Samish Bay Watershed Fecal Coliform Bacteria Total Maximum Daily Load

Volume 1. Water Quality Study Findings

November 2008

Publication No. 08-03-029

DEPARTMENT OF
ECOLOGY
State of Washington

Publication and Contact Information

This report is available on the Department of Ecology's website at
www.ecy.wa.gov/biblio/0803029.html

Data for this project are available at Ecology's Environmental Information Management (EIM) website www.ecy.wa.gov/eim/index.htm. Search User Study ID, TSWA0001.

Ecology's Study Tracker Code for this study is 05-017.

Ecology's TMDL database code is Sami03FC.

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/

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

Cover photo: Samish River flowing through Samish Bay tide flats at low tide. Photo by Trevor Swanson.

Samish Bay Watershed
Fecal Coliform Bacteria
Total Maximum Daily Load

Volume 1. Water Quality Study Findings

by
Trevor Swanson

Environmental Assessment Program
Washington State Department of Ecology
Olympia, Washington 98504-7710

Waterbody Numbers:
WA-PS-0210; WA-03-2010; WA-03-2100

This page is purposely left blank

Table of Contents

Page

List of Figures 3

List of Tables 5

Abstract 7

Acknowledgements 8

Executive Summary 9
- What is a Water Quality Plan or Total Maximum Daily Load (TMDL)? 9
- Why is Ecology conducting a TMDL in this watershed? 9
- Goals and objectives 9
- Watershed description 10
- TMDL analysis 10
- Conclusions and recommendations 13

What is a Total Maximum Daily Load (TMDL)? 15
- Federal Clean Water Act requirements 15
- TMDL process overview 15
- Elements required in a TMDL 16
- Total Maximum Daily Load analyses: Loading capacity 16

Why is Ecology conducting a TMDL study in this watershed? 17
- Overview 17
- Study area 17
- Pollutants addressed by this TMDL 20
- Impaired beneficial uses and waterbodies on Ecology's 303(d) list of impaired waters 21
- Why are we doing this TMDL now? 22

Water Quality Standards and Beneficial Uses 23
- Bacteria 23

Watershed Description 27
- Samish Bay 27
- Samish River and tributaries 28
- Shellfish 28
- Potential sources of bacteria 30

Goals and Objectives 33

Study Methods 35
- Data analysis methods 38

Study Quality Assurance Evaluation 39
- Laboratory duplicates 39
- Field replicates 39

Results and Discussion 41
Samish River 43
Friday Creek 47
Thomas Creek 49
Samish Bay fecal coliform – Washington State Department of Health 51
Comparison of critical periods for Samish Bay and the Samish River 53
Rain events 58
Special surveys 61
Bacterial comparisons 63
Fecal coliform bacteria 65

Margin of safety 79

Conclusions 81

Recommendations 82

References 83

Appendices 87
Appendix A. Glossary, acronyms, and abbreviations 89
Appendix B. Equations for statistical analysis – Statistical Theory of Rollback 93
Appendix C. Bacteria results 95
Appendix D. Other laboratory and field results 101
Appendix E. Investigatory sites maps 123

List of Figures

Page

Figure 1. Map of the Samish Bay watershed showing 303(d) listed areas and sampling sites. 18

Figure 2. Washington State Department of Health classifications for harvesting shellfish in Samish Bay (DOH, 2005). DOH FC sampling sites are also shown. 29

Figure 3. Samish River longitudinal FC concentration profile from data collected during the 2006-07 TMDL study....43

Figure 4. Seasonal longitudinal FC loading profile of the Samish River and tributary mouths. 44

Figure 5. Average monthly FC concentrations at Samish River mile 0.7 (Bayview/ Edison Road), 2006-07. 45

Figure 6. Average monthly loading and flows at Samish River mile 0.7 (Bayview/ Edison Road), 2006-07. 45

Figure 7. Results of Seasonal Kendall trend test at Samish RM 10.3, 1976 to 2008. 46

Figure 8. Longitudinal FC concentrