	7.0			7.1	35	4529 x_3
12/08/2003	14:04	6.2					3677 x_3
12/15/2003	12:54	5.8					2943 x_3
01/13/2004	10:34	5.5			7.1	63	2875 x_3
01/20/2004	12:22						3182 x_3
02/18/2004	09:34	6.8			7.2	50	2057 x_3
03/09/2004	09:58	7.6X			7.3X	30	4885 x_3
03/15/2004	10:37						2277 x_3
04/06/2004	09:35	8.2			7.6	36	2188 x_3
04/20/2004	13:15	9.4					2049 x_3
08/03/2004	11:56	20.1	8.8X		7.4	62	571 x_3
08/10/2004	10:34	20.1					650 x_3

Date	Time	Temperature (°C)	Winkler Dissolved Oxygen (mg/L)	Winkler Meter (mg/L)	pH (SU)	Conductivity (µmhos)	Flow Discharge (cfs)
08/17/2004	10:00	19.7	9.6		7.4	70	507 x_3
08/24/2004	10:47	16.4					283 x_3
08/31/2004	10:08	16.2			6.7	42	1671 x_3
09/08/2004	10:09	14.1					1161 x_3
09/14/2004	10:25	12.3	10.5		7.3	32	6170 x_3
09/21/2004	10:30	11.5					2348 x_3
09/28/2004	10:17	12.7	10.3		7.5	50	1349 x_3
10/06/2004	09:50	12.3					882 x_3
10/12/2004	10:45	11.2	10.4		7.3	35	1605 x_3
10/19/2004	10:15	9.5					3521 x_3
10/26/2004	10:20	7.8	11.2		7.0		2192 x_3
11/16/2004	10:06	8.3			7.4	50	1879 x_3
12/15/2004	11:20	6.3			7.1	23	9427 x_3
01/25/2005	10:05	8.3			7.3	32	4216 x_3
02/23/2005	12:00	3.7			7.5	62	1180 x_3
Snoqualmie mainstem at River Mile 2.7							
08/06/2003	16:18	20.3	9.2		6.7	72	nd
08/12/2003	16:24	20.5					nd
08/19/2003	16:28	21.3	9.9		6.8	75X	nd
08/26/2003	18:18	19.5			7.7	79	nd
09/03/2003	12:50	19.3	10.3		7.8	73	nd
09/16/2003	14:45	15.0	9.5		7.5	57	nd
09/23/2003	15:40	14.8					nd
09/30/2003	10:37	15.5	9.3		7.6	68	nd
10/07/2003	19:02	14.8	9.6				nd
10/14/2003	13:25	10.5	10.8		6.8	29	nd
10/21/2003	16:28	12.8	10.8				nd
10/28/2003	10:40	10.7	9.6		6.2	56	nd
11/03/2003	16:02	5.6					nd
11/12/2003	13:18	7.6			6.9	24	nd
11/17/2003	15:37	7.0X					nd
12/02/2003	12:38	7.1			6.5	39	nd
12/08/2003	16:39	6.1					nd
12/15/2003	14:39	5.9					nd
01/13/2004	14:09	6.1			6.5	73	nd
02/18/2004	13:00	6.9			6.9	55	nd
03/09/2004	12:09	8.3X			7.1X	33	nd
04/06/2004	12:19	9.8			7.2	38	nd
04/20/2004	15:33	10.8					nd
08/03/2004	18:15	21.0	8.8X		7.4	64	nd
08/10/2004	16:00	21.0					nd
08/17/2004	14:13	21.3	8.8		7.5	72	nd

Date	Time	Temperature (°C)	Winkler Dissolved Oxygen (mg/L)	Winkler Meter (mg/L)	pH (SU)	Conductivity (μmhos)	Flow Discharge (cfs)
08/24/2004	14:15	17.7					nd
08/31/2004	13:13	17.0	9.1		7.1	42	nd
09/08/2004	14:27	15.7					nd
09/14/2004	13:54	12.8	10.3		7.0	37	nd
09/21/2004	15:39	12.0					nd
09/28/2004	13:35	13.2	9.9		7.2	52	nd
10/06/2004	13:31	13.3					nd
10/12/2004	14:55	11.8	10.4		7.1	37	nd
10/19/2004	14:37	10.0					nd
10/26/2004	13:37	8.1	11.2		7.1		nd
11/16/2004	13:13	8.5			7.0	57	nd
12/15/2004	15:25	6.8			6.6	26	nd
01/25/2005	13:23	6.9			6.6	39	nd
02/23/2005	16:44	4.7			7.0	67	nd

X: Field measurement did not meet data quality objectives and should be used with caution.

nd: No data available.

x_1 Flow discharge data obtained from USGS station 12144500, Snoqualmie River near the city of Snoqualmie at RM 40.0.

x_2: Flow discharge obtained by adding data from the USGS gauging station 12145500, Raging River near Fall City at RM 2.6; and flow discharge from USGS station 12144500, Snoqualmie River near the city of Snoqualmie at RM 40.0.

x_3: Flow discharge represents flow at USGS gauging station 121490000 (Snoqualmie RM 24.9) subtracting flow at USGS station 12148500 (Tolt River).

Table E-3. Laboratory results for Snoqualmie tributaries.

Date	Fecal Coliform (cfu/100mL)		*E-coli* (cfu/100mL)		Orthophosphate (mg/L)		Ammonia-Nitrogen (mg/L)		Nitrite-nitrate Nitrogen (mg/L)		Total Persulfate Nitrogen (mg/L)		BOD5 (mg/L)	Inhibited BOD (mg/L)
Middle Fork Snoqualmie RM 45.3														
08/05/2003	16		14		0.0046		0.010 U		0.028		0.085	0.086		
08/11/2003	12		12											
08/18/2003	17		15		0.0031		0.010 U		0.038		0.095	0.100		
08/25/2003	7		3											
09/02/2003	14		13		0.0043		0.010 U		0.058	0.057	0.094			
09/09/2003	52		54											
09/15/2003	27		31			0.003U	0.010 U		0.099		0.170		2U	
09/22/2003	8		5											
09/29/2003	13 J		15 J		0.003U		0.010 U		0.065		0.170			
10/06/2003	13		13											
10/13/2003	51		50		0.003U		0.010 U							
10/20/2003	37 J		37 J											
10/27/2003	5		4		0.0045		0.010 U		0.163		0.280			
11/03/2003	3		3											
11/11/2003	53		43		0.0042		0.010 U		0.179		0.258	0.257		
11/17/2003	11		6											
12/01/2003	2		2		0.003U		0.010 U		0.156		0.190			
12/08/2003	2		1											
12/15/2003	5		5											
01/12/2004	1 U		NAF		0.0032		0.010 U	0.010U	0.158		0.652			
01/20/2004	1 U		NAF											
02/17/2004	2		2		0.0071		0.010 U		0.142		0.170			
03/08/2004	1 U		NAF		0.003U		0.010 U				0.170			
03/15/2004	1 UJ		NAF											
04/05/2004	1		1 U		0.003U		0.010 U		0.073		0.130	0.140		
04/20/2004	4		4											
08/02/2004	28		24		0.0031		0.010 U		0.046		0.110			
080/9/2004	26		22											
08/16/2004	13		10		0.0032		0.010 U		0.051		0.150			
08/23/2004	130		120											
08/30/2004	23		11				0.010 U		0.128		0.160			

Date	Fecal Coliform (cfu/100mL)		*E-coli* (cfu/100mL)		Orthophosphate (mg/L)		Ammonia-Nitrogen (mg/L)		Nitrite-nitrate Nitrogen (mg/L)		Total Persulfate Nitrogen (mg/L)		BOD5 (mg/L)	Inhibited BOD (mg/L)
09/07/2004	6		6											
09/13/2004	15		14		0.0041		0.010 U	0.010U	0.104		0.140			
09/20/2004	7		5											
09/27/2004	8		7		0.0031		0.011		0.079		0.120			
10/05/2004	11		9											
10/11/2004	8 J		7 J		0.0036		0.010 U		0.147		0.187			
10/18/2004	24		24											
10/25/2004	1		1		0.003U	0.0033	0.010 U	0.010U	0.125		0.160			
11/15/2004	1 UJ		NAF				0.010 U							
12/13/2004	2		1				0.010 U	0.010U						
01/24/2005	1 U						0.010 U							
02/22/2005	1 U						0.010 U	0.010U						
North Fork Snoqualmie RM 44.9														
08/05/2003	20		23		0.0043		0.010 U		0.317		0.420			
08/11/2003	8	8	9	12										
08/18/2003	2		3		0.003U		0.010 U		0.317		0.361			
08/25/2003	4		3											
09/02/2003	3		6		0.0030		0.010 U		0.343		0.367			
09/09/2003	19		35											
09/15/2003	12		21		0.003U		0.010 U		0.258		0.339			
09/22/2003	4		11											
09/29/2003	5		7		0.003U		0.012		0.229		0.322			
10/06/2003	4		3											
10/13/2003	5		5		0.003U		0.010 U							
10/20/2003	39 J		31 J											
10/27/2003	1		1 U		0.003U		0.010 U		0.258		0.337			
11/03/2003	1 U		NAF											
11/11/2003	15		15		0.003U		0.010 U		0.132		0.220			
11/17/2003	12		9											
12/01/2003	1		1 U		0.003U		0.010 U	0.010U	0.252		0.286			
12/08/2003	1 U		NAF											
12/15/2003	2		2											
01/12/2004	1 U		NAF		0.003U		0.010 U		0.220		0.261			

Date	Fecal Coliform (cfu/100mL)		*E-coli* (cfu/100mL)		Orthophosphate (mg/L)		Ammonia-Nitrogen (mg/L)		Nitrite-nitrate Nitrogen (mg/L)		Total Persulfate Nitrogen (mg/L)		BOD5 (mg/L)	Inhibited BOD (mg/L)
01/20/2004	1 U		NAF											
02/17/2004	1 U		NAF		0.0055		0.010 U		0.250		0.282			
03/08/2004	1		1 U		0.003U		0.010 U				0.210			
03/15/2004	1 UJ		NAF											
04/05/2004	1		1		0.003U		0.010 U		0.179		0.220			
04/20/2004	1		1 U											
08/02/2004	6		5		0.003U		0.010 U		0.284		0.328			
08/09/2004	7		7											
08/16/2004	11		11		0.003U		0.010 U		0.264		0.279			
08/23/2004	130		120											
08/30/2004	37		31		0.0322		0.010 U		0.204		0.230			
09/07/2004	10		9											
09/13/2004	17		16		0.003U		0.010 U		0.161		0.220			
09/20/2004	11		9											
09/27/2004	10		9		0.003U		0.010 U		0.214		0.240			
10/05/2004	2		2											
10/11/2004	7 J		6 J		0.003U		0.010 U		0.152		0.217			
10/18/2004	5		5											
10/25/2004	1		1		0.003U				0.199		0.220			
11/15/2004	4 J		4 J				0.010 U							
12/13/2004	2		1				0.010 U							
01/24/2005	1						0.015							
02/22/2005	1						0.010 U							
South Fork (Snoqualmie RM 44.4) at RM 1.5														
08/05/2003	150		120		0.0701		0.010 U		0.534	0.534	0.618			
08/11/2003	88		84											
08/18/2003	110		80		0.0524		0.010 U		0.481		0.553			
08/25/2003	84		87											
09/02/2003	59		72		0.0096		0.010 U		0.310		0.359			
09/09/2003	100		120											
09/15/2003	86		100		0.0045		0.010 U		0.311		0.425		2U	
09/22/2003	29		31											
09/29/2003	120 J	100 J	150 J	180J	0.0140		0.010 U		0.335		0.486			

Date	Fecal Coliform (cfu/100mL)			*E-coli* (cfu/100mL)			Orthophosphate (mg/L)		Ammonia-Nitrogen (mg/L)			Nitrite-nitrate Nitrogen (mg/L)		Total Persulfate Nitrogen (mg/L)		BOD5 (mg/L)	Inhibited BOD (mg/L)
10/06/2003	92			68													
10/13/2003	47			37					0.010	U							
10/20/2003	92	J	170 J	68	J	160J											
10/27/2003	17			10					0.010	U							
11/03/2003	36			32													
11/11/2003	47			45					0.010	U							
11/17/2003	25			22													
12/01/2003	3			1					0.010	U							
12/08/2003	10			5													
12/15/2003	5			2													
01/12/2004	3			2					0.010	U							
01/20/2004	2			1													
02/17/2004	6			5					0.010	U							
3/8/2004	8			8					0.010	U							
3/15/2004	1	UJ		NAF													
4/5/2004	5			5			0.0034		0.010	U							
4/20/2004	18	J		2	J												
8/2/2004	190	J		170	J				0.010	U							
8/9/2004	83			71													
8/16/2004	340			330					0.029								
8/23/2004	680			560													
8/30/2004	85			69					0.010	U							
9/7/2004	190			120													
9/13/2004	100			96			0.0270	0.0270	0.010	U		0.215		0.250			
9/20/2004	36			23													
9/27/2004	84			52					0.010	U							
10/5/2004	93			85													
10/11/2004	66	J		32	J				0.010	U	0.010U						
10/18/2004	31			31													
10/25/2004	39			28					0.010	U							
11/15/2004	23	J		16	J				0.010	U							
12/13/2004	7			6					0.010	U							
1/24/2005	36								0.010								
2/22/2005	10								0.010	U							

Date	Fecal Coliform (cfu/100mL)		*E-coli* (cfu/100mL)		Orthophosphate (mg/L)		Ammonia-Nitrogen (mg/L)			Nitrite-nitrate Nitrogen (mg/L)		Total Persulfate Nitrogen (mg/L)		BOD5 (mg/L)	Inhibited BOD (mg/L)
South Fork (Snoqualmie RM 44.4) at RM 2.0															
08/05/2003	32		51		0.0050		0.010	U	0.010U	0.25		0.298			
08/11/2003	140		110												
08/18/2003	89		87		0.0044		0.010	U		0.256		0.308			3U
08/25/2003	59		36												
09/02/2003	59		65		0.0054		0.018		0.018	0.305		0.387			
09/09/2003	140		96												
09/15/2003	75		63		0.0039		0.035			0.313		0.427		2U	
09/22/2003	34		43												
09/29/2003	160		160		0.0051		0.010	U		0.313		0.387			
10/06/2003	69		46												
10/13/2003	33		31		0.003U		0.010	U							2U
10/20/2003	100	J	92	J											
10/27/2003	18		9		0.0041		0.010	U		0.349		0.427			
11/03/2003	12		8												
11/11/2003	46	J	46	J	0.003U		0.010	U		0.219		0.318			3U
11/17/2003	11		9												
12/01/2003	3		2		0.0034		0.010	U		0.287		0.318			
12/08/2003	15		14												
12/15/2003	15		10												
01/12/2004	5		3		0.0044		0.010	U		0.31		0.346			
01/20/2004	1	J	1	J											
02/17/2004	4		3		0.0084		0.010	U		0.344	0.363	0.376			
03/08/2004	11		9		0.0033		0.010	U				0.292			
03/15/2004	1	J	1	J											
04/05/2004	1	U	NAF		0.0031		0.010	U		0.203		0.348			
04/20/2004	6	J	6	J											
08/02/2004	47		43		0.0069		0.010	U		0.222		0.254			
08/09/2004	49		45												
08/16/2004	120		110		0.0046		0.010	U		0.253		0.311			2U
08/23/2004	500		420												
08/30/2004	38		31		0.0058		0.010	U	0.010U	0.264	0.265	0.28			
09/07/2004	48		43												
09/13/2004	65	J	60		0.0033		0.010	U		0.212		0.257			2U

Date	Fecal Coliform (cfu/100mL)		*E-coli* (cfu/100mL)		Orthophosphate (mg/L)		Ammonia-Nitrogen (mg/L)		Nitrite-nitrate Nitrogen (mg/L)		Total Persulfate Nitrogen (mg/L)		BOD5 (mg/L)	Inhibited BOD (mg/L)
09/20/2004	22		11											
09/27/2004	80 J		42 J		0.0036		0.010 U		0.222		0.252			
10/05/2004	67		57											
10/11/2004	12 J		10 J		0.0039		0.010 U	0.010U	0.203		0.246			2U
10/18/2004	25		25											
10/25/2004	16		14		0.0042		0.010 U		0.223		0.262			
11/15/2004	10 J		8 J				0.010 U							
12/13/2004	4		3				0.010 U							
01/24/2005	1						0.010 U	0.010U						
02/22/2005	10						0.010 U							
Kimball Creek: Snoqualmie RM 41.1														
08/05/2003	92		140				0.023							
08/11/2003	540		540											
08/18/2003	140		140				0.028							3U
08/25/2003	120		180											
09/02/2003	200		200				0.025		0.251		0.385			
09/09/2003	1500		1700											
09/17/2003	800		1200										2U	
09/22/2003	150		280				0.024		0.281		0.450			
09/29/2003	54		180		0.0049		0.026		0.254		0.482			
10/06/2003	44		23											
10/13/2003	190		170				0.010 U							2U
10/20/2003	2900 J		2900 J											
10/27/2003	31		29				0.029							
11/03/2003	27		23											
11/11/2003	55		52				0.010 U							2
11/17/2003	120		120											
12/01/2003	10		6				0.018							
12/08/2003	31		25											
12/15/2003	14		9											
01/12/2004	15		13		0.0064		0.012		0.629		0.827	0.790		
01/20/2004	9		9											
02/17/2004	9		8				0.011							

Date	Fecal Coliform (cfu/100mL)		*E-coli* (cfu/100mL)		Orthophosphate (mg/L)		Ammonia-Nitrogen (mg/L)			Nitrite-nitrate Nitrogen (mg/L)		Total Persulfate Nitrogen (mg/L)		BOD5 (mg/L)	Inhibited BOD (mg/L)
03/08/2004	36		35				0.014								
03/15/2004	13		9												
04/05/2004	19		16				0.010	U							
04/20/2004	140		120												
08/02/2004	120		110				0.024								
080/9/2004	96		88												
08/16/2004	180		150				0.024								4U
08/23/2004	2300	J	2300	J											
08/30/2004	200		160				0.030								
09/07/2004	180		150												
09/13/2004	460		410				0.024								2U
09/20/2004	91		30												
09/27/2004	340		330				0.029		0.029						
10/05/2004	92		92												
10/11/2004	96		88				0.010	U							2U
10/18/2004	180	J	140												
10/25/2004	35		28				0.010	U							
11/15/2004	60		37				0.013								
12/13/2004	110		110				0.014								
01/24/2005	32						0.021								
02/22/2005	8						0.028								
Tokul Creek: Snoqualmie RM 39.6															
08/05/2003	43		28				0.021								
08/11/2003	27		49												
08/18/2003	23		23				0.024								3U
08/25/2003	38		38												
09/02/2003	28		18				0.020			0.565		0.653			
09/09/2003	39		48												
09/17/2003	59		55											2U	
09/22/2003	8		4				0.018			0.556		0.624			
09/29/2003	13		15		0.0160		0.019			0.558		0.763			
10/06/2003	11		9												
10/13/2003	5		4				0.012								2U
10/20/2003	190	J	160	J											

Date	Fecal Coliform (cfu/100mL)		*E-coli* (cfu/100mL)		Orthophosphate (mg/L)		Ammonia-Nitrogen (mg/L)		Nitrite-nitrate Nitrogen (mg/L)		Total Persulfate Nitrogen (mg/L)		BOD5 (mg/L)	Inhibited BOD (mg/L)
10/27/2003	8		6				0.010 U							
11/03/2003	3		3											
11/11/2003	6		6				0.010 U							2U
11/17/2003	3	2	2	2										
12/01/2003	4		3				0.010 U							
12/08/2003	2		1											
12/15/2003	2		1											
01/12/2004	7		5				0.010 U							
01/20/2004	3		3											
02/17/2004	1 U		NAF				0.010 U							
03/08/2004	3		3				0.010 U							
03/15/2004	1		1											
04/05/2004	1		1 U				0.010 U							
04/20/2004	8		7											
08/02/2004	20		18				0.011	0.010U						
08/09/2004	37		35											
08/16/2004	160		150				0.027							2U
08/23/2004	110		92											
08/30/2004	34		34				0.010 U							
09/07/2004	12		12											
09/13/2004	18		17				0.010 U							2U
09/20/2004	21		20											
09/27/2004	14		10				0.010							
10/05/2004	9		9											
10/11/2004	17		13				0.015							2U
10/18/2004	18		18											
10/25/2004	23		21				0.010 U							
11/15/2004	7		7				0.010 U							
12/13/2004	4		4				0.010 U							
01/24/2005	4						0.010 U							
02/22/2005	1						0.010 U							

Date	Fecal Coliform (cfu/100mL)		*E-coli* (cfu/100mL)		Orthophosphate (mg/L)		Ammonia-Nitrogen (mg/L)		Nitrite-nitrate Nitrogen (mg/L)		Total Persulfate Nitrogen (mg/L)		BOD5 (mg/L)	Inhibited BOD (mg/L)
Raging River: Snoqualmie RM 36.2														
08/05/2003	35		56				0.010 U							
08/11/2003	56		48											
08/18/2003	85		81				0.010 U							3U
08/25/2003	32		32											
09/02/2003	39		44				0.010 U		0.062	0.062	0.140	0.140		
09/09/2003	200		240											
09/17/2003	69		88				0.010 U		0.332		0.460		2U	
09/22/2003	33		28				0.010 U		0.382		0.460			
09/29/2003	11		36		0.0046		0.010 U		0.126		0.248			
10/06/2003	23		19											
10/13/2003	37		34				0.010 U							2U
10/20/2003	1100 J		1100 J											
10/27/2003	28		26				0.010 U							
11/03/2003	10		10											
11/11/2003	14		12				0.010 U							2U
11/17/2003	8		6											
12/01/2003	9		7				0.010 U							
12/08/2003	14		12											
12/15/2003	10		9											
01/12/2004	5		4				0.010 U							
01/20/2004	10		8											
02/17/2004	2		2				0.010 U							
03/08/2004	10		10				0.010 U							
03/15/2004	2		2											
04/05/2004	3		1				0.010 U							
04/20/2004	12		10											
08/02/2004	50		50				0.010 U							
08/09/2004	77		71											
08/16/2004	43		40				0.010 U							2U
08/23/2004	600 J		340											
08/30/2004	54		46				0.010 U							
09/07/2004	17		15											
09/13/2004	67		64				0.010 U	0.010U						2U

Date	Fecal Coliform (cfu/100mL)		*E-coli* (cfu/100mL)		Orthophosphate (mg/L)		Ammonia-Nitrogen (mg/L)		Nitrite-nitrate Nitrogen (mg/L)		Total Persulfate Nitrogen (mg/L)		BOD5 (mg/L)	Inhibited BOD (mg/L)
09/20/2004	27		20											
09/27/2004	9		7				0.010 U							
10/05/2004	28		28											
10/11/2004	15		10				0.010 U							2U
10/18/2004	39 J		37											
10/25/2004	10		10				0.010 U							
11/15/2004	32		30				0.010 U	0.010U						
12/13/2004	11		9				0.010 U							
01/24/2005	72						0.010 U							
02/22/2005	1						0.010 U							
Patterson Creek: Snoqualmie RM 31.2														
08/06/2003	170	250	180	170	0.0270	0.0260	0.021		0.665		0.959			
08/12/2003	160 J		130 J											
08/19/2003	140		200				0.011							3U
08/26/2003	100		130											
09/03/2003	190		200				0.014		0.646		0.781			
09/10/2003	240		240											
09/16/2003	870		980										2U	
09/23/2003	92		92				0.016		0.538		0.755			
09/30/2003	80	36	77	77	0.0327		0.015		0.555		0.846			
10/07/2003	120		120											
10/14/2003	26		26				0.010 U							2U
10/21/2003	1800		1800											
10/28/2003	29		21				0.028							
11/03/2003	35		32											
11/12/2003	21		19				0.022							3U
11/17/2003	15 J		20 J											
12/02/2003	16		15				0.025							
12/08/2003	4		3											
12/15/2003	14		11											
01/13/2004	7		6				0.012							
01/20/2004	6		6											
02/18/2004	6		6				0.011							

Date	Fecal Coliform (cfu/100mL)	*E-coli* (cfu/100mL)	Orthophosphate (mg/L)	Ammonia-Nitrogen (mg/L)		Nitrite-nitrate Nitrogen (mg/L)	Total Persulfate Nitrogen (mg/L)	BOD5 (mg/L)	Inhibited BOD (mg/L)
03/09/2004	16	12		0.016					
03/15/2004	22	21							
04/06/2004	25	22		0.010 U					
04/20/2004	36	35							
08/03/2004	140	130		0.010 U					
08/10/2004	110	110							
08/17/2004	150	130		0.010					4U
08/24/2004	1900 J	1900 J							
08/31/2004	320 J	260 J		0.024					
09/08/2004	120	96							
09/14/2004	150	130		0.020	0.018				2U
09/21/2004	80	57							
09/28/2004	110	100		0.021					
10/06/2004	160	120							
10/12/2004	51	41		0.010 U					2U
10/19/2004	100 J	100 J							
10/26/2004	32	29		0.010 U					
11/16/2004	56	49		0.021					
12/15/2004	32	28		0.027					
01/25/2005	15 J			0.028					
02/23/2005	14			0.020					
Griffin Creek: Snoqualmie RM 27.2									
08/06/2003	120	110		0.010 U					
08/12/2003	81	81							
08/19/2003	140	250		0.010 U					3U
08/26/2003	96	120							
09/03/2003	92	130		0.010 U		0.376	0.514		
09/10/2003	96	96							
09/16/2003	1300	1200						2	
09/23/2003	25 U	25		0.010 U		0.336	0.420		
09/30/2003	52 J	130 J	0.0170	0.010 U		0.350	0.513		
10/07/2003	44 J	43							
10/14/2003	15	13		0.010 U					2U

Date	Fecal Coliform (cfu/100mL)		*E-coli* (cfu/100mL)		Orthophosphate (mg/L)		Ammonia-Nitrogen (mg/L)		Nitrite-nitrate Nitrogen (mg/L)		Total Persulfate Nitrogen (mg/L)		BOD5 (mg/L)	Inhibited BOD (mg/L)
10/21/2003	590		570											
10/28/2003	20		14				0.010 U	0.010U						
11/03/2003	5		5											
11/12/2003	7		7				0.010 U							2U
11/17/2003	23		13											
12/02/2003	2		1				0.010 U							
12/08/2003	4		4											
12/15/2003	12		12											
01/13/2004	4		4				0.010 U							
01/20/2004	2		1											
02/18/2004	2		2				0.010 U							
03/09/2004	22		22				0.010 U							
03/15/2004	6		5											
04/06/2004	1	U	NAF				0.010 U							
04/20/2004	2		2											
08/03/2004	79		76				0.010 U							
08/10/2004	120		120											
08/17/2004	92		76				0.010 U							4U
08/24/2004	1600	J	1500											
08/31/2004	60	J	51	J			0.010 U							
09/08/2004	33		26											
09/14/2004	69		68				0.010 U							2U
09/21/2004	48		40											
09/28/2004	14		10				0.010 U							
10/06/2004	30		23											
10/12/2004	28		24				0.010 U							2U
10/19/2004	160	J	150	J										
10/26/2004	49		40				0.010 U							
11/16/2004	2		2				0.010 U							
12/15/2004	7		6				0.010							
01/25/2005	37						0.010 U							
02/23/2005	28						0.010 U							

Date	Fecal Coliform (cfu/100mL)	*E-coli* (cfu/100mL)	Orthophosphate (mg/L)	Ammonia-Nitrogen (mg/L)	Nitrite-nitrate Nitrogen (mg/L)	Total Persulfate Nitrogen (mg/L)	BOD5 (mg/L)	Inhibited BOD (mg/L)
Tolt River: Snoqualmie RM 24.9								
08/06/2003	16	17		0.010 U				
08/12/2003	43 J	42 J						
08/19/2003	10	10		0.010 U				3U
08/26/2003	13	11						
09/03/2003	8	8		0.010 U	0.175	0.210		
09/10/2003	25	16						
09/16/2003	61	76					2U	
09/23/2003	25	14		0.010 U	0.202	0.263		
09/30/2003	4	12	0.0029	0.010 U	0.174	0.270		
10/07/2003	19	16						
10/14/2003	9	7		0.010 U				2U
10/21/2003	80	80						
10/28/2003	9	7		0.010 U				
11/03/2003	3	3						
11/12/2003	1	1		0.010 U	0.272	0.299		2U
11/17/2003	3	4						
12/02/2003	3	2		0.010 U				
12/08/2003	11	9						
12/15/2003	6	6						
01/13/2004	5	4		0.010 U				
01/20/2004	7	6						
02/18/2004	2	2		0.010 U				
03/09/2004	1	1		0.010 U				
03/15/2004	1 U	NAF						
04/06/2004	14	7		0.010 U				
04/20/2004	4	4						
080/3/2004	9	9		0.010 U				
08/10/2004	41	34						
08/17/2004	14	13		0.010 U				4U
08/24/2004	840	840						
08/31/2004	14 J	14 J		0.010 U				
09/08/2004	4	4						
09/14/2004	100	96		0.010 U				2U

Date	Fecal Coliform (cfu/100mL)			*E-coli* (cfu/100mL)			Orthophosphate (mg/L)		Ammonia-Nitrogen (mg/L)			Nitrite-nitrate Nitrogen (mg/L)		Total Persulfate Nitrogen (mg/L)		BOD5 (mg/L)	Inhibited BOD (mg/L)
09/21/2004	8			6													
09/28/2004	3			3					0.010	U							
10/06/2004	14			7													
10/12/2004	17			16					0.010								2U
10/19/2004	4	J		4	J												
10/26/2004	10			7					0.010	U							
11/16/2004	4			4					0.010	U							
12/15/2004	2			2					0.010	U							
01/25/2005	2								0.010	U							
02/23/2005	1	U							0.010	U							
Harris Creek: Snoqualmie RM 21.3																	
08/06/2003	32			45					0.010	U							
08/12/2003	23			47													
08/19/2003	27			31					0.010	U							3U
08/26/2003	50			68													
09/03/2003	29			35					0.010	U		0.832		0.887			
09/10/2003	45			51													
09/16/2003	800	J		650	J											2U	
09/23/2003	8	U		8	U				0.010	U		0.676		0.767			
09/30/2003	5	J		13	J		0.021		0.010	U		0.687		0.905			
10/07/2003	25			23													
10/14/2003	11			11					0.010	U							2U
10/21/2003	270			260													
10/28/2003	31		30	22		18			0.010	U							
11/03/2003	88			85													
11/12/2003	6			5					0.010	U							2U
11/17/2003	18			18													
12/02/2003	2			1					0.010	U							
12/08/2003	7			6													
12/15/2003	4			3													
01/13/2004	13			9					0.010	U							
01/20/2004	11			5													
02/18/2004	8			5					0.010	U							

Date	Fecal Coliform (cfu/100mL)		*E-coli* (cfu/100mL)		Orthophosphate (mg/L)		Ammonia-Nitrogen (mg/L)		Nitrite-nitrate Nitrogen (mg/L)		Total Persulfate Nitrogen (mg/L)		BOD5 (mg/L)	Inhibited BOD (mg/L)
03/09/2004	37		37				0.010 U							
03/15/2004	1 U		NAF											
04/06/2004	6		5				0.010 U							
04/20/2004	12		7											
08/03/2004	21		20				0.010 U							
08/10/2004	41		26											
08/17/2004	84		55				0.010 U							2U
08/24/2004	630 J		590											
08/31/2004	40 J		34 J				0.010 U							
09/08/2004	40		32											
09/14/2004	480		450				0.010 U							2U
09/21/2004	46		40											
09/28/2004	120		100				0.010 U							
10/06/2004	12		8											
10/12/2004	24		21				0.010							2U
10/19/2004	40		38											
10/26/2004	16		9				0.023							
11/16/2004	26		26				0.015							
12/15/2004	5		4				0.013							
01/25/2005	11						0.011							
02/23/2005	41						0.012							
Ames Creek: Snoqualmie RM 17.5														
08/06/2003	550		460				0.019							
08/12/2003	200		570											
08/19/2003	330		290				0.030							3U
08/26/2003	580		800											
09/03/2003	330		340				0.018		0.644		0.806			
09/10/2003	200		290											
09/16/2003	7000 J		4300										3	
09/23/2003	230		250				0.022		0.588		0.787			
09/30/2003	430	410	700	600	0.0427		0.027		0.590		0.906			
10/07/2003	140		140											
10/14/2003	26		23				0.021	0.022						2U

Date	Fecal Coliform (cfu/100mL)		*E-coli* (cfu/100mL)		Orthophosphate (mg/L)		Ammonia-Nitrogen (mg/L)		Nitrite-nitrate Nitrogen (mg/L)		Total Persulfate Nitrogen (mg/L)		BOD5 (mg/L)	Inhibited BOD (mg/L)
10/21/2003	390		390											
10/28/2003	120 J		76 J				0.208							
11/03/2003	40		37											
11/12/2003	220		210				0.206							2U
11/17/2003	51		43											
12/02/2003	29		27				0.194							
12/08/2003	16		16											
12/15/2003	28 J		28											
01/13/2004	21		20				0.184		1.68					
01/20/2004	13		12											
02/18/2004	24		22				0.242							
03/09/2004	38		37				0.183							
03/15/2004	20 J		14											
04/06/2004	28		27				0.124							
04/20/2004	290		280											
08/03/2004	320		310				0.032							
08/10/2004	330		330											
08/17/2004	520		470				0.046							4U
08/24/2004	4500		1300											
08/31/2004	480 J		460 J				0.075	0.074						
09/08/2004	220		180											
09/14/2004	520		460				0.069							
09/21/2004	160		120											
09/28/2004	1200		1200				0.091							
10/06/2004	110		84											
10/12/2004	57		57				0.083							2U
10/19/2004	83		80											
10/26/2004	140		96											
11/16/2004	60		57				0.211							
12/15/2004	200 J		92				0.164							
01/25/2005	75 J						0.281							
02/23/2005	32						0.112							

Date	Fecal Coliform (cfu/100mL)		*E-coli* (cfu/100mL)		Orthophosphate (mg/L)		Ammonia-Nitrogen (mg/L)		Nitrite-nitrate Nitrogen (mg/L)		Total Persulfate Nitrogen (mg/L)		BOD5 (mg/L)	Inhibited BOD (mg/L)
Tuck Creek: Snoqualmie RM 10.3														
08/06/2003	290		310				0.028							
08/12/2003	80		140											
08/19/2003	68		120				0.034							3U
08/26/2003	100		130											
09/03/2003	80		92				0.016		0.041		0.220			
09/10/2003	88		140											
09/16/2003	1300		1500										2	
09/23/2003	50		100				0.023		0.053		0.240	0.250		
09/30/2003	96		170		0.0384		0.043		0.123		0.356			
10/07/2003	210		200											
11/03/2003	12		10											
11/12/2003	15		11				0.047							2U
11/17/2003	230		230											
12/02/2003	110		100				0.054							
12/08/2003	140		140											
12/15/2003	32		29											
01/13/2004	25		17				0.019							
01/20/2004	200		190											
02/18/2004	7		4				0.030							
030/9/2004	7		6				0.027							
03/15/2004	12	J	12											
04/06/2004	32		29				0.571							
04/20/2004	32		32											
08/03/2004	100		100				0.019							
08/10/2004	80		76											
08/17/2004	120		96				0.024							
08/24/2004	170		150											
090/8/2004	70		57											
09/14/2004	260		240											
09/21/2004	33		29											
09/28/2004	29		23				0.034							
10/12/2004	27		23				0.021							
10/19/2004	280		280											

Date	Fecal Coliform (cfu/100mL)		*E-coli* (cfu/100mL)		Orthophosphate (mg/L)		Ammonia-Nitrogen (mg/L)		Nitrite-nitrate Nitrogen (mg/L)		Total Persulfate Nitrogen (mg/L)		BOD5 (mg/L)	Inhibited BOD (mg/L)
10/26/2004	54		51				0.039							
11/16/2004	160		160				0.072							
12/15/2004	120		96				0.061							
01/25/2005	240						0.153							
02/23/2005	5						0.093							
Cherry Creek: Snoqualmie RM 6.7														
08/06/2003	60		75				0.014							
08/12/2003	120		120											
08/19/2003	170		110				0.015							3U
08/26/2003	180		310											
09/03/2003	57		80				0.021		0.310		0.476			
09/10/2003	130		180											
09/16/2003	920		1000										2U	
09/23/2003	25		75				0.019		0.430		0.577			
09/30/2003	48		100		0.013		0.025		0.471		0.655			
10/07/2003	44		37											
10/14/2003	96		84				0.024							2U
10/21/2003	380		380											
10/28/2003	180		150				0.094							
11/03/2003	1	U	NAF											
11/12/2003	27		23				0.010	U						9
11/17/2003	11		10											
12/02/2003	12		10				0.013							
12/08/2003	30		20											
12/15/2003	21		20											
01/13/2004	16		12				0.028							
01/20/2004	26		21											
02/18/2004	73		69				0.110							
03/09/2004	6		6				0.010	U						
03/15/2004	2		2											
04/06/2004	7		7				0.010	U						
04/20/2004	5		5											
08/03/2004	210	J	210	J			0.042							

Date	Fecal Coliform (cfu/100mL)		*E-coli* (cfu/100mL)		Orthophosphate (mg/L)		Ammonia-Nitrogen (mg/L)		Nitrite-nitrate Nitrogen (mg/L)		Total Persulfate Nitrogen (mg/L)		BOD5 (mg/L)	Inhibited BOD (mg/L)
08/10/2004	300		300											
08/17/2004	1000		1000				0.023							4U
08/24/2004	420		330											
08/31/2004	320		280				0.067							
09/08/2004	220		210											
09/14/2004	940		890				0.014	0.019						2U
09/21/2004	54		49											
09/28/2004	93		83				0.030							
10/06/2004	44		33											
10/12/2004	35		23				0.010 U							2U
10/19/2004	140		130											
10/26/2004	33		33				0.010 U							
11/16/2004	17		15				0.022							
12/15/2004	47		4				0.013							
01/25/2005	7						0.031							
02/23/2005	17						0.033							

U – The analyte was not detected at or above the reported sample quantitation limit.
NAF – Not analyzed for.
J – The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample. For bacteria, this indicates estimated count; samples are analyzed over 24 hours after collection.

Table E-4: Field results for Snoqualmie tributaries.

Date	Time	Temperature (°C)	Winkler Dissolved Oxygen (mg/L)	pH (SU)	Conductivity (µmhos)	Flow Discharge (cfs)
Middle Fork Snoqualmie RM 45.3						
08/05/2003	12:55	18.0	9.8	6.9	36	174 x_1
08/11/2003	11:52	16.8				159 x_1
08/18/2003	13:19	18.6	9.5	6.8	39	150 x_1
08/25/2003	13:30	17.5		7.7	39	126 x_1
09/02/2003	11:55	15.8		7.5	41	117 x_1
09/09/2003	12:10	14.9				163 x_1
09/15/2003	10:55	13.1	11.3	7.4	31	200 x_1
09/22/2003	12:00	12.0				265 x_1
09/29/2003	10:38	13.4	10.3	7.5	37	161 x_1
10/06/2003	13:00	12.9				129 x_1
10/13/2003	11:40	9.8	11.6	7.0	20	1930 x_1
10/20/2003	13:00	10.7	10.7			5290 x_1
10/27/2003	11:35	9.9	11.1	7.1	25	747 x_1
11/03/2003	10:22	4.0				632 x_1
11/11/2003	11:22	8.3		7.0	15	4700 x_1
11/17/2003	10:18	6.4				1700 x_1
12/01/2003	11:10	5.4		7.1	18	1770 x_1
12/08/2003	10:32	5.2				1100 x_1
12/15/2003	10:50	4.6				946 x_1
01/12/2004	11:33	3.9		7.4	23	912 x_1
01/20/2004	14:30					1060 x_1
02/17/2004	10:55	6.2		7.3	26	604 x_1
03/08/2004	10:15	7.5		7.3	17	2000 x_1
03/15/2004	08:34					883 x_1
04/05/2004	10:40	8.0		7.3	56	1010 x_1
04/20/2004	10:43	7.8				856 x_1
08/02/2004	13:20	19.8	9.3	7.5	32	214 x_1
08/09/2004	13:00	19.0				261 x_1
08/16/2004	11:52	18.9	9.4	7.3	33	189 x_1
08/23/2004	10:20	15.3				485 x_1
08/30/2004	12:05	14.8	10.0	7.2	22	729 x_1
09/07/2004	12:29	13.7				429 x_1
09/13/2004	12:15	11.7	10.7	7.1	20	1090 x_1
09/20/2004	11:52	10.5				1250 x_1
09/27/2004	11:00	12.4		7.3	25	483 x_1
10/05/2004	11:30	10.6				288 x_1
10/11/2004	11:30	10.0	11.5	7.3	21	912 x_1
10/18/2004	11:25	9.3				2300 x_1
10/25/2004	11:55	7.2	12.1	7.3		1060 x_1
11/15/2004	11:18	7.5		7.3	24	564 x_1
12/13/2004	11:00	5.1		7.0	17	1910 x_1
01/24/2005	14:15	5.8		7.2	17	1780 x_1
02/22/2005	11:07	2.4		7.3	30	339 x_1

Date	Time	Temperature (°C)	Winkler Dissolved Oxygen (mg/L)	pH (SU)	Conductivity (µmhos)	Flow Discharge (cfs)	
North Fork Snoqualmie RM 44.9							
08/05/2003	13:35	15.2	9.2	6.8	65	46	x_2
08/11/2003	12:41	14.6				44	x_2
08/18/2003	14:08	15.8	9.6	6.9	109	40	x_2
08/25/2003	13:35	14.5		7.4	129	37	x_2
09/02/2003	12:18	13.4	9.7	7.4	67	35	x_2
09/09/2003	12:20	13.1				42	x_2
09/15/2003	11:15	13.4	10.3	7.1	40	100	x_2
09/22/2003	12:15	11.2				150	x_2
09/29/2003	10:58	12.5	9.9	7.4	50	71	x_2
10/06/2003	13:50	12.3				50	x_2
10/13/2003	12:00	9.8	11.5	6.8	21	655	x_2
10/20/2003	13:28	12.2	10.6			2760	x_2
10/27/2003	12:08	10.2	10.9	7.2	36	319	x_2
11/03/2003	10:48	5.0				261	x_2
11/11/2003	11:44	7.2		6.8	14	2110	x_2
11/17/2003	10:30	6.5				665	x_2
12/01/2003	11:36	5.8		6.8	27	809	x_2
12/08/2003	10:58	5.6				551	x_2
12/15/2003	10:59	5.3				408	x_2
01/12/2004	11:54	4.9		7.0	29	566	x_2
01/20/2004	14:20					541	x_2
02/17/2004	11:20	6.4		7.1	55	418	x_2
03/08/2004	10:37	6.3		6.9	18	1180	x_2
03/15/2004	08:58					439	x_2
04/05/2004	10:52	7.9		7.0	29	434	x_2
04/20/2004	11:00	8.1				412	x_2
08/02/2004	14:38	17.2	9.4	7.2	58	58	x_2
08/09/2004	13:25	14.1				87	x_2
08/16/2004	12:15	16.2	9.4	7.2	55	56	x_2
08/23/2004	10:32	14.4				215	x_2
08/30/2004	12:40	14.7	9.9	7.1	31	295	x_2
09/07/2004	12:47	12.7				186	x_2
09/13/2004	12:45	12.0	10.5	7.1	27	499	x_2
09/20/2004	12:15	10.9				592	x_2
09/27/2004	11:25	11.4	10.6	7.2	39	213	x_2
10/05/2004	11:42	10.1				124	x_2
10/11/2004	11:48	10.2	10.6	7.2	29	363	x_2
10/18/2004	11:35	9.6				1130	x_2
10/25/2004	12:28	7.2	11.8	7.2		677	x_2
11/15/2004	11:33	7.8		7.1	36	311	x_2
12/13/2004	11:20	5.9		7.0	27	812	x_2
01/24/2005	14:30	6.2		7.0	27	803	x_2
02/22/2005	11:35	3.4		7.4	47	154	x_2

Date	Time	Temperature (°C)	Winkler Dissolved Oxygen (mg/L)	pH (SU)	Conductivity (µmhos)	Flow Discharge (cfs)
South Fork (Snoqualmie RM 44.4) at RM 1.5						
08/05/2003	11:55	14.2	10.0	6.7	101	106 x_3
08/11/2003	11:25	10.3				104 x_3
08/18/2003	12:31	14.8	10.4	6.8	96	93 x_3
08/25/2003	12:16	13.9		7.6	248	89 x_3
09/02/2003	11:26	12.7		7.5	108	84 x_3
09/09/2003	11:45	12.8				109 x_3
09/15/2003	10:22	13.0	10.5	7.6	79	106 x_3
09/22/2003	11:38	11.4				123 x_3
09/29/2003	10:06	11.9	9.7	7.4	84	92 x_3
10/06/2003	11:39	11.7				87 x_3
10/13/2003	11:15	9.5	11.1	7.1	39	570 x_3
10/20/2003	12:30	10.9				1110 x_3
10/27/2003	11:00	10.1	10.4	7.0	65	314 x_3
11/03/2003	09:57	5.5				275 x_3
11/11/2003	10:55	7.7		7.2	33	1050 x_3
11/17/2003	10:05	6.5				521 x_3
12/01/2003	12:16	5.8		6.9	39	926 x_3
12/08/2003	10:03	6.1				556 x_3
12/15/2003	10:32	5.7				487 x_3
01/12/2004	11:13	5.6		7.1	77	306 x_3
01/20/2004	09:48					447 x_3
02/17/2004	10:35	6.0		7.2	72	351 x_3
03/08/2004	10:02	11.1		7.2	61	599 x_3
03/15/2004	08:30					459 x_3
04/05/2004	10:13	7.9		7.0	46	565 x_3
04/20/2004	10:21	7.3				491 x_3
08/02/2004	12:15	14.8	10.1	7.3	89	157 x_3
08/09/2004	12:16	15.3				161 x_3
08/16/2004	11:15	14.3	9.1	7.3	90	138 x_3
08/23/2004	10:02	13.4				233 x_3
08/30/2004	11:32	13.8	9.5	7.1	60	362 x_3
09/07/2004	11:18	12.2				219 x_3
09/13/2004	11:23	11.2	10.3	7.0	52	441 x_3
09/20/2004	11:25	10.3				550 x_3
09/27/2004	10:15	11.2	10.3	7.1	66	275 x_3
10/05/2004	11:05	10.3				213 x_3
10/11/2004	10:48	9.8	10.9	7.1	60	326 x_3
10/18/2004	11:10	9.2				744 x_3
10/25/2004	10:51	7.5	11.8	7.1		406 x_3
11/15/2004	10:54	8.3		7.2	59	273 x_3
12/13/2004	10:35	5.1		6.9	36	1180 x_3
01/24/2005	13:20	6.4		7.1	43	898 x_3
02/22/2005	10:23	4.7		7.3	69	234 x_3

Date	Time	Temperature (°C)	Winkler Dissolved Oxygen (mg/L)	pH (SU)	Conductivity (µmhos)	Flow Discharge (cfs)	
South Fork (Snoqualmie RM 44.4) at RM 2.0							
08/05/2003	11:05	14.0	10.3	6.4	80	106	x_3
08/11/2003	10:10	12.9				104	x_3
08/18/2003	11:32	14.0	11.7	6.6	82	93	x_3
08/25/2003	11:08	13.0		7.6	97	89	x_3
09/02/2003	10:51	12.5	10.3	7.4	87	84	x_3
09/09/2003	10:30	12.4				109	x_3
09/15/2003	09:50		10.6	7.4	247	106	x_3
09/22/2003	10:20	10.8				123	x_3
09/29/2003	09:45	12.0	9.9	7.3	81	92	x_3
10/06/2003	11:11	11.4	10.3			87	x_3
10/13/2003	10:50	9.9	11.2	7.0	39	570	x_3
10/20/2003	11:57	10.7	10.5			1110	x_3
10/27/2003	10:30	9.8	10.5	7.2	54	314	x_3
11/03/2003	09:38	5.3				275	x_3
11/11/2003	10:10	8.3		6.9	30	1050	x_3
11/17/2003	09:50	6.9				521	x_3
12/01/2003	10:40	6.6		7.2	39	926	x_3
12/08/2003	09:43	5.9				556	x_3
12/15/2003	10:14	5.6				487	x_3
01/12/2004	10:55	5.4		6.9	84	306	x_3
01/20/2004	09:17					447	x_3
02/17/2004	09:50	7.3		7.1	101	351	x_3
03/08/2004	09:34	8.1		6.8	114	599	x_3
03/15/2004	08:15					459	x_3
04/05/2004	09:49	7.6		6.9	45	565	x_3
04/20/2004	10:10	7.1				491	x_3
08/02/2004	11:30	14.6	10.1	7.3	18	157	x_3
08/09/2004	10:48	14.1				161	x_3
08/16/2004	10:48	14.2	9.6	7.3	77	138	x_3
08/23/2004	09:45	13.4				233	x_3
08/30/2004	11:00	13.6	9.8	6.8	52	362	x_3
09/07/2004	10:45	11.8				219	x_3
09/13/2004	11:00	11.1	10.5	7.4	46	441	x_3
09/20/2004	11:00	10.1				550	x_3
09/27/2004	09:45	11.0	10.5	6.8	57	275	x_3
10/05/2004	09:59	10.0				213	x_3
10/11/2004	10:17	9.7	11.2	7.5	52	326	x_3
10/18/2004	10:35	9.0				744	x_3
10/25/2004	10:28	7.3		6.8		406	x_3
11/15/2004	10:30	8.0		7.1	54	273	x_3
12/13/2004	10:10	5.2		6.3	35	1180	x_3
01/24/2005	12:20	6.1		7.5	40	898	x_3
02/22/2005	09:45	4.6		7.4	68	234	x_3

Date	Time	Temperature (°C)	Winkler Dissolved Oxygen (mg/L)	pH (SU)	Conductivity (µmhos)	Flow Discharge (cfs)
Kimball Creek: Snoqualmie RM 41.1						
08/05/2003	15:40	17.1		6.8	106	nd
08/11/2003	14:18	17.0				0.69
08/18/2003	16:05	18.0	7.2	7.0	101	nd
08/25/2003	15:45	15.6		7.4	99	0.51
09/02/2003	14:10	15.6		7.2	106	nd
09/09/2003	15:30	14.8				0.84
09/17/2003	09:42	12.7	8.9	7.4	95	nd
09/22/2003	15:10	11.9				1.34
09/29/2003	11:44	13.5	8.2	7.4	97	nd
10/06/2003	15:35	13.3				nd
10/13/2003	14:00	11.3	9.3	7.2	93	nd
10/20/2003	15:24	14.0	8.6			nd
10/27/2003	13:05	10.9	7.4	6.7	76	nd
11/03/2003	11:37	4.2				nd
11/11/2003	13:20	8.4		6.8	72	nd
11/17/2003	11:02	7.4				nd
12/01/2003	13:02	6.7		6.7	54	nd
12/08/2003	11:43	6.6				nd
12/15/2003	11:27	6.0				nd
01/12/2004	13:43	5.2		6.8	67	nd
01/20/2004	13:53					nd
02/17/2004	12:55	6.6		6.8	61	nd
03/08/2004	11:17	9.4		6.7	54	nd
03/15/2004	09:22					nd
04/05/2004	11:23	10.1		7.8	73	nd
04/20/2004	11:43	10.5				nd
08/02/2004	16:05	18.4	6.9	7.0	100	nd
08/09/2004	15:28	18.6				nd
08/16/2004	14:12	19.2	6.9	7.0	102	nd
08/23/2004	11:40	15.8				5.01
08/30/2004	13:58	16.9	6.5	6.8	84	nd
09/07/2004	13:45	14.4				nd
09/13/2004	14:10	14.0	8.3	6.9	75	nd
09/20/2004	15:33	13.0				nd
09/27/2004	12:20	12.4	7.9	6.9	88	nd
10/05/2004	13:58	10.8				2.88
10/11/2004	13:55	11.4	8.4	6.9	83	nd
10/18/2004	13:59	11.1				20.09
10/25/2004	13:08	8.6		6.9		nd
11/15/2004	13:21	8.4		6.9	74	nd
12/13/2004	12:35	6.6		6.6	51	nd
01/24/2005	15:12	8.7		6.8	61	nd
02/22/2005	13:15	2.8		6.8	75	nd

Date	Time	Temperature (°C)	Winkler Dissolved Oxygen (mg/L)	pH (SU)	Conductivity (µmhos)	Flow Discharge (cfs)	
Tokul Creek: Snoqualmie RM 39.6							
e/E= Flow is an estimate based on flow curve relationship (r2=0.97, n=10) between Tokul Creek flows and flows at the Tolt River USGS gauging station 12148500.							
08/05/2003	16:36	15.1		6.9	137	20	e
08/11/2003	15:15	15.3				24	
08/18/2003	17:45	16.2	9.8	7.0	138	20	e
08/25/2003	16:58	14.7		8.4	138	19	e
09/02/2003	14:50	14.2	10.6	8.6	138	19	e
09/09/2003	15:55	13.0				18	
09/17/2003	10:38	12.0	11.0	8.1	130	28	e
09/22/2003	16:15	12.0				20	
09/29/2003	12:15	12.1	10.8	8.2	139	20	e
10/06/2003	16:44	12.5				18	
10/13/2003	14:50	11.1	11.4	8.0	136	47	e
10/20/2003	16:42	12.5	10.2			524	E
10/27/2003	13:50	9.8	11.3	7.7	121	49	e
11/03/2003	12:07	4.4				41	e
11/11/2003	14:04	8.5		7.8	102	102	E
11/17/2003	11:32	7.4				101	E
12/01/2003	13:40	6.6		7.4	64	87	E
12/08/2003	12:26	6.9				70	e
12/15/2003	11:46	6.5				61	e
01/12/2004	14:45	5.2		7.3	76	75	e
01/20/2004	13:29					65	e
02/17/2004	13:30	6.5		7.5	86	66	e
03/08/2004	11:44	9.3		7.4	73	100	E
03/15/2004	09:41					59	e
04/05/2004	11:57	9.5		7.2	101	48	e
04/20/2004	12:12	10.0				52	e
08/02/2004	17:58	16.8	9.6	8.0	133	22	e
08/09/2004	16:30	17.4				25	
08/16/2004	15:02	17.5	9.7	8.1	123	21	e
08/23/2004	13:38	15.2				35	
08/30/2004	15:00	16.2	9.9	7.1	111	36	e
09/07/2004	15:11	13.7				31	
09/13/2004	15:20	13.0	10.3	7.9	108	40	e
09/20/2004	16:50	12.4				64	
09/27/2004	12:55	11.9	10.9	7.8	110	39	e
10/05/2004	14:25	10.3				31	
10/11/2004	14:52	10.9	11.1	7.7	108	45	e
10/18/2004	14:27	10.4				78	
10/25/2004	13:51	8.1	11.8	7.5		66	e
11/15/2004	13:48	8.7		7.5	95	44	e
12/13/2004	13:45	7.4		7.3	61	119	E
01/24/2005	15:49	7.7		7.3	76	93	E
02/22/2005	13:53	4.1		7.6	102	34	e

Date	Time	Temperature (°C)	Winkler Dissolved Oxygen (mg/L)	pH (SU)	Conductivity (µmhos)	Flow Discharge (cfs)
Raging River: Snoqualmie RM 36.2						
e/E: flow is an estimate based on flow curve relationship (r2=0.97, n=11) between Raging River sample site flows and flows at Raging River USGS gauging station 12145500						
08/05/2003	17:14	19.6		8.6	108	6 e
08/11/2003	16:14	20.0				9
08/18/2003	18:35	23.5	8.6	8.3	101	6 e
08/25/2003	17:20	21.9		9.5	103	5 e
09/02/2003	15:20	19.4		9.5	103	4 e
09/09/2003	17:40	15.3				11
09/17/2003	11:43	12.6	12.2	9.1	93	28 e
09/22/2003	17:20	14.8				21
09/29/2003	13:20	14.3	10.6	9.7	88	10 e
10/06/2003	17:46	15.3	10.1			11
10/13/2003	15:12	10.2	11.4	7.7	26	49 e
10/20/2003	17:58	14.2	9.9			1415 E
10/27/2003	14:38	11.8	10.7	7.6	51	100 e
11/03/2003	12:51	4.5				54 e
11/11/2003	14:55	9.5		7.2	47	100 e
11/17/2003	12:04	7.6				122 e
12/01/2003	14:30	7.1		7.0	37	336 E
12/08/2003	13:03	7.0				316 E
12/15/2003	12:13	6.6				273 E
01/12/2004	15:23	6.9		6.7	41	252 E
01/20/2004	12:55					173 E
02/17/2004	14:00	6.6		7.2	44	155 E
03/08/2004	12:12	10.8		7.4	36	175 E
03/15/2004	10:02					88 e
04/05/2004	12:36	10.5		6.9	52	65 e
04/20/2004	12:38	8.8				50 e
08/02/2004	18:57	23.1	8.8	8.9	102	9 e
08/09/2004	17:43	24.4				11
08/16/2004	15:55	23.1	9.8	9.3	96	7 e
08/23/2004	14:48	16.3				52
08/30/2004	15:50	18.3		7.6	49	55 e
09/07/2004	16:00	16.8				24
09/13/2004	16:05	14.3	10.3	7.7	43	113 e
09/20/2004	18:00	13.5				103
09/27/2004	14:10	13.4	11.3	8.6	54	40 e
10/05/2004	15:50	12.4				24
10/11/2004	16:00	12.6	11.0	7.7	57	65 e
10/18/2004	15:42	11.0				236 e
10/25/2004	14:39	9.3	11.8	7.9		65 e
11/15/2004	14:26	9.3		7.2	56	130 e
12/13/2004	14:25	5.8		7.0	36	417 E
01/24/2005	16:30	6.8		7.2	43	224 E
02/22/2005	14:30	4.5		7.6	59	45 e

Date	Time	Temperature (°C)	Winkler Dissolved Oxygen (mg/L)	pH (SU)	Conductivity (µmhos)	Flow Discharge (cfs)
Patterson Creek: Snoqualmie RM 31.2						
08/06/2003	09:51	13.9	8.8	7.0	177	nd
08/12/2003	09:09	13.5				nd
08/19/2003	10:21	13.7	9.0	7.1	99	nd
08/26/2003	10:45	12.9		7.7	217	6.98
09/03/2003	09:15	12.3	8.8	7.7	164	nd
09/10/2003	09:09	13.4				nd
09/16/2003	09:45	11.7	8.7	7.6	166	nd
09/23/2003	09:00	11.6				nd
09/30/2003	13:00	13.1	9.3	7.6	170	nd
10/07/2003	09:38	12.5	8.6			7.63
10/14/2003	09:38	10.9	9.2	7.4	165	nd
10/28/2003	13:29	11.7	8.6	6.6	139	nd
11/03/2003	13:34	5.2				nd
11/12/2003	09:23	6.7		7.3	145	nd
11/17/2003	12:42	7.6				nd
12/02/2003	09:30	7.2		6.8	90	nd
12/08/2003	13:45	7.0				nd
12/15/2003	12:39	6.0				nd
01/13/2004	10:05	6.0		6.9	133	nd
01/20/2004	13:10					nd
02/18/2004	09:10	7.6		7.0	104	nd
03/09/2004	09:40	10.0		6.7	111	nd
03/15/2004	10:22					nd
04/06/2004	09:14	9.7		7.2	137	nd
04/20/2004	12:57					nd
08/03/2004	10:53	15.3	8.4	7.7	165	nd
08/10/2004	09:22	15.1				nd
08/17/2004	09:22	15.2	7.9	7.4	177	nd
08/24/2004	10:32	15.8				29.09
08/31/2004	09:40	19.2	7.7	7.2	175	nd
09/08/2004	09:49	12.6				nd
09/14/2004	09:45	13.6	7.7	7.2	161	nd
09/21/2004	10:15	11.9				nd
09/28/2004	09:45	12.4	8.6	7.7	169	nd
10/06/2004	09:30	12.3				nd
10/12/2004	10:16	11.5	8.8	7.3	147	nd
10/19/2004	09:50	10.8				20.49
10/26/2004	09:35	9.0	9.2	7.6		nd
11/16/2004	09:42	8.8		7.3	154	nd
12/15/2004	10:52	7.7		7.1	88	nd
01/25/2005	09:40			7.2	106	nd
02/23/2005	11:28	3.0		7.4	144	nd

Date	Time	Temperature (°C)	Winkler Dissolved Oxygen (mg/L)	pH (SU)	Conductivity (µmhos)	Flow Discharge (cfs)	
Griffin Creek: Snoqualmie RM 27.2							
e/E: flow is an estimate based on flow curve relationship (r2=0.99, n=13) between Griffin Ck. sample site flows and flows at Griffin Ck. King County gauging station 21A							
08/06/2003	12:28	14.5		7.3	107	2.08	e
08/12/2003	11:20	14.4				2.20	
08/19/2003	12:48	15.3	10.3	7.4		1.96	e
08/26/2003	13:32	14.2		8.2	108	1.73	
09/03/2003	10:35	12.7	10.5	7.8	95	2.06	e
09/10/2003	11:20	13.1				2.53	
09/16/2003	11:05	11.5	10.2	7.8	100	2.37	e
09/23/2003	11:18	11.6				3.01	
09/30/2003	08:54	12.4	10.3	7.5	98	2.37	e
10/07/2003	14:10	13.2	10.3			2.38	
10/14/2003	10:37	10.5	10.9	7.5	97	2.70	e
10/21/2003	11:47	14.2	9.8			64.02	E
10/28/2003	13:00	11.0	10.4	6.6	60	17.29	E
11/03/2003	14:21	4.6				15.20	E
11/12/2003	10:27	5.9		7.4	64	9.32	e
11/17/2003	13:45	7.2				12.91	e
12/02/2003	10:30	7.3		7.3	42	49.46	E
12/08/2003	14:41	6.8				51.83	E
12/15/2003	13:14	6.3				29.17	E
01/13/2004	11:05	4.3		7.0	65	41.60	E
01/20/2004	12:30					37.40	E
02/18/2004	10:20	6.9		7.3	50	21.99	E
03/09/2004	10:25	9.2		7.2	48	24.99	E
03/15/2004	10:54					17.73	E
04/06/2004	10:13	9.4		7.5	62	12.55	e
04/20/2004	13:55	11.5				8.19	e
08/03/2004	13:52	16.1	10.2	7.9	90	2.40	e
08/10/2004	12:03	16.5				2.12	
08/17/2004	11:05	15.7	10.0	7.7	96	2.32	e
08/24/2004	12:15	15.7				7.48	e
08/31/2004	10:45	15.5	9.8	7.5	83	5.37	e
09/08/2004	11:41	13.5				3.42	
09/14/2004	11:26	13.8	10.2	7.5	81	7.40	e
09/21/2004	12:00	12.3				13.80	
09/28/2004	11:06	12.4	10.6	7.7	75	6.91	e
10/06/2004	11:00	12.3				4.51	
10/12/2004	12:08	12.1	10.7	7.6	63	12.37	e
10/19/2004	11:11	10.5				23.66	E
10/26/2004	10:58	8.4	11.2	7.4		35.07	E
11/16/2004	10:47	8.2		7.5	63	12.55	e
12/15/2004	11:40	7.1		7.1	44	59.86	E
01/25/2005	10:40			7.3	48	22.29	E
02/23/2005	13:09	3.7		7.6	63	11.51	e

Date	Time	Temperature (°C)	Winkler Dissolved Oxygen (mg/L)	pH (SU)	Conductivity (µmhos)	Flow Discharge (cfs)	
Tolt River: Snoqualmie RM 24.9							
e/E: flow is an estimate based on flow curve relationship (r2=0.85, n=8) between Tolt R. sample site flows and flows at Tolt R. USGS gauging station 12148500.							
08/06/2003	11:19	14.5		7.2	53	128	e
08/12/2003	09:45	14.3				131	
08/19/2003	12:03	15.9	10.3	7.2	48	124	e
08/26/2003	12:03	14.2		7.9	64	121	e
09/03/2003	09:51	14.3	10.4	7.7	54	117	e
09/10/2003	10:25	14.1				86	
09/16/2003	10:45	11.8	10.8	7.8	51	131	e
09/23/2003	10:15	12.3				126	
09/30/2003	12:10	14.3	10.8	8.2	51	131	e
10/07/2003	12:20	14.1				93	
10/14/2003	11:00	10.2	11.4	7.3	40	212	E
10/21/2003	12:26	12.9				2225	E
10/28/2003	12:20	11.0	10.7	6.4	50	352	E
11/03/2003	14:05	6.4				278	E
11/12/2003	10:07	6.8		7.2	41	426	E
11/17/2003	13:32	7.2				656	E
12/02/2003	10:12	7.4		7.1	44	587	E
12/08/2003	14:26	7.0				494	E
12/15/2003	13:04	6.5				426	E
01/13/2004	10:50	5.5		7.1	59	583	E
01/20/2004	12:10					457	E
02/18/2004	09:46	6.7		7.1	43	469	E
03/09/2004	10:09	8.0		7.1	34	693	E
03/15/2004	10:45					411	E
04/06/2004	09:15	8.4		7.4	42	333	E
04/20/2004	13:43	9.8				356	E
08/03/2004	12:37	16.0	10.3	7.7	50	143	e
08/10/2004	10:36	15.8				147	
08/17/2004	10:40	15.7	10.2	7.7	55	137	e
08/24/2004	10:59	13.6				1429	E
08/31/2004	10:32	13.7	10.5	7.4	50	223	E
09/08/2004	10:54	12.2				175	
09/14/2004	10:46	11.5	10.7	6.9	28	1603	E
09/21/2004	11:04	10.6				438	E
09/28/2004	10:35	10.8	11.2	7.6	54	254	E
10/06/2004	10:00	11.2				207	E
10/12/2004	11:05	10.8	11.5	7.5	46	278	E
10/19/2004	10:30	9.2				445	E
10/26/2004	10:35	8.3	11.7	7.3		445	E
11/16/2004	10:29	8.0		7.4	47	379	E
12/15/2004	12:03	6.5		7.7	31	1054	E
01/25/2005	10:23			7.2	38	720	E
02/23/2005	12:39	4.8		7.4	57	230	E

Date	Time	Temperature (°C)	Winkler Dissolved Oxygen (mg/L)	pH (SU)	Conductivity (µmhos)	Flow Discharge (cfs)	
Harris Creek: Snoqualmie RM 21.3							
e/E: flow is an estimate based on flow curve relationship (r2=0.98, n=11) between Harris Ck. sample site flows and flows at Harris Ck. King County gauging station 22A.							
08/06/2003	13:33	14.0		6.8	120	1.94	e
08/12/2003	12:52	13.6				2.35	
08/19/2003	13:40	14.6	9.8	7.3	104	1.94	e
08/26/2003	15:05	14.1		8.0	114	1.99	
09/03/2003	11:00	12.4	10.3	7.8	113	1.91	E
09/10/2003	12:55	12.5				2.13	
09/16/2003	12:30	12.9	10.3	7.8	127	2.31	e
09/23/2003	13:00	12.0				2.41	
09/30/2003	09:14	12.1	10.1	7.8	120	2.08	e
10/07/2003	15:34	12.9				1.92	
10/14/2003	11:30	10.5	10.8	7.5	107	3.86	e
10/21/2003	13:05	14.5	9.8			44.74	E
10/28/2003	11:35	11.4	10.2	6.7	74	8.33	e
11/03/2003	14:35	5.4				8.21	e
11/12/2003	10:47	6.8		7.4	74	7.24	e
11/17/2003	14:14	7.6				12.06	e
12/02/2003	10:55	7.6		7.5	50	21.79	E
12/08/2003	15:13	6.9				26.55	E
12/15/2003	13:25	6.3				18.90	E
01/13/2004	12:23	4.4		7.3	72	31.80	E
01/20/2004	12:04					25.31	E
02/18/2004	10:46	7.1		7.3	57	17.97	E
03/09/2004	10:52	9.3		7.2	54	17.52	E
03/15/2004	11:07					12.98	E
04/06/2004	10:39	10.2		7.6	64	8.88	e
04/20/2004	14:12	11.2				7.17	e
08/03/2004	14:45	14.6	9.7	7.8	114	2.03	e
08/10/2004	13:57	16.2				2.21	e
08/17/2004	11:48	14.8	9.9	7.7	114	1.98	e
08/24/2004	12:57	15.5				4.38	e
08/31/2004	11:25	14.5	9.8	7.5	118	2.75	e
09/08/2004	12:44	12.8				2.43	e
09/14/2004	12:00	14.6	10.0	7.6	72	19.10	E
09/21/2004	12:21	12.8				6.77	
09/28/2004	11:30	12.4	10.3	7.7	85	4.61	e
10/06/2004	11:46	12.2				4.06	e
10/12/2004	12:48	12.3	10.5	7.6	68	6.89	e
10/19/2004	12:18	10.8				12.50	
10/26/2004	11:52	9.4	11.0	7.4		20.05	E
11/16/2004	11:21	9.0		7.5	68	10.80	e
12/15/2004	12:53	7.5		6.9	49	37.50	E
01/25/2005	11:01			7.4	58	22.78	E
02/23/2005	14:21	5.3		7.4	71	9.80	e

Date	Time	Temperature (°C)	Winkler Dissolved Oxygen (mg/L)	pH (SU)	Conductivity (µmhos)	Flow Discharge (cfs)
Ames Creek: Snoqualmie RM 17.5						
08/06/2003	14:13	15.2		6.9	162	nd
08/12/2003	13:50	15.6				3.9
08/19/2003	14:35	15.3	9.8	7.1	132	nd
08/26/2003	16:21	13.9		7.7	160	3.4
09/03/2003	11:22	12.6	9.6	7.7	155	nd
09/10/2003	14:02	13.3				4.6
09/16/2003	13:05	13.3	8.4	7.4	148	nd
09/23/2003	14:15	12.7				4.2
09/30/2003	11:25	12.9	9.3	7.6	165	nd
10/07/2003	16:42	13.3				4.1
10/14/2003	12:00	11.0	9.7	7.6	165	nd
10/21/2003	13:35	14.9				nd
10/28/2003	11:10	13.2	4.6	5.8	197	nd
11/03/2003	14:55	7.2				nd
11/12/2003	11:20	7.4		6.9	175	nd
11/17/2003	14:35	8.1				nd
12/02/2003	11:25	7.8		7.4	140	nd
12/08/2003	15:31	7.7				nd
12/15/2003	13:44	7.0				nd
01/13/2004	12:55	5.8		6.6	214	nd
01/20/2004	11:45					nd
02/18/2004	11:15	7.1		6.6	146	nd
03/09/2004	11:16	9.2		6.8	141	nd
03/15/2004	11:24					nd
04/06/2004	11:09	10.4		7.2	140	nd
04/20/2004	14:30	12.1				nd
08/03/2004	15:37	16.1	8.9	7.6	156	nd
08/10/2004	14:20	16.1				nd
08/17/2004	12:18	14.9	9.0	7.5	170	nd
08/24/2004	13:16	15.5				nd
08/31/2004	11:50	14.6	8.0	7.3	171	nd
09/08/2004	13:26	12.9				nd
09/14/2004	12:34	13.6	7.3	7.2	149	nd
09/21/2004	13:45	12.3				3.4
09/28/2004	12:00	12.5	8.2	7.3	170	nd
10/06/2004	12:35	12.3				nd
10/12/2004	13:17	12.5	8.3	7.1	168	nd
10/19/2004	13:33	11.0				5.6
10/26/2004	12:20	10.2	6.5	6.8		nd
11/16/2004	11:45	9.3		6.9	200	nd
12/15/2004	13:26	7.5		6.3	56	nd
01/25/2005	11:27			6.4	126	nd
02/23/2005	14:59	5.7		6.9	164	nd

Date	Time	Temperature (°C)	Winkler Dissolved Oxygen (mg/L)	pH (SU)	Conductivity (µmhos)	Flow Discharge (cfs)
Tuck Creek: Snoqualmie RM 10.3						
e/E: flow is an estimate based on flow curve relationship (r2=0.78, n=8) between Tuck Ck. sample site flows and flows at Harris Ck. King County gauging station 22A.						
08/06/2003	14:59	16.4	8.6	7.0	35	0.11 e
08/12/2003	14:48	17.2				0.22
08/19/2003	15:10	16.2	8.8	7.0	135	0.11 e
08/26/2003	17:02	15.2		7.6	126	0.10
09/03/2003	11:50	13.9	9.8	7.6	123	0.09 e
09/10/2003	14:43					0.16
09/16/2003	13:40	12.7	9.6	7.4	123	0.31 e
09/23/2003	15:00	12.9				0.41
09/30/2003	11:00	12.4	10.1	7.6	122	0.19 e
10/07/2003	17:29	13.2				0.43
11/03/2003	15:20					2.52 E
11/12/2003	12:50	7.9		6.7	113	2.19 E
11/17/2003	14:57	7.2				3.72 E
12/02/2003	11:50	7.5		6.3	121	6.47 E
12/08/2003	15:52	7.1				7.73 E
12/15/2003	14:12	6.5				5.68 E
01/13/2004	13:24	5.3		6.6	133	9.08 E
01/20/2004	10:54					7.41 E
02/18/2004	11:40	6.8		6.6	94	5.43 E
03/09/2004	11:34	9.9		6.8	86	5.30 E
03/15/2004	11:39					3.99 E
04/06/2004	11:28	11.3		7.1	107	2.73 E
04/20/2004	15:00	13.4				2.17 E
08/03/2004	16:35	18.4		7.5	122	0.16 e
08/10/2004	15:21	20.1				0.26 e
08/17/2004	12:55	16.1		7.4	129	0.13 e
08/24/2004	13:43	17.3				1.18 E
09/08/2004	13:55	15.3				0.37 e
09/14/2004	12:58					5.74 E
09/21/2004	15:01					2.26 E
09/28/2004	12:45	13.4	8.5	7.4	132	1.27 E
10/12/2004	14:05	13.5		7.1	125	2.08 E
10/19/2004	14:03					3.79 E
10/26/2004	12:53	9.9		6.8		6.00 E
11/16/2004	12:11	9.3		6.9	136	3.34 E
12/15/2004	13:58	7.3		6.2	67	10.49 E
01/25/2005	11:57			6.4	105	6.74 E
02/23/2005	15:36			7.2	111	3.02 E

Date	Time	Temperature (°C)	Winkler Dissolved Oxygen (mg/L)	pH (SU)	Conductivity (µmhos)	Flow Discharge (cfs)
Cherry Creek: Snoqualmie RM 6.7						
08/06/2003	15:56	17.6		7.0	117	1.44 e
08/12/2003	15:59	17.9				1.83 e
08/19/2003	15:45	18.0	12.3	7.2	128	1.42 e
08/26/2003	17:49	17.0		8.0	111	0.93 e
09/03/2003	12:18	14.6	8.3	7.5	113	0.81 e
09/10/2003	15:00					1.44 e
09/16/2003	14:10	13.7	9.5	7.5	124	3.59 e
09/23/2003	15:30	13.8				1.87 e
09/30/2003	10:04	12.6	7.7	7.4	116	1.58 e
10/07/2003	18:27	14.4				1.30 e
10/14/2003	13:00	11.4	8.0	7.3	124	2.17 e
10/21/2003	15:31	13.1				nd
10/28/2003	10:06	12.3	5.2	6.4	99	320.00 e
11/03/2003	15:40	5.9				27.14 e
11/12/2003	13:45	7.2			64	21.31 e
11/17/2003	15:14	7.9				17.30 e
12/02/2003	12:10	6.9		6.5	36	26.26 e
12/08/2003	16:14	7.0				86.85 e
12/15/2003	14:26	7.0				125.41 e
01/13/2004	13:45	5.8		6.7	84	74.00 e
01/20/2004	11:11					135.42 e
02/18/2004	12:45	7.4		6.9	72	78.41 e
03/09/2004	11:51	9.2		6.9	54	50.69 e
03/15/2004	11:50					56.92 e
04/06/2004	11:49	11.1		7.1	68	39.82 e
04/20/2004	15:17	13.2				21.23 e
08/03/2004	17:13	17.4	10.4	7.4	208	11.71 e
08/10/2004	15:37	18.3				1.70 e
08/17/2004	13:35	18.7	9.0	7.4	121	1.94 e
08/24/2004	13:58	16.2				1.83 e
08/31/2004	12:45	16.6	6.5	6.6	113	11.44 e
09/08/2004	14:13	14.1				7.09 e
09/14/2004	13:17	13.8	9.8	7.1	61	3.52 e
09/21/2004	15:20	13.4				62.00 e
09/28/2004	13:20	12.4	9.5	7.1	87	41.20 e
10/06/2004	13:14	12.6				11.55 e
10/12/2004	14:32	13.0	10.7	7.1	70	6.01 e
10/19/2004	14:22	10.8				22.40 e
10/26/2004	13:15	9.6	10.0	6.6		50.40 e
11/16/2004	12:52	9.3		7.0	76	58.20 e
12/15/2004	15:02	7.8		6.5	41	34.64 e
01/25/2005	13:00			6.5	40	132.44 e
02/23/2005	16:09	5.3		7.0	75	nd

X: Field measurement did not meet data quality objectives and should be used with caution.x_1:

Flow discharge data obtained from USGS station 12141300 on Middle Fork Snoqualmie River at Snoqualmie RM 55.6.

x_2: Flow discharge data obtained from USGS station 12142000 at North Fork Snoqualmie RM 9.2.

x_3: Flow discharge data obtained from USGS station 12144000 at South Fork Snoqualmie RM 2.0.

nd: Parameter not obtained.

E: Flow estimates are extrapolated and not considered reliable.

Table E-5: Laboratory results for the Snoqualmie intensive survey.

Date	Fecal Coliform (cfu/100mL)		Orthophosphate (mg/L)	Ammonia-Nitrogen (mg/L)		Nitrite-nitrate Nitrogen (mg/L)		Total Persulfate Nitrogen (mg/L)		Total Organic Carbon (mg/L)	Inhibited BOD (mg/L)
Middle Fork Snoqualmie RM 45.3											
08/30/2005	53		0.0034	0.010 U		0.076		0.130		1.0 U	
08/30/2005	43		0.0030 U	0.010 U		0.097		0.170		1.0	
08/31/2005	27		0.0030 U	0.010 U		0.117		0.180		1.0	
08/31/2005	10		0.0030 U	0.010 U		0.087		0.170		1.3	
North Fork Snoqualmie RM 44.9											
08/30/2005	17		0.0030 U	0.010 U		0.277		0.351		1.0 U	
08/30/2005	120		0.0030 U	0.010 U		0.304		0.359		1.0 U	
08/31/2005	26	22	0.0030 U	0.010 U		0.260		0.310		1.0 U	
08/31/2005	7		0.0030 U	0.010 U		0.254	0.257	0.331	0.318	1.0 U	
South Fork (Snoqualmie RM 44.4) at RM 2.0											
08/30/2005	260 J		0.0030 U	0.010 U		0.239		0.297		1.0 U	
08/30/2005	61		0.0049	0.010 U		0.298		0.361		1.0 U	
08/31/2005	88 J		0.0045	0.010 U		0.264		0.325		1.0 U	
08/31/2005	29		0.0039	0.010 U		0.236		0.299		1.0 U	
North Bend Wastewater Treatment Plant South Fork Snoqualmie RM 1.5											
08/30/2005	68		2.52	0.235		20.5		23.4		12.2	4 U
08/30/2005	49		3.92	0.262		20.9		22.7		11.1	4 U
08/31/2005	150 J		3.52	0.133		19.4		20.6		10.6	4 U
08/31/2005	390 J		3.40	0.151		19.6		21.7		9.9	4 U
South Fork (Snoqualmie RM 44.4) at RM 1.5											
08/30/2005	320		0.0552	0.010 U		0.579		0.660		1.0 U	
08/30/2005	140		0.0630	0.010 U		0.599		0.698		1.0	
08/31/2005	140 J		0.0580	0.010 U		0.606		0.688		1.0 U	
08/31/2005	77		0.0583	0.010 U		0.549		0.624		1.0 U	
Snoqualmie mainstem at RM 42.3											
8/30/2005	130		0.0034	0.010 U		0.195		0.288		1.0 U	
8/30/2005	59	41	0.0047	0.010 U		0.214		0.286		1.0 U	
8/31/2005	51		0.0036	0.010 U		0.196		0.269		1.0 U	
8/31/2005	29		0.0049	0.010 U		0.199		0.287		1.0 U	
Kimball Creek: Snoqualmie RM 41.1											
8/30/2005	480		0.0036	0.015		0.234		0.365		2.9	
8/30/2005	280		0.0036	0.016		0.253		0.438		3.2	
8/31/2005	200		0.0042	0.015		0.232		0.412		3.0	
8/31/2005	130		0.0039	0.016		0.229		0.382		2.9	
Snoqualmie Wastewater Treatment Plant Snoqualmie RM 40.8											
8/30/2005	1 U		1.68	0.010 U		0.450				5.3	4 U
8/30/2005	1 U		1.67	0.015		0.469		1.07		5.1	4 U
8/31/2005	1		1.96	0.010 U		0.375		0.913		5.7	4 U
8/31/2005	1		1.66	0.014		0.343		0.959		5.5	4 U

Date	Fecal Coliform (cfu/100mL)		Orthophosphate (mg/L)	Ammonia-Nitrogen (mg/L)	Nitrite-nitrate Nitrogen (mg/L)	Total Persulfate Nitrogen (mg/L)	Total Organic Carbon (mg/L)	Inhibited BOD (mg/L)
Snoqualmie mainstem at RM 40.7								
8/30/2005	200		0.0037	0.010 U	0.213	0.267	1.4	
8/30/2005	100		0.0030 U	0.010 U	0.220	0.296	1.1	
8/31/2005	100		0.0038	0.010 U	0.195	0.252	1.0 U	
8/31/2005	29	14	0.0030	0.010 U	0.186	0.250	1.0	
Tokul Creek: Snoqualmie RM 39.6								
8/30/2005	92 J		0.0096	0.013	0.570	0.648	1.3	
8/30/2005	80		0.0093	0.016	0.605	0.694	1.2	
8/31/2005	270		0.0110	0.010 U	0.569	0.637	1.3	
8/31/2005	170		0.0097	0.010	0.557	0.614	1.5	
Raging River: Snoqualmie RM 36.2								
8/30/2005	150		0.0030 U	0.010 U	0.120	0.190	2.0	
8/30/2005	60 J		0.0030 U	0.010 U	0.078	0.160	2.2	
8/31/2005	100 J		0.0030 U	0.010 U	0.115	0.180	1.7	
8/31/2005	39		0.0030	0.010 U	0.530	0.140	1.9	
Snoqualmie mainstem at RM 35.3								
8/30/2005	210		0.0032	0.010 U	0.220	0.282	1.0 U	
8/30/2005	160		0.0037	0.010 U	0.209	0.264	1.9	
8/31/2005	200 J		0.0037	0.010 U	0.209	0.258	1.3	
8/31/2005	40		0.0038	0.010 U	0.190	0.250	1.1	
Patterson Creek: Snoqualmie RM 31.2								
8/30/2005	200		0.0337	0.014	0.537	0.696	2.8	
8/30/2005	190		0.0350	0.012	0.526	0.638	3.1	
8/31/2005	190 J		0.0323	0.014	0.539	0.705	2.8	
8/31/2005	180		0.0318	0.010 U	0.555	0.707	2.9	
Griffin Creek: Snoqualmie RM 27.2								
8/30/2005	80		0.0100	0.010 U	0.204	0.301	2.7	
8/30/2005	120		0.0120	0.010 U	0.190	0.300	2.0	
8/31/2005	120		0.0091	0.010 U	0.228	0.310	2.3	
8/31/2005	100		0.0100	0.010 U	0.214	0.303	2.0	
Snoqualmie mainstem at RM 25.2								
8/30/2005	40	47	0.0030 U	0.010 U	0.207	0.276	1.0 U	
8/30/2005	59		0.0030 U	0.010 U	0.198	0.274	1.1	
8/31/2005	180		0.0030 U	0.010 U	0.198	0.280	1.8	
8/31/2005	68		0.0030 U	0.010 U	0.198	0.256	1.1	
Tolt River: Snoqualmie RM 24.9								
8/30/2005	31 J		0.0030 U	0.010 U	0.222	0.275	1.0 U	
8/30/2005	9		0.0030 U	0.010 U	0.186	0.210	1.2	
8/31/2005	8 J	13 J	0.0030 U	0.010 U	0.210	0.250	1.1	
8/31/2005	3		0.0030 U	0.010 U	0.184	0.240	1.0 U	
Harris Creek: Snoqualmie RM 21.3								
8/30/2005	47		0.0150	0.010 U	0.740	0.851	2.0	
8/30/2005	28		0.0150	0.010 U	0.712	0.799	2.1	
8/31/2005	85 J		0.0140	0.010 U	0.728	0.930	2.0	

Date	Fecal Coliform (cfu/100mL)		Orthophosphate (mg/L)		Ammonia-Nitrogen (mg/L)		Nitrite-nitrate Nitrogen (mg/L)		Total Persulfate Nitrogen (mg/L)		Total Organic Carbon (mg/L)	Inhibited BOD (mg/L)
8/31/2005	47	57	0.0150		0.010 U		0.739		0.767		2.1	
Ames Creek: Snoqualmie RM 17.5												
8/30/2005	370		0.0413		0.240		0.516		0.679		3.4	
8/30/2005	270	290	0.0449		0.022		0.507		0.683		3.3	
8/31/2005	820 J		0.0402		0.025		0.428		0.795		3.2	
8/31/2005	480		0.0358		0.038		0.491		0.673		5.4	
Duvall Wastewater Treatment Plant Snoqualmie RM 11.0												
8/30/2005	3 U		2.36		0.985		4.98		6.76		5.6	4 U
8/30/2005	3 U		3.28		0.698		4.39		5.51		5.3	4 U
8/31/2005	1		1.53		0.453		4.79		5.78		5.5	4 U
8/31/2005	3	1	2.62		0.383		5.07		6.42		5.4	4 U
Tuck Creek: Snoqualmie RM 10.3												
8/30/2005	170		0.0460		0.160		0.047		0.200		3.8	
8/30/2005	200		0.0270		0.015		0.045		0.230		3.6	
8/31/2005	230		0.0270		0.019		0.042		0.230		4.1	
8/31/2005	170		0.0280		0.011		0.052		0.210		4.1	
Cherry Creek: Snoqualmie RM 6.7												
8/30/2005	590		0.0076		0.150		0.373		0.488		2.6	
8/30/2005	310	230	0.0073		0.014		0.369		0.513		2.5	
8/31/2005	240		0.0066		0.014		0.343		0.505		2.9	
8/31/2005	640		0.0066		0.011		0.331		0.493		2.7	
Snoqualmie mainstem at RM 2.7												
8/30/2005	160	100	0.0048		0.010		0.188	0.189	0.250	0.253		
8/30/2005	67		0.0059		0.010 U		0.188		0.250			
8/31/2005	26		0.0047		0.010 U		0.191		0.257			
8/31/2005	20		0.0042		0.010 U		0.190		0.250			

U – The analyte was not detected at or above the reported sample quantitation limit.
J – The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample. For bacteria, this indicates estimated count; samples are analyzed over 24 hours after collection.

Table E-6: Field results for the Snoqualmie intensive survey.

Date	Time	Temperature (°C)	Winkler Dissolved Oxygen (mg/L)	pH (SU)	Conductivity (µmhos)	Flow Discharge (cfs)
Middle Fork Snoqualmie RM 45.3						
8/30/2005	11:30	15.5	10.0	6.4	40	
8/30/2005	18:15	17.6	9.6	7.0	38	
8/31/2005	9:35	15.5	9.6	7.1	40	
8/31/2005	16:55	19.4	9.5	7.2	40	
North Fork Snoqualmie RM 44.9						
8/30/2005	12:15	13.3	10.3	7.1	63	
8/30/2005	18:30	14.3	9.8	7.0	63	
8/31/2005	11:10	13.7	9.9	7.1	59	90.64
8/31/2005	17:15	15.5	9.8	7.2	60	
South Fork (Snoqualmie RM 44.4) at RM 2.0						
8/30/2005	9:15	12.4	9.6	6.7	72	126.21
8/30/2005	16:30	14.6	10.0	6.7	77	139.72
8/31/2005	8:05	12.7	9.9	6.9	80	127.58
8/31/2005	14:40	16.0	9.8	7.3	81	
North Bend Wastewater Treatment Plant South Fork Snoqualmie RM 1.5						
8/30/2005	10:45			2.8	1140	
8/30/2005	15:30			3.2	595	
8/31/2005	11:35			4.3	339	
8/31/2005	15:05			4.3	385	
South Fork (Snoqualmie RM 44.4) at RM 1.5						
8/30/2005	10:11	12.6	9.7	7.0	85	142.24
8/30/2005	17:40	14.7	9.8	6.9	86	
8/31/2005	9:00	12.8	9.4	7.0	88	137.93
8/31/2005	16:20	16.5	9.7	7.0	89	150.55
Snoqualmie mainstem at RM 42.3						
8/30/2005	12:45	14.6	9.8	7.2	61	
8/30/2005	19:15	15.8	10.3	7.2	59	
8/31/2005	12:08	14.5	9.5	6.7	61	
8/31/2005	18:11	16.6	10.3	7.3	61	
Kimball Creek: Snoqualmie RM 41.1						
8/30/2005	13:20		7.5	7.0	101	1.66
8/30/2005	19:15	15.8	7.4	7.0	102	1.60
8/31/2005	12:30	15.8	7.5	6.9	102	1.24
8/31/2005	17:40	16.4	7.4	7.1	101	1.36
Snoqualmie Wastewater Treatment Plant Snoqualmie RM 40.8						
8/30/2005	11:20	20.3		7.5	471	
8/30/2005	16:00	22.0		7.5	474	
8/31/2005	10:45	20.6		7.5	480	
8/31/2005	16:00	21.8		7.5	480	

Date	Time	Temperature (°C)	Winkler Dissolved Oxygen (mg/L)	pH (SU)	Conductivity (µmhos)	Flow Discharge (cfs)
Snoqualmie mainstem at RM 40.7						
8/30/2005	9:14	14.8	8.6	7.2	63	
8/30/2005	16:10	15.1	9.5	7.4	60	
8/31/2005	11:15	14.9	8.9	7.2	60	
8/31/2005	16:20	15.7	9.5	7.3	60	
Tokul Creek: Snoqualmie RM 39.6						
8/30/2005	8:37	12.2	10.5	8.0	126	24.94
8/30/2005	16:20	14.1	10.2	8.2	124	29.54
8/31/2005	11:40	13.6	10.3	8.0	129	26.97
8/31/2005	16:40	15.1	9.9	8.2	129	26.21
Raging River: Snoqualmie RM 36.2						
8/30/2005	10:32	14.7	10.4	8.1	75	
8/30/2005	14:30	16.6	10.3	9.1	73	16.37
8/31/2005	7:40	14.6	9.8	7.7	86	12.66
8/31/2005	12:55	16.9	10.4	8.9	84	13.37
Snoqualmie mainstem at RM 35.3						
8/30/2005	9:45	15.3	9.6	7.5	70	
8/30/2005	13:44	16.2	10.5	7.8	68	
8/31/2005	8:00	15.0	9.5	7.5	66	
8/31/2005	12:19	16.2	10.3	7.7	65	
Patterson Creek: Snoqualmie RM 31.2						
8/30/2005	11:45	13.7	8.8	7.7	170	7.69
8/30/2005	17:05	14.8	9.2	7.8	169	8.48
8/31/2005	8:45	13.7	8.5	7.6	175	8.31
8/31/2005	13:50	15.1	9	7.7	174	8.83
Griffin Creek: Snoqualmie RM 27.2						
8/30/2005	13:00	13.6	10.5	7.9	91	3.09
8/30/2005	18:05	14.8	9.7	7.8	93	3.26
8/31/2005	9:50	13.8	10.1	7.6	96	2.83
8/31/2005	15:18	16.2	9.4	7.8	95	2.75
Snoqualmie mainstem at RM 25.2						
8/30/2005	12:20	17.2	9.3	7.6	76	
8/30/2005	17:45	18.0	9.5	7.6	75	
8/31/2005	9:20	16.6	9.3	7.5	75	
8/31/2005	14:58	17.8	9.7	7.6	73	
Tolt River: Snoqualmie RM 24.9						
8/30/2005	8:57	12.2	10.6	7.7	57	
8/30/2005	13:50	14.7	10.6	8.0	56	120.50
8/31/2005	7:58	13.0	10.4	7.6	57	112.52
8/31/2005	13:00	15.9	10.3	7.9	56	120.19

Date	Time	Temperature (°C)	Winkler Dissolved Oxygen (mg/L)	pH (SU)	Conductivity (µmhos)	Flow Discharge (cfs)
Harris Creek: Snoqualmie RM 21.3						
8/30/2005	9:30	12.2	10.2	7.7	110	3.04
8/30/2005	14:30	13.6	10.2	7.8	110	2.77
8/31/2005	8:20	12.7	9.9	7.6	112	2.69
8/31/2005	13:40	14.6	9.8	7.8	110	2.61
Ames Creek: Snoqualmie RM 17.5						
8/30/2005	10:20	12.6	8.5	7.5	166	3.48
8/30/2005	15:35	13.8	9	7.6	167	3.39
8/31/2005	8:55	13.3	8.3	7.5	167	3.55
8/31/2005	14:20	15.8	7.6	7.5	185	5.38
Duvall Wastewater Treatment Plant Snoqualmie RM 11.0						
8/30/2005	10:10			7.1	361	
8/30/2005	15:05			7.0	346	
8/31/2005	11:00			7.1	348	
8/31/2005	14:55			7.2	356	
Tuck Creek: Snoqualmie RM 10.3						
8/30/2005	11:50	14.6	7.7	7.5	132	0.37
8/30/2005	16:20	15.8	9.3	7.6	131	0.44
8/31/2005	9:30	15.1	8.9	7.5	132	0.30
8/31/2005	15:22	16.6	8.9	7.6	131	0.39
Cherry Creek: Snoqualmie RM 6.7						
8/30/2005	12:19	14.5	8.5	7.4	115	6.02
8/30/2005	16:20	15.8	9.3	7.6	131	6.46
8/31/2005	10:10	15.1	7.9	7.3	115	5.87
8/31/2005	15:50	16.6	10.1	7.5	115	5.52
Snoqualmie mainstem at RM 2.7						
8/30/2005	12:55	18.1	9.0	7.6	80	
8/30/2005	17:40	18.4	9.2	7.5	79	
8/31/2005	11:30	17.8	9.2	7.6	80	
8/31/2005	16:30	18.5	9.6	7.6	80	

Table E-7: Field and laboratory results for wastewater treatment plants.

Date	Fecal Coliform (cfu/100mL)		*E-coli* (cfu/100mL)		Orthophosphate (mg/L)		Ammonia-Nitrogen (mg/L)		Nitrite-nitrate Nitrogen (mg/L)	Total Persulfate Nitrogen (mg/L)		Inhibited BOD (mg/L)		Temperature (°C)	pH (SU)	Conductivity (µmhos)
North Bend Wastewater Treatment Plant (South Fork Snoqualmie RM 1.5)																
08/26/2003	6				2.99		0.262	0.261						18.7	7.0	352
08/27/2003												4 U	3			
10/29/2003	3 U						0.093					4 U	3			
11/19/2003	25000 J				3.98	3.95	4.15					6		6.8	7.0	279
12/17/2003	1 U				3.39	3.35			10.2					4.5	7.0	305
01/21/2004	1 U	1 U			0.5270	0.5240	0.032	0.030								
2/11/2004	1 UJ	1 J			0.0630	0.0633	0.043									
3/17/2004	2 J				1.82	1.76	0.052	0.052						12.9	6.9	294
4/21/2004	8 J				1.12		0.129							6.8	6.9	
8/18/2004	7 J		5 J		2.21		0.194					4 U		10.6	7.4	317
9/15/2004	14 J		10 J		1.48		0.120		0.072	0.775	0.753	3				
10/13/2004	4 J				2.64		0.037					2.4		16.6	7.0	300
11/17/2004														13.2	7.1	326
Snoqualmie Wastewater Treatment Plant																
1/28/2004	1 UJ	1 UJ			0.4260	0.3910	0.010 U		0.010U							
3/31/2004							0.010									
4/21/2004	1 UJ	1 UJ			0.6400									12.3	7.7	
4/28/2004	330				2.59	2.41										
10/27/2004	21 J	21 J			1.92		0.037		0.018	0.879		4	4			
Duvall Wastewater Treatment Plant																
10/29/2003	180	200	120	130			0.090	0.094				3				
11/19/2003	280	290					0.122	0.119				5	4	9.5	6.9	324
12/17/2003	7	14							17.1					7.2	6.9	373
01/21/2004	5500 J						0.638									
2/11/2004	1 U						2.25									
3/17/2004	80	80					0.197							13.9	6.7	356
4/28/2004	730	970					0.088									
8/18/2004	17000 J	17000 J	17000 J	17000 J	3.86		0.241					12 U		13.5	7.0	434
9/15/2004	13000	11000					16.5									
10/13/2004	90000 J	70000 J					0.241					8 G		18.4	7.1	443
11/17/2004														14.5	7.0	410

U - Analyte was not detected at or above the reported result.
J - For bacteria, indicates estimated count; samples analyzed over 24 hours after collection.
G - Value is likely greater than result reported; result is an estimated minimum value.

Table E-8. Field and laboratory results for Fall City transect sampling surveys.

Station Name	Fecal Coliform (cfu/100mL)		Ammonia-Nitrogen (mg/L)		Nitrite-nitrate Nitrogen (mg/L)		Total Persulfate Nitrogen (mg/L)		Ortho-phosphate (mg/L)		Chloride (mg/L)		Conductivity (µmhos)		Temperature (°C)	
9/8/2003	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB
Upstream	2000	1200	0.010 U	0.010 U	0.352	0.418			0.0081	0.0069	1.97	1.77	67	67		
	2600	1200	0.010 U	0.010 U	0.458	0.425			0.0079	0.0071	1.83	1.72	67	66		
	1800	1800	0.010 U	0.010 U	0.442	0.432			0.0078	0.0064	1.85	1.83	66	66		
	1800	2000	0.010 U	0.010 U	0.385	0.448			0.0077	0.0071	1.83	1.80	66	66		
Downstream	2000	2100	0.010 U	0.010 U	0.463	0.457			0.0084	0.0072	1.84	1.81	66	66		
9/24/2003	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB
Upstream	9	9			0.169	0.153	0.21	0.18	0.0041	0.0045	1.54	1.38	57	55	13.4	13.8
	6	14			0.174	0.141	0.21	0.17	0.0043	0.0036	1.39	1.50	56	58	13.5	14.4
	6	17			0.156	0.155	0.13	0.18	0.0042	0.0038	1.32	1.40	55	55	13.4	14.3
	29	17			0.156	0.155	0.19	0.17	0.004	0.0039	1.33	1.32	54	55	13.5	13.7
Downstream	9	9			0.157	0.154	0.19	0.18	0.004	0.004	1.36	1.36	54	55	13.5	13.6
10/8/2003	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB
Upstream	47	45	0.010 U	0.010 U	0.152	0.141			0.0047	0.0046	1.71	1.56	69	68		
	32	27	0.010 U	0.010 U	0.147	0.139			0.0042	0.0042	1.58	1.63	68	68		
	31	64	0.010 U	0.010 U	0.145	0.145			0.0046	0.0043	1.58	1.69	68	69		
	27	29	0.010 U	0.010 U	0.145	0.145			0.0046	0.0048	1.58	1.66	68	68		
Downstream	48	32	0.010 U	0.010 U	0.146	0.145			0.0045	0.0043	1.63	1.59	68	68		
5/26/2004	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB
Upstream	1400	160			0.218	0.098					1.61	0.66	39	22	12.1	10.3
	340	150			0.109	0.097					0.93	0.65	23	22	10.5	10.2
	210	140			0.102	0.097					0.65	0.66	23	22	10.5	10.3
	170	150			0.102	0.098					0.69	0.62	23	22	10.4	10.4
Downstream	180	110			0.101	0.098					0.71	0.71	23	22	10.3	10.4
6/9/2004	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB
US Raging R.	17															
Upstream	84	20			0.1895	0.104					1.41	0.8	37	25	12.8	11.3
	20	17			0.117	0.102					0.69	0.71	26	25	11.5	11.3
	11	37			0.106	0.104					0.77	0.73	26	25	11.5	11.4
	29	6			0.107	0.106					0.74	0.72	25	25	11.5	11.7
Downstream	31	20			0.107	0.105					0.77	0.75	26	26	11.5	11.6

Station Name	Fecal Coliform (cfu/100mL)		Ammonia-Nitrogen (mg/L)		Nitrite-nitrate Nitrogen (mg/L)		Total Persulfate Nitrogen (mg/L)		Ortho-phosphate (mg/L)		Chloride (mg/L)		Conductivity (µmhos)		Temperature (°C)	
8/30/2004	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB
US Raging R.	60		0.010 U		0.192								38		16.4	
Upstream	100	84			0.230	0.186					1.20	1.00	40	38	16.0	16.1
	80	59			0.220	0.189					1.10	0.94	39	38	16.1	16.0
	77	79			0.203	0.190					1.10	0.95	38	38	16.0	16.0
	76	64			0.198	0.194					1.00	1.00	38	38	15.8	16.0
Downstream	67	72			0.197	0.193					0.97	0.99	38	38	15.7	16.0
10/14/2004	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB
US Raging R.	9				0.169								37			
Upstream	520	11			0.193	0.168					1.43	1.22	36	46	11.8	11.9
	12	19			0.179	0.167					1.26	1.28	46	46	11.7	11.6
	18	11			0.177	0.176					1.34	1.39	46	49	11.5	12.6
	16	23			0.175	0.176					1.29	1.35	46	46	11.4	11.6
Downstream	11	16			0.174	0.174					1.23	1.22	36	46	11.8	11.9
4/6/2005	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB
US Raging R.	3				0.248						1.44		43		8.1	
Raging R.	4				0.557						1.82		46		10.0	
Upstream	3	1			0.357	0.246					1.60	1.54	45	44	8.3	7.9
	6	3			0.314	0.257					1.47	1.42	45	45	8.1	8.3
	7	4			0.278	0.277					1.49	1.52	44	46	8.0	8.4
	5	2			0.284	0.318					1.50	1.56	44	47	7.9	8.2
Downstream	2	6			0.273	0.279					1.45	1.52	44	49	8.9	8.3
7/13/2005	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB
US Raging R.	47				0.162						0.98		56		15.1	
Raging R.	32				0.284						2.48		44		14.5	
Upstream	45	36			0.164	0.164					1.07	1.04	45	44	14.5	14.5
	82	33			0.187	0.167					1.16	1.04	46	45	14.5	14.5
	38	45			0.174	0.165					1.12	1.03	45	45	14.4	14.5
	58	50			0.167	0.172					1.04	1.06	45	45	14.4	14.5
Downstream	45	45			0.170	0.170					1.06	1.09	45	45	14.4	14.5

Station Name	Fecal Coliform (cfu/100mL)		Ammonia-Nitrogen (mg/L)		Nitrite-nitrate Nitrogen (mg/L)		Total Persulfate Nitrogen (mg/L)		Ortho-phosphate (mg/L)		Chloride (mg/L)		Conductivity (µmhos)		Temperature (°C)	
8/2/2005	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB
US Raging R.	31				0.218						1.37		81		15.8	
Raging R.	57				0.183						4.65		63		17.1	
Upstream	45	36			0.224	0.21					1.49	1.48	64	64	16.9	16.9
	43	27			0.232	0.223					1.48	1.55	64	64	16.8	17.4
	28	27			0.228	0.222					1.46	1.47	63	64	16.7	16.8
	36	39			0.223	0.226					1.49	1.48	64	64	16.6	16.6
Downstream	39	47			0.227	0.225					1.49	1.50	64	64	16.5	16.6
8/23/2005	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB
US Raging R.	17				0.211						1.48				16.8	
Raging R.	68				0.019						5.82		73		17.0	
Upstream	42	22			0.213	0.212					1.58	1.59	73	73	16.8	16.8
	47	21			0.219	0.205					1.57	1.70	75	74	17.0	16.7
	35	32			0.214	0.215					1.60	1.58	73	74	16.6	16.7
	44	44			0.219	0.219					1.58	1.58	74	74	16.6	16.6
Downstream	42	44			0.220	0.215					1.59	1.58	74	74	16.6	16.6
9/7/2005	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB
US Raging R.	31				0.200						1.46		93		14.2	
Raging R.	31				0.081						6.76		73		14.6	
Upstream	52	25			0.203	0.197					1.68	1.63	74	74	14.5	14.4
	48	21			0.212	0.194					1.69	1.64	74	74	14.4	14.8
	37	41			0.209	0.198					1.63	1.62	74	74	14.2	14.3
	43	51			0.208	0.203					1.63	1.79	74	74	14.2	14.2
Downstream	49	52			0.206	0.204					1.62	1.67	74	74	14.0	14.1

LB – left bank
RB – right bank
U – The analyte was not detected at or above the reported sample quantitation limit.

This page is purposely left blank

Appendix F: Quality Assurance / Quality Control Results

Laboratory Data

Laboratory samples were analyzed according to quality assurance (QA) and quality control procedures followed by Ecology's Manchester Environmental Laboratory (MEL) (MEL, 2001). All general chemistry samples met holding time requirements. Microbiology samples were analyzed within 30 hours, which is standard procedure for MEL. Microbiology samples were not analyzed within the 6-hour window described in Standard Methods (APHA, 1998) because of the logistical challenges in collecting and transporting samples within the given timeframe. MEL was used for all laboratory analysis of membrane filter (MF) fecal coliform and *E-coli* bacteria, nutrients, biochemical oxygen demand, and chloride.

Duplicate field samples were used to estimate total variation (field and laboratory), expressed as the percent relative standard deviation (RSD). Duplicates are two field samples collected sequentially at the same site as close as possible in time. The percent RSD is calculated by dividing the standard deviation of two or more values by their mean, and then multiplying by 100. Field duplicates were collected for approximately 20% of all bacteria samples and 10% of the general chemistry samples analyzed by MEL.

Values below the detection limit were assumed to be the detection limit for analysis purposes.

Table F-1 describes precision of each parameter expressed as percent RSD for each parameter and the acceptable measurement quality objectives. Measurement quality objectives were based on recommendations made in *Replicate Precision for 12 TMDL Studies and Recommendations for Precision Measurement Quality Objectives for Water Quality Parameters* (Mathieu, 2006).

Table F-1. Percent relative standard deviation and measurement quality objectives (MQO) for Snoqualmie sampling parameters.

Parameter	%RSD for values ≤ 5 times the detection limit	%RSD for values > 5 times the detection limit	Precision MQO
Ammonia-nitrogen	3.7%	1.3%	10%
Nitrite-nitrate Nitrogen	n/a	2.5%	10%
Orthophosphate	1.3%	5.9%	10%
Chloride	n/a	0.9%	5%
Biochemical Oxygen Demand	All duplicate values ≤ detection limit		
Bacteria Parameters	%RSD for ≤ 50% of pairs	% RSD for 90% of pairs	
For Fecal Coliform values ≤ 20 cfu/100 mL	35.4% RSD	78.6% RSD	
For Fecal Coliform values > 20 cfu/100 mL	10.9% RSD[1]	34.4% RSD[1]	
For *E-coli* values ≤ 20 cfu/100 mL	29.8% RSD	81.9% RSD	
For *E-coli* values > 20 cfu/100 mL	12.5% RSD[1]	34.0% RSD[1]	

[1] For bacteria duplicates where the mean is ≤ 20 then the MQO for 50% of pairs is ≤ 20% RSD, and 90% of pairs is ≤ 50% RSD.

Precision for all parameters was very good, meeting measurement quality objectives. For bacteria results where the mean of paired results is ≤ 20 cfu/100 mL, precision is evaluated on a case-by-case basis. Precision for results ≤ 20 cfu/100 mL is good; higher % RSD results are due to the low values and not poor data quality. All laboratory data were acceptable for use without qualification. Data variability will be taken into consideration during data analysis as well as interpreting results.

Field Data

Field instruments were calibrated according to the manufacturer's instructions, and pre-calibrated and post-checked with certified standards. Pre-calibrations and post-checks were done the day the field meters were used.

Winkler dissolved oxygen samples were obtained in the field to check the meters. Duplicates of temperature, conductivity, and pH readings were obtained during sampling, and pre- and post-calibration checks were conducted. During the synoptic surveys, field meters did not meet data quality objectives for the following parameters and dates:

- Dissolved oxygen – September 29, 2003 and August 3, 2004.
- pH – August 18 and December 1, 2003, and March 9, April 5, and October 11, 2004.
- Temperature – September 17 and November 17, 2003, and March 9, 2004.
- Conductivity – August 19 and September 16, 2003.

Field meter parameters that did not meet quality control standards are qualified in Appendix E. These values should not be used to determine compliance with water quality standards, and values should be used with caution. Table F-2 lists data quality standards for field measurements.

Table F-2. Measurement quality objectives for field determinations.

Analysis	*Accuracy* % deviation from true value	*Precision* Relative standard deviation	*Bias* % deviation from true value
pH[1]	0.2 SU	0.05 SU	0.10 SU
Water Temperature[1]	± 0.2°C	--	--
Dissolved Oxygen	15%	5% RSD*	5%
Specific Conductivity	10%	<10% RSD*	5%

[1] As units of measurement, not percentages.

QA results for meters used for in-situ continuous monitoring are described in Table F-3. Only dissolved oxygen QA results were available for the 2003-2004 continuous monitoring data. QA results were available for the 2005 in-situ continuous monitoring data quality, and data quality standards were met for all parameters.

Table F-3. Continuous monitoring sample sites, sample period, and quality assurance results.

Sites and monitoring period	Met QA objectives?
Snoqualmie RM 2.7	
September 8-18, 2003	Meter results were consistently 0.5 mg/L higher than Winkler titrations. A correction factor of 0.57 mg/L was applied to all DO data.
July 13-22, 2004	Met data quality objectives for DO.
August 29 – September 1, 2005	Met data quality objectives for all meter parameters.
Snoqualmie RM 25.2	
September 8-11, 2003	Meter results were consistently lower than Winkler titrations. A correction factor of 0.445 mg/L was applied to all DO data.
July 13 – August 3, 2004	No QA results available; all data discarded.
August 29 – September 1, 2005	Met data quality objectives for all meter parameters.
Snoqualmie RM 40.7	
September 8-18, 2003	DO results did not meet data quality objectives.
July 13 – August 2, 2004	No QA results available; all data discarded.
August 29 – September 1, 2005	Met data quality objectives for all meter parameters.

DO – dissolved oxygen

This page is purposely left blank

Appendix G. Precipitation Data for Synoptic and Intensive Sampling, and Fall City Special Study

Table G-1. Precipitation data (inches) for the 2003-05 *Effectiveness Monitoring Study* (synoptic/intensive sampling).

Date	Day of rainfall	Previous 24-hour rainfall	Previous 48-hour rainfall
8/5/2003	0.00	0.00	0.00
8/6/2003	0.03	0.00	0.00
8/11/2003	0.00	0.00	0.00
8/12/2003	0.00	0.00	0.00
8/18/2003	0.00	0.00	0.00
8/19/2003	0.00	0.00	0.00
8/25/2003	0.00	0.00	0.00
8/26/2003	0.00	0.00	0.00
9/2/2003	0.00	0.00	0.00
9/3/2003	0.00	0.00	0.00
9/8/2003	1.30	0.11	0.11
9/9/2003	0.50	1.30	1.41
9/10/2003	0.16	0.50	1.80
9/16/2003	0.37	0.00	0.00
9/17/2003	0.53	0.37	0.37
9/22/2003	0.00	0.00	0.03
9/23/2003	0.00	0.00	0.00
9/24/2003	0.00	0.00	0.00
9/29/2003	0.00	0.00	0.00
9/30/2003	0.00	0.00	0.00
10/6/2003	0.00	0.00	0.00
10/7/2003	0.10	0.00	0.00
10/8/2003	0.00	0.10	0.10
10/13/2003	0.20	0.57	0.66
10/14/2003	0.01	0.20	0.77
10/20/2003	0.76	0.11	0.12
10/21/2003	2.20	0.76	0.87
10/27/2003	0.00	0.00	0.00
10/28/2003	0.03	0.00	0.00
11/2/2003	0.00	0.00	0.00
11/3/2003	0.00	0.00	0.00
11/11/2003	0.00	0.00	0.00
11/12/2003	0.00	0.00	0.00
11/17/2003	0.00	0.00	0.00
12/1/2003	0.11	0.00	0.00
12/2/2003	0.10	0.11	0.11
12/8/2003	0.24	0.08	0.64
12/15/2003	0.03	0.39	0.93
1/12/2004	0.00	0.01	0.38
1/13/2004	0.10	0.00	0.01
1/20/2004	0.00	0.08	0.17
2/17/2004	0.66	0.22	0.36
2/18/2004	0.22	0.66	0.88
3/8/2004	0.01	0.38	0.70
3/9/2004	0.01	0.01	0.39
3/15/2004	0.00	0.02	0.02
4/5/2004	0.00	0.00	0.00
4/6/2004	0.00	0.00	0.00
4/20/2004	0.20	0.03	0.13
5/26/2004	0.74	0.00	0.00
6/9/2004	0.03	0.01	0.61
8/2/2004	0.00	0.00	0.00
8/3/2004	0.00	0.00	0.00
8/9/2004	0.00	0.00	0.71
8/10/2004	0.00	0.00	0.00
8/16/2004	0.00	0.00	0.00
8/17/2004	0.00	0.00	0.00
8/23/2004	0.58	1.10	1.10
8/24/2004	1.39	0.58	1.68
8/30/2004	0.00	0.00	0.00
8/31/2004	0.00	0.00	0.00
9/7/2004	0.00	0.00	0.00
9/8/2004	0.00	0.00	0.00
9/13/2004	0.23	0.07	1.50
9/14/2004	0.05	0.23	0.30
9/20/2004	0.13	0.15	0.42
9/21/2004	0.00	0.13	0.28
9/27/2004	0.00	0.00	0.00
9/28/2004	0.00	0.00	0.00
10/5/2004	0.00	0.00	0.00
10/6/2004	0.17	0.00	0.00
10/11/2004	0.00	0.07	1.26
10/12/2004	0.00	0.00	0.07
10/14/2004	0.00	0.00	0.00
10/18/2004	0.44	1.22	1.47
10/19/2004	0.06	0.44	1.66
10/25/2004	0.00	0.00	0.17
10/26/2004	0.00	0.00	0.00

Table G-2: Precipitation data (inches) for the Fall City transect study.

Date	Day of rainfall	Previous 24-hour rainfall	Previous 48-hour rainfall
11/15/2004	0.04	0.01	0.17
11/16/2004	0.33	0.04	0.05
12/13/2004	0.00	0.00	2.20
12/15/2004	0.00	0.74	0.74
1/24/2005	0.00	0.00	0.18
1/25/2005	0.00	0.00	0.00
2/22/2005	0.00	0.00	0.00
2/23/2005	0.00	0.00	0.00
4/6/2005	0.00	0.13	0.36
7/13/2005	0.18	0.11	0.11
8/2/2005	0.00	0.00	0.00
8/23/2005	0.00	0.00	0.00
9/7/2005	0.00	0.00	0.00

Table G-3: Precipitation data (inches) for TMDL sampling.

Date	Day of rainfall	Previous 24-hour rainfall	Previous 48-hour rainfall
7/24/1989	0.00	0.00	0.00
7/25/1989	0.00	0.00	0.00
8/15/1989	0.00	0.06	0.00
8/16/1989	0.01	0.00	0.06
9/5/1989	0.00	0.00	0.00
9/6/1989	0.00	0.00	0.00
9/26/1989	0.72	0.12	0.00
9/27/1989	0.00	0.72	0.00
7/30/1991	0.00	0.00	0.00
7/31/1991	0.00	0.00	0.00
9/23/1991	0.00	0.00	0.00
9/24/1991	0.00	0.00	0.00
9/25/1991	0.00	0.00	0.00

This page is purposely left blank

Appendix H. Snoqualmie River / Fall City Transect Study

From September 2003 – September 2005, a special diagnostic study was conducted on the mainstem Snoqualmie River near Fall City (River Mile 35.3). The objective of the study was to determine levels of nitrite-nitrate nitrogen, chloride, fecal coliform/*E. Coli* bacteria, and conductivity levels around the Fall City area. The results would provide additional information on the possibility of on-site sewage treatment system failures in the nearshore area.

The Quality Assurance Project Plan (Onwumere and Batts, 2003) describes the sampling plan, including timing and sampling parameters. Five samples were obtained along each shore (left and right banks) during the first four sample events (Figure H-1). Two mainstem Snoqualmie sites upstream and downstream of the Raging River, and a site at the mouth of Raging River, were added later on in the study.

Sample results and dates are described in Appendix E.

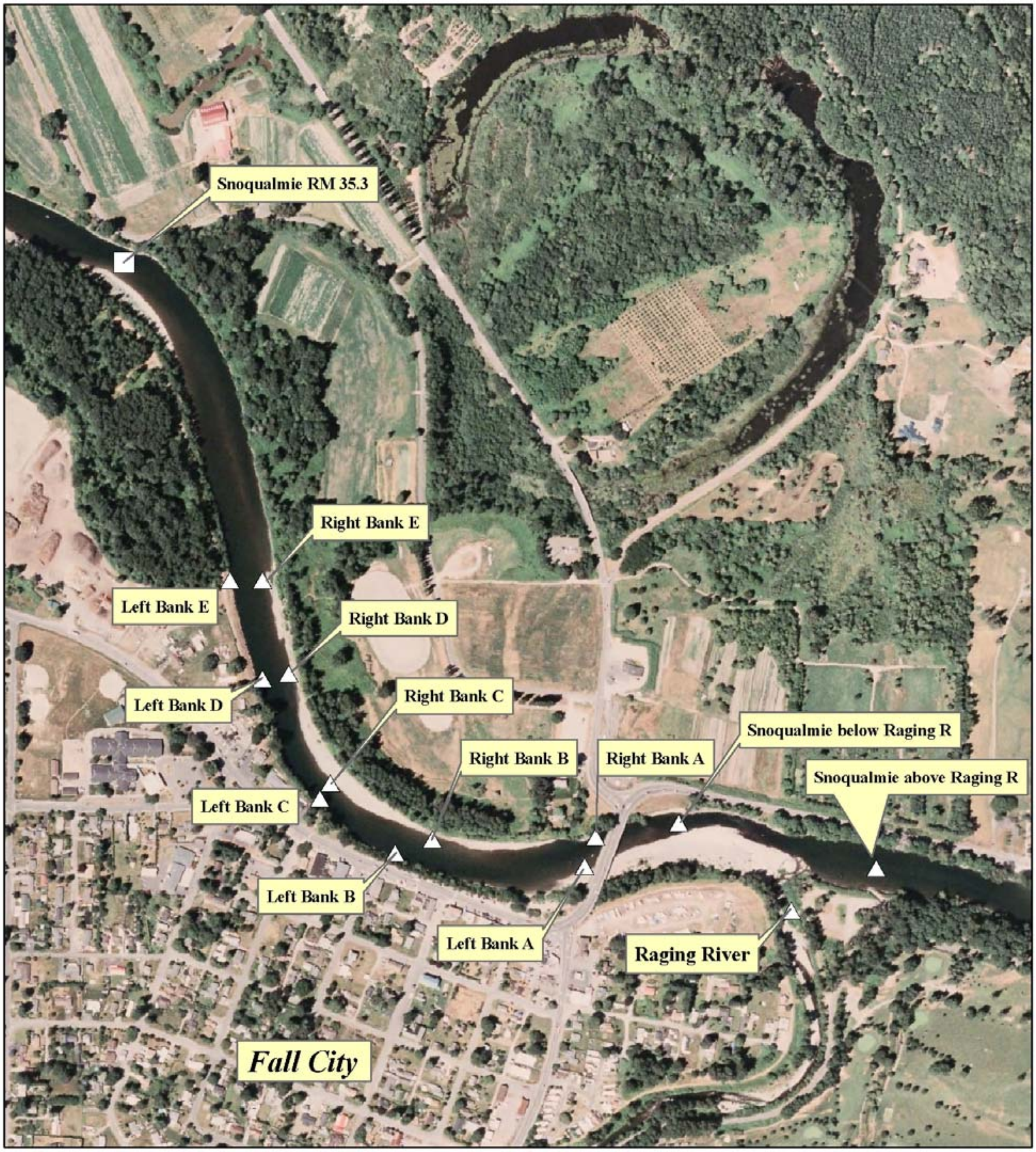

Figure H-1. Fall City transect study area and sites.

Effectiveness Monitoring Survey Results and Discussion

During the 2003-05 *Effectiveness Monitoring Surveys*, a site on the mainstem Snoqualmie RM 35.3 was sampled (mid-stream) as well as the mouth of the Raging River. Figure H-2 presents estimated fecal coliform loading for the Raging River and Snoqualmie mainstem upstream of the Raging River. Loading for the upstream Snoqualmie site is estimated by subtracting Raging River loading from loading at Snoqualmie mainstem RM 35.3. The body of this report (*Raging River: Snoqualmie RM 36.2*) describes how loading/flow estimates were obtained.

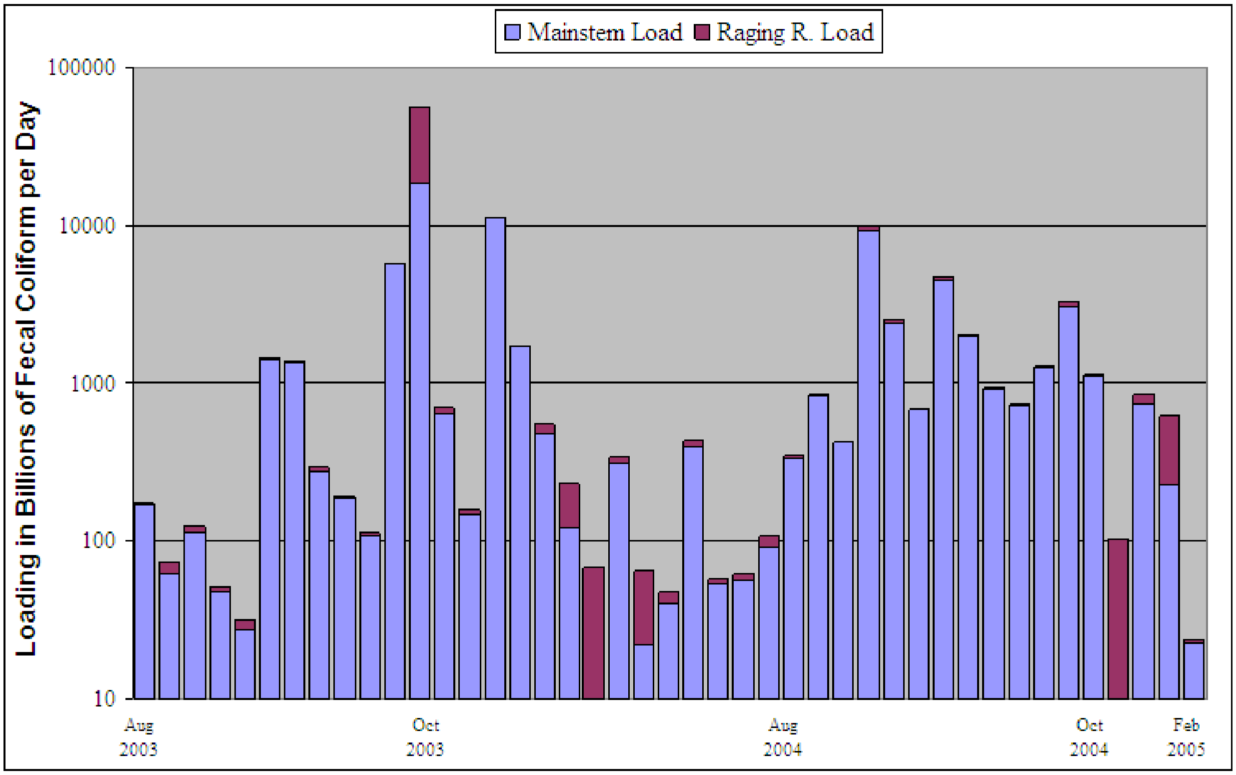

Figure H-2. Estimated fecal coliform loading for the Snoqualmie upstream of Raging River and for the Raging River.

During most of the synoptic surveys, the greatest fecal coliform loading was from the upstream mainstem Snoqualmie site (RM 35.3). Estimated Raging River fecal coliform loading was greater than the mainstem site on October 20 and December 15, 2003, November 15, 2004, and January 24, 2005. The percent flow contribution to the mainstem Snoqualmie RM 35.3 was 96% of flow from the mainstem Snoqualmie and 4% from Raging River. Likewise the percent bacterial loading contribution from the upstream Snoqualmie averaged 83% and the Raging River 15%. Raging River bacterial loading contributions on average are 3-4 times greater than flow contribution.

Fall City Transect Survey Sampling Results and Discussion

During the 2003-05 transect surveys, both banks of the mainstem Snoqualmie were sampled. Figure H-3 presents fecal coliform statistics for the surveys. Box plots describe results from upstream to downstream (LB: left bank, RB: right bank). Fall City and Raging River are located on the left bank of the Snoqualmie River.

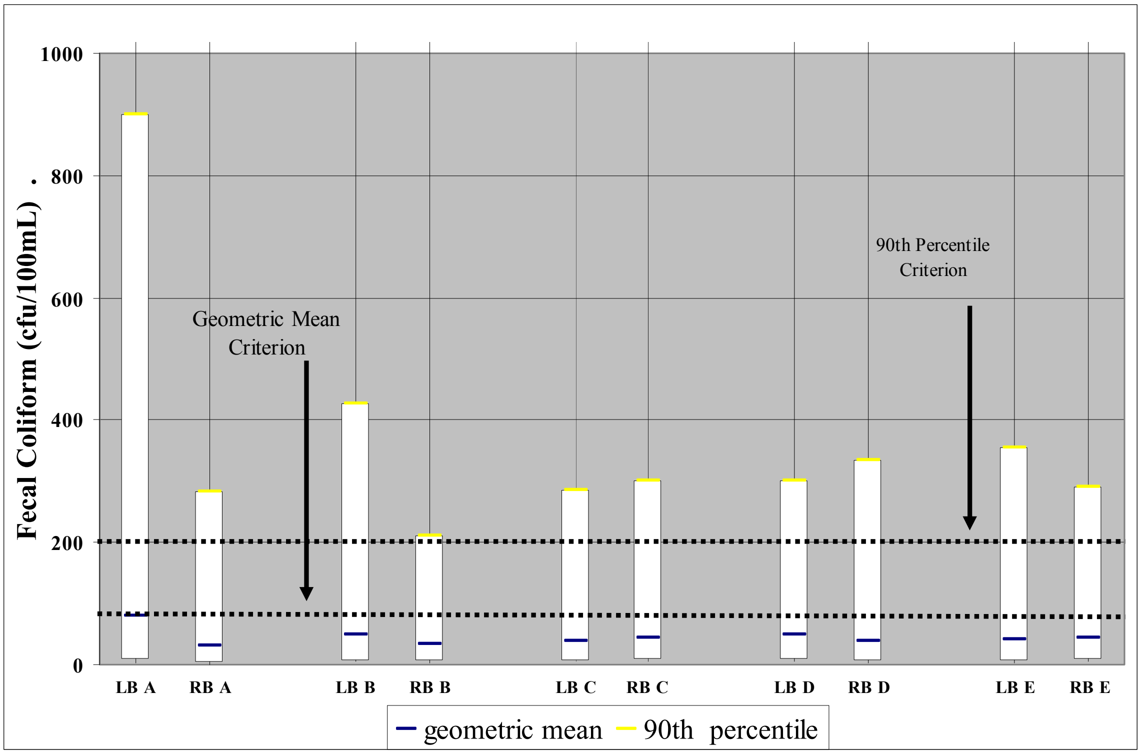

Figure H-3. Fecal coliform statistics for the transect sampling of Snoqualmie River in the vicinity of Fall City, September 2003 – 2005.

Bacteria results are highest near the left bank upstream. Downstream bacteria levels gradually become more consistent between the left and right banks, likely due to mixing. During the transect surveys, the three most upstream left bank sites did not meet fecal coliform bacteria standards, while all the other sites did. High bacteria levels upstream near the left bank could indicate that Fall City shoreline bacterial sources are present, and/or there are bacterial sources from the Raging River.

Sampling was also conducted for nitrite-nitrate nitrogen and chloride. For both parameters, higher levels were seen upstream on the left bank (Table H-1).

Table H-1. Average nitrite-nitrate nitrogen and chloride for Fall City sample sites. Sites are listed upstream to downstream.

Parameter	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB
Average Nitrite-nitrate Nitrogen (mg/L)	0.222	0.191	0.214	0.192	0.203	0.198	0.197	0.205	0.203	0.203
Average Chloride (mg/L)	1.52	1.31	1.35	1.31	1.33	1.32	1.31	1.33	1.31	1.31

A non-parametric Wilcoxon paired sample test was used to compare fecal coliform bacteria, nitrite-nitrate nitrogen, and chloride between the right and left banks. A two-tailed test with a significance level of $\alpha = 0.05$ was used. The only significant difference was in chloride between the right and left banks at the upstream site (n=12).

Five sample events occurred that included a sample site on the Raging River and Snoqualmie River upstream of Raging River. During these sample events, bacteria, nitrite-nitrate nitrogen, and chloride levels were low and not significantly different enough to determine possible sources of pollution. The periods when high bacteria levels occur is sporadic, but are generally associated with higher day of, or previous 24-hour, rainfall.

Table H-2 presents rainfall data for the day of sampling and previous 24- and 48-hour rainfall for sample events where fecal coliform levels were ≥ 100 cfu/100mL. Data from both the synoptic and transect survey are included.

Table H-2. Comparison of high fecal coliform events and rainfall for synoptic and transect surveys.

	Fecal Coliform (cfu/100 mL)		Rainfall (inches)		
Synoptic Survey					
Date	Raging R.	Snoqualmie R.	Day of sampling	Previous 24-hour	Previous 48-hour
09/09/2003	140	140	0.50	1.30	1.41
10/20/2003	330	330	0.76	0.11	0.12
8/23/2004	370	370	0.58	1.10	1.10
Transect Survey					
Date	LB Snoqualmie RM 35.0	RB Snoqualmie RM 35.0	Day of sampling	Previous 24-hour	Previous 48-hour
9/8/2003	2000	1200	1.30	0.11	0.11
5/26/2004	1400	160	0.74	0.00	0.00
8/30/2004	100	84	0.00	0.00	0.00
10/14/2004	520	11	0.00	0.00	0.00

LB – left bank
RB – right bank

Conclusions

Water quality results indicate higher fecal coliform bacteria, nitrite-nitrate nitrogen, and chloride values are found along the upstream left bank of the Snoqualmie River near Fall City. Sources of these pollutants could be from:

- Upstream Fall City sources along the left bank of the Snoqualmie River.
- The Raging River.

Higher fecal coliform levels may be associated with rain events.

Recommendations for Additional Water Quality Study

More water quality information is needed to determine if sources are from the Raging River or the upstream left bank Snoqualmie River area near Fall City, or both. An additional study to determine locations of bacteria and nutrient sources is recommended. The study should include the following elements:

- Circulation study to determine how Raging River water impacts the mainstem Snoqualmie River in the vicinity of Fall City.
- Monitoring timed to capture some rain events
- Monitoring parameters include: fecal coliform bacteria, nutrient, and chloride sampling including the following sites:
    - Mainstem Snoqualmie River upstream of Raging River.
    - Mouth of Raging River.
    - Mainstem Snoqualmie River left bank.

In the body of this report (Raging River at RM 35), recommendations include a pH TMDL study for the Raging River. A monitoring study of Raging River should also include segmenting sampling of the Raging River for fecal coliform bacteria and nutrients.

Because budgetary, resource, and access constraints can greatly affect study design, Ecology cannot make detailed recommendations on site locations, sampling frequencies, timing, and other procedures needed to accomplish the additional study noted above. Ecology is however available for consultation in study design and other elements of project collaboration.

Appendix I. TMDL Study and Effectiveness Monitoring Study, Water Quality Comparison

Table I-1. TMDL Study (1989-91) and Effectiveness Monitoring Study (2003-05),Water Quality Comparison.

Parameter	Snoqualmie Middle Fork		Snoqualmie North Fork		Snoqualmie South Fork at RM 2.0		Snoqualmie South Fork at RM 1.5	
	TMDL Study	2003-05 Study	TMDL Study	2003-05 Study	TMDL Study	2003-05 Study	TMDL Study	2003-05 Study
Fecal Coliform (cfu/100 mL)								
Minimum	8	1	6	1	12	12	6	17
Maximum	11	130	47	130	49	500	35	680
Arith. Average	10	22	21	15	26	81	23	120
Geometric Mean	10	15	16	7	22	56	19	87
No. of Samples	4	26	4	26	5	26	4	26
Orthophosphate (mg/L)								
Minimum	not	0.0030	not	0.0030	0.003	0.0033	0.004	0.0045
Maximum	done	0.0046	done	0.0322	0.004	0.0069	0.016	0.0701
Arith. Average		0.0035		0.0052	0.004	0.0046	0.011	0.0296
No. of Samples		13		14	5	13	4	6
Nitrate-Nitrite Nitrogen (mg/L)								
Minimum	0.046	0.028	0.149	0.152	0.217	0.203	0.226	0.215
Maximum	0.066	0.163	0.178	0.343	0.296	0.349	0.259	0.534
Arith. Average	0.054	0.087	0.158	0.246	0.256	0.260	0.246	0.364
No. of Samples	4	13	4	13	5	13	4	6
Ammonia Nitrogen (mg/L)								
Minimum	0.010 U	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Maximum	0.010 U	0.011	0.019	0.012	0.015	0.035	0.011	0.029
Arith. Average	0.010 U	0.010	0.012	0.010	0.012	0.012	0.011	0.011
No. of Samples	4	14	4	13	5	14	4	14
Total Nitrogen* (mg/L)								
Minimum	not	0.086	not	0.217	0.371	0.246	0.407	0.250
Maximum	done	0.280	done	0.420	0.625	0.427	0.595	0.618
Arith. Average		0.148		0.298	0.509	0.315	0.500	0.449
No. of Samples		13		13	5	13	4	6
Temperature (°C)								
Minimum	13.1	7.2	12.8	7.2	11.3	7.3	11.5	7.5
Maximum	14.7	19.8	14.3	17.2	12.1	14.6	12.2	15.3
Arith. Average	14.1	13.7	13.5	12.6	11.8	11.7	11.9	11.9
No. of Samples	4	26	4	26	5	25	4	26
Dissolved Oxygen (mg/L)								
Minimum	10.2	9.3	not	9.2	9.8	9.6	10.1	9.1
Maximum	10.5	12.1	done	11.8	10.5	11.7	10.6	11.8
Arith. Average	10.3	10.6		10.3	10.1	10.5	10.3	10.3
No. of Samples	4	13		15	5	15	4	13
pH (SU)								
Minimum	6.7	6.8	6.7	6.8	6.7	6.4	6.8	6.7
Maximum	7.4	7.7	7.3	7.4	7.4	7.6	7.2	7.6
Arith. Average	7.0	7.3	6.9	7.1	7.0	7.1	7.0	7.2
No. of Samples	4	15	4	15	5	15	4	15
Conductivity (μmhos)								
Minimum	31	20	43	21	71	18	74	39
Maximum	39	41	57	129	85	247	89	248
Arith. Average	34	30	49	54	77	76	79	88
No. of Samples	4	14	4	14	5	14	4	14
Flow (cfs; flows based on USGS data)								
Minimum	161	117	58	35	109	84	109	84
Maximum	462	5290	163	2760	215	1110	215	1110
Arith. Average	299	742	112	340	151	277	160	277
No. of Samples	4	26	4	26	5	26	4	26

Parameter	Snoqualmie RM 42.3		Snoqualmie RM 40.7		Snoqualmie RM 35.3		Snoqualmie RM 25.2	
	TMDL Study	2003-05 Study	TMDL Study	2003-05 Study	TMDL Study	2003-05 Study	TMDL Study	2003-05 Study
Fecal Coliform (cfu/100 mL)								
Minimum	5	4	13	3	3	4	22	5
Maximum	37	380	37	840	16	370	109	330
Arith. Average	20	41	23	63	11	59	62	64
Geometric Mean	15	25	21	25	9	31	50	39
No. of Samples	5	26	4	26	5	26	5	26
Orthophosphate (mg/L)								
Minimum	0.001	0.0037	0.003	0.0030	0.002	0.0041	0.002	0.0030
Maximum	0.005	0.0055	0.007	0.0051	0.006	0.0060	0.004	0.0068
Arith. Average	0.003	0.0045	0.005	0.0038	0.004	0.0050	0.003	0.0045
No. of Samples	5	4	4	14	7	2	7	13
Nitrate-Nitrite Nitrogen (mg/L)								
Minimum	0.120	0.172	0.117	0.152	0.105	0.139	0.118	0.138
Maximum	0.172	0.176	0.142	0.240	0.164	0.208	0.160	0.304
Arith. Average	0.136	0.174	0.130	0.172	0.124	0.165	0.136	0.182
No. of Samples	5	3	4	13	7	4	7	13
Ammonia Nitrogen (mg/L)								
Minimum	0.010	0.010	0.014	0.010	0.010	0.010U	0.010	0.010
Maximum	0.022	0.011	0.023	0.013	0.026	0.010U	0.027	0.014
Arith. Average	0.015	0.010	0.018	0.011	0.014	0.010U	0.016	0.011
No. of Samples	5	13	4	14	7	14	7	14
Total Nitrogen* (mg/L)								
Minimum	0.202	0.220	0.186	0.200	0.208	0.200	0.209	0.200
Maximum	0.398	0.275	0.482	0.290	0.370	0.281	0.606	0.375
Arith. Average	0.281	0.248	0.349	0.239	0.279	0.245	0.330	0.247
No. of Samples	5	3	4	13	7	4	7	13
Temperature (°C)								
Minimum	11.8	7.4	13.9	7.4	12.7	7.8	14.2	7.8
Maximum	14.4	17.9	15.2	18.1	17.5	22.4	17.7	20.1
Arith. Average	13.3	13.1	14.4	13.5	15.6	15.0	16.0	14.4
No. of Samples	6	26	4	26	10	26	7	26
Dissolved Oxygen (mg/L)								
Minimum	9.8	9.1	9.5	8.6	9.6	9.7	9.4	8.8
Maximum	10.5	11.7	10.4	11.6	11.4	11.5	10.7	11.2
Arith. Average	10.1	10.3	9.8	9.9	10.6	10.6	9.9	10.0
No. of Samples	5	15	4	14	9	12	7	12
pH (SU)								
Minimum	6.8	6.7	6.8	6.9	6.8	6.8	7.0	6.3
Maximum	7.4	7.6	7.1	7.5	7.6	8.3	7.8	7.7
Arith. Average	7.0	7.1	6.9	7.2	7.3	7.7	7.3	7.2
No. of Samples	5	15	4	15	9	15	7	15
Conductivity (µmhos)								
Minimum	46	24	46	24	50	33	50	28
Maximum	68	195	62	67	82	73	77	74
Arith. Average	56	58	53	48	63	55	61	56
No. of Samples	5	14	4	14	9	14	6	14
Flow (cfs; flows based on USGS data)								
Minimum	No		409	314	419	322	501	283
Maximum	data		912	5943	1325	7003	1145	27742
Arith. Average	available		634	1427	831	1504	799	2313
No. of Samples			4	26	7	26	7	26

Parameter	Kimball Creek TMDL Study	Kimball Creek 2003-05 Study	Raging River TMDL Study	Raging River 2003-05 Study	Patterson Creek TMDL Study	Patterson Creek 2003-05 Study	Griffin Creek TMDL Study	Griffin Creek 2003-05 Study
Fecal Coliform (cfu/100 mL)								
Minimum	460	31	8	9	96	26	140	14
Maximum	3500	2900	77	1100	290	1900	430	1600
Arith. Average	1448	428	35	107	193	287	238	194
Geometric Mean	1066	190	25	44	179	142	212	77
No. of Samples	4	26	4	26	5	26	4	26
Orthophosphate (mg/L)								
Minimum	0.002	0.0049	0.002	0.0046	0.026	0.0265	0.004	0.0170
Maximum	0.006	0.0049	0.008	0.0046	0.041	0.0327	0.010	0.0170
Arith. Average	0.004	0.0049	0.004	0.0046	0.036	0.0296	0.008	0.0170
No. of Samples	4	1	6	1			6	1
Nitrate-Nitrite Nitrogen (mg/L)								
Minimum	0.295	0.251	0.036	0.062	0.708	0.538	0.232	0.336
Maximum	0.404	0.281	0.165	0.382	0.924	0.665	0.443	0.376
Arith. Average	0.337	0.262	0.109	0.226	0.779	0.601	0.349	0.354
No. of Samples	4	3	6	4	5	4	6	3
Ammonia Nitrogen (mg/L)								
Minimum	0.010	0.010	0.010	0.010 U	0.012	0.010	0.017	0.010 U
Maximum	0.025	0.030	0.024	0.010 U	0.035	0.028	0.043	0.010 U
Arith. Average	0.018	0.023	0.013	0.010 U	0.027	0.016	0.029	0.010 U
No. of Samples	4	14	6	15	5	14	6	14
Total Nitrogen* (mg/L)								
Minimum	0.521	0.385	0.273	0.140	1.57	0.755	0.556	0.420
Maximum	0.833	0.482	0.394	0.460	1.97	0.959	1.28	0.514
Arith. Average	0.701	0.439	0.322	0.327	1.72	0.835	0.832	0.482
No. of Samples	4	3	6	4	5	4	6	3
Temperature (°C)								
Minimum	13.1	8.6	15.5	9.3	10.7	9.0	12.7	8.4
Maximum	15.7	19.2	24.5	24.4	14.6	19.2	21.6	16.5
Arith. Average	14.4	14.2	19.7	16.2	12.6	13.0	15.4	13.2
No. of Samples	4	26	6	26	6	25	6	26
Dissolved Oxygen (mg/L)								
Minimum	9.6	6.5	10.2	8.6	9.3	7.7	9.5	9.8
Maximum	10.8	9.3	11.2	12.2	10.6	9.3	11.9	11.2
Arith. Average	10.3	7.9	10.7	10.5	9.9	8.6	10.7	10.4
No. of Samples	6	12	5	13	6	15	8	15
pH (SU)								
Minimum	6.8	6.7	8.1	7.6	7.1	6.6	7.3	6.6
Maximum	7.1	7.4	9.4	9.7	7.7	7.7	7.9	8.2
Arith. Average	7.0	7.0	8.8	8.5	7.4	7.4	7.5	7.6
No. of Samples	4	15	6	15	5	15	6	15
Conductivity (μmhos)								
Minimum	82	75	82	26	128	99	88	60
Maximum	97	106	95	108	163	217	129	108
Arith. Average	92	93	87	77	148	164	101	89
No. of Samples	4	14	6	14	5	14	6	13
Flow (cfs; flows based on USGS data)								
Minimum	1.20	0.51	10	4	6.5	7.0	2.90	1.73
Maximum	2.70	20.09	15	1415	8.1	29.1	3.70	13.80
Arith. Average	1.74	4.48	13	95	7.2	16.0	3.38	4.25
No. of Samples	4	7	6	26	4	4	4	22

Parameter	Tolt River		Harris Creek		Ames Creek		Tuck Creek	
	TMDL Study	2003-05 Study	TMDL Study	2003-05 Study	TMDL Study	2003-05 Study	TMDL Study	2003-05 Study
Fecal Coliform (cfu/100 mL)								
Minimum	3	3	20	5	365	26	20	27
Maximum	67	840	95	800	18000	7000	110	1300
Arith. Average	25	54	50	113	6963	737	74	159
Geometric Mean	16	17	43	43	3291	302	62	93
No. of Samples	5	26	4	26	5	26	4	23
Orthophosphate (mg/L)								
Minimum	0.001	0.0029	0.008	0.0210	0.063	0.0427	0.016	0.0384
Maximum	1.05	0.0029	0.042	0.0210	0.120	0.0427	0.028	0.0384
Arith. Average	0.152	0.0029	0.020	0.0210	0.090	0.0427	0.021	0.0384
No. of Samples	7	1	4	1	5	1	4	1
Nitrate-Nitrite Nitrogen (mg/L)								
Minimum	0.107	0.174	0.458	0.676	0.602	0.588	0.024	0.041
Maximum	0.152	0.202	0.797	0.832	0.789	0.644	0.072	0.123
Arith. Average	0.128	0.184	0.611	0.732	0.696	0.607	0.040	0.072
No. of Samples	7	3	4	3	5	3	4	3
Ammonia Nitrogen (mg/L)								
Minimum	0.010	0.010	0.011	0.010	0.049	0.018	0.029	0.016
Maximum	0.029	0.010	0.021	0.023	0.330	0.281	0.088	0.571
Arith. Average	0.013	0.010	0.016	0.011	0.195	0.089	0.051	0.077
No. of Samples	7	14	4	14	5	17	4	11
Total Nitrogen* (mg/L)								
Minimum	0.182	0.210	1.10	0.767	1.60	0.787	0.335	0.220
Maximum	0.339	0.270	1.45	0.905	2.61	0.906	0.419	0.356
Arith. Average	0.262	0.248	1.33	0.853	2.04	0.833	0.389	0.274
No. of Samples	7	3	4	3	4	3	4	3
Temperature (°C)								
Minimum	12.7	8.3	11.4	9.4	12.3	10.2	14.1	9.9
Maximum	19.1	16.0	14.4	16.2	18.7	16.1	17.5	20.1
Arith. Average	14.8	12.8	12.7	13.1	14.6	13.5	15.7	14.9
No. of Samples	8	26	4	26	6	26	4	17
Dissolved Oxygen (mg/L)								
Minimum	9.4	10.2	10.4	9.7	8.4	4.6	7.8	8.5
Maximum	11.4	11.7	11.2	11.0	9.4	9.8	8.6	10.1
Arith. Average	10.6	10.8	10.8	10.2	9.0	8.3	8.2	9.2
No. of Samples	8	13	4	14	8	13	6	6
pH (SU)								
Minimum	7.3	6.4	7.3	6.7	7.1	5.8	6.8	6.8
Maximum	7.7	8.2	7.5	8.0	7.5	7.7	7.2	7.6
Arith. Average	7.6	7.5	7.4	7.5	7.4	7.2	7.1	7.3
No. of Samples	8	15	4	15	6	15	4	11
Conductivity (μmhos)								
Minimum	54	28	88	68	145	132	121	35
Maximum	73	64	101	127	181	197	126	135
Arith. Average	60	49	95	103	162	162	123	117
No. of Samples	7	14	4	14	5	14	4	10
Flow (cfs; all Tolt flows based on USGS data)								
Minimum	117	86	2.70	1.92	3.80	3.36	0.60	0.09
Maximum	186	175	3.50	12.50	4.50	5.55	0.90	0.43
Arith. Average	155	128	3.03	3.72	4.07	4.17	0.73	0.22
No. of Samples	7	14	3	22	4	7	4	14

Parameter	Cherry Creek	
	TMDL Study	2003-05 Study
Fecal Coliform (cfu/100 mL)		
Minimum	91	25
Maximum	1200	1000
Arith. Average	444	239
Geometric Mean	307	136
No. of Samples	5	26
Orthophosphate (mg/L)		
Minimum	0.005	0.0130
Maximum	0.011	0.0130
Arith. Average	0.009	0.0130
No. of Samples	5	1
Nitrate-Nitrite Nitrogen (mg/L)		
Minimum	0.418	0.310
Maximum	0.517	0.471
Arith. Average	0.482	0.404
No. of Samples	5	3
Ammonia Nitrogen (mg/L)		
Minimum	0.018	0.010
Maximum	0.062	0.094
Arith. Average	0.037	0.029
No. of Samples	5	14
Total Nitrogen* (mg/L)		
Minimum	1.03	0.476
Maximum	1.56	0.655
Arith. Average	1.19	0.569
No. of Samples	5	3
Temperature (°C)		
Minimum	13.5	9.6
Maximum	17.4	18.7
Arith. Average	14.7	14.9
No. of Samples	6	21
Dissolved Oxygen (mg/L)		
Minimum	6.0	6.5
Maximum	17.4	12.3
Arith. Average	12.9	9.4
No. of Samples	4	11
pH (SU)		
Minimum	4.0	6.6
Maximum	17.4	8.0
Arith. Average	10.1	7.2
No. of Samples	4	13
Conductivity (μmhos)		
Minimum	92	61
Maximum	115	208
Arith. Average	100	114
No. of Samples	5	12
Flow (cfs; flows based on USGS data)		
Minimum	3.00	0.81
Maximum	8.90	62.00
Arith. Average	6.08	11.26
No. of Samples	5	22

* Total nitrogen for the TMDL Study was calculated the sum of total kjeldahl nitrogen and nitrite-nitrate nitrogen.

Appendix J. Intensive Survey Results

An intensive monitoring survey was conducted on August 30 and 31, 2005 of all Snoqualmie sites. Each site was sampled twice a day (AM and PM) for fecal coliform bacteria, nutrients, total organic carbon, flow discharge, dissolved oxygen, temperature, and pH. Laboratory results are presented in Table J-1, and field results are presented in Table J-2.

Fecal coliform results were not compared to the standard, but Ames and Cherry Creeks had mean and geometric mean fecal coliform values greater than 200 cfu/100 mL. During the intensive survey, Ames, Cherry, Kimball, Tuck, and Patterson Creeks and the South Fork Snoqualmie at RM 1.5 sites had the highest bacteria levels, in that order.

The wastewater treatment plants (WWTPs) had the highest total organic carbon and nutrient levels. Of the tributaries, the South Fork RM 1.5, and Ames, Patterson, and Tuck Creeks had the highest orthophosphate levels. The highest ammonia-nitrogen levels were detected at Ames, Tuck, and Cherry Creeks. Similarly, the highest nitrite-nitrate nitrogen levels were detected at Harris Creek, the South Fork at RM 1.5, and Tokul, Patterson, and Ames Creeks.

Three sites did not meet pH standards. The Middle Fork Snoqualmie site and North Bend WWTP had a pH value below the 6.5 SU standard. The Raging River had a pH value above the 8.5 SU standard.

Water quality temperature standard was not met on the Middle Fork Snoqualmie and the Snoqualmie mainstem RM 2.7. Kimball, Ames, Cherry, and Tuck Creeks did not meet the dissolved oxygen standard.

Table J-1. Field sampling results for the Snoqualmie intensive survey, August 30-31, 2005.

August 30-31, 2005 n=4	Temperature (°C)		Dissolved Oxygen (mg/L)		pH (SU)		Conductivity (μmhos)
Sites	Min	Max	Min	Max	Min	Max	Mean
Middle Fork	15.5	19.4	9.5	10.0	6.4	7.2	40
North Fork	13.3	15.5	9.8	10.3	7.0	7.2	61
South Fork RM 2.8	12.4	16.0	9.6	10.0	6.7	7.3	78
North Bend WWTP	ND	ND	ND	ND	2.8	4.3	615
South Fork RM 2.0	12.6	16.5	9.4	9.8	6.9	7.0	87
Snoqualmie RM 42.3	14.5	16.6	9.5	10.3	6.7	7.3	61
Kimball Ck	15.8	16.4	7.4	7.5	6.9	7.1	102
Snoqualmie WWTP	20.3	22.0	ND	ND	7.5	7.5	476
Snoqualmie RM 40.7	14.8	15.7	8.6	9.5	7.2	7.4	61
Tokul River	12.2	15.1	9.9	10.5	8.0	8.2	127
Raging River	14.6	16.9	9.8	10.4	7.7	9.1	80
Snoqualmie RM 35.3	15.0	16.2	9.5	10.5	7.5	7.8	67
Patterson Ck	13.7	15.1	8.5	9.2	7.6	7.8	172
Griffin Ck	13.6	16.2	9.4	10.5	7.6	7.9	94
Snoqualmie RM 25.2	16.6	18.0	9.3	9.7	7.5	7.6	75
Tolt River	12.2	15.9	10.3	10.6	7.6	8.0	57
Harris Ck	12.2	14.6	9.8	10.2	7.6	7.8	110
Ames Ck	12.6	15.8	7.6	9.0	7.5	7.6	171
Duval WWTP	ND	ND	ND	ND	7.0	7.2	353
Cherry Ck	14.5	16.6	7.9	10.1	7.3	7.6	119
Tuck Ck	14.6	16.6	7.7	9.3	7.5	7.6	131
Snoqualmie RM 2.7	17.8	18.5	9.0	9.6	7.5	7.6	80

ND – parameter not sampled for

Table J-2. Laboratory results for the Snoqualmie intensive survey, August 30-31, 2005.

August 30-31, 2005 n=4	Fecal Coliform (cfu/100 mL)		Ortho-Phosphate mg/L	Total Persulfate Nitrogen (mg/L)	Nitrite nitrate Nitrogen (mg/L)	Ammonia Nitrogen (mg/L)	Organic Nitrogen (mg/L)	Total Organic Carbon (mg/L)	Inhibited BOD (mg/L)
Sites	Average	Geomean	Average						
Upper Snoqualmie									
Middle Fork	33	28	0.0031	0.163	0.094	0.010 U	0.058	1.08	
North Fork	42	24	0.0030 U	0.336	0.274	0.010 U	0.052	1.00 U	
South Fork RM 2.8	110	80	0.0041	0.321	0.259	0.010 U	0.051	1.00 U	
North Bend WWTP	164	118	3.340	22.1	20.1	0.195	1.81	11.0	4 U
South Fork RM 2.0	169	148	0.0586	0.668	0.583	0.010 U	0.074	1.00	
Snoqualmie RM 42.3	65	56	0.0042	0.283	0.201	0.010 U	0.072	1.00 U	
Kimball Ck	273	243	0.0038	0.399	0.237	0.016	0.147	3.00	
Snoqualmie WWTP	1	1	1.743	0.981	0.409	0.012	0.559	5.40	4 U
Snoqualmie RM 40.7	105	81	0.0034	0.266	0.204	0.010 U	0.053	1.13	
Lower Snoqualmie									
Tokul River	153	136	0.0099	0.648	0.575	0.012	0.061	1.33	
Raging River	87	77	0.0030	0.168	0.211	0.010 U	0.000	1.95	
Snoqualmie RM 35.3	153	128	0.0036	0.264	0.207	0.010 U	0.047	1.33	
Patterson Ck	190	190	0.0332	0.687	0.539	0.013	0.135	2.90	
Griffin Ck	105	104	0.0103	0.304	0.209	0.010 U	0.085	2.25	
Snoqualmie RM 25.2	88	75	0.0030 U	0.272	0.200	0.010 U	0.061	1.25	
Tolt River	13	10	0.0030 U	0.244	0.201	0.010 U	0.033	1.08	
Harris Ck	53	49	0.0148	0.837	0.730	0.010 U	0.097	2.05	
Ames Ck	488	449	0.0406	0.708	0.486	0.081	0.141	3.83	
Duval WWTP	2	2	2.448	6.12	4.81	0.630		5.45	4 U
Cherry Ck	435	396	0.0070	0.500	0.354	0.047	0.099	2.68	
Tuck Ck	193	191	0.0320	0.218	0.047	0.051	0.120	3.90	
Snoqualmie RM 2.7	61	46	0.0049	0.253	0.189	0.010		1.08	

U – The analyte was not detected at or above the reported sample quantitation limit.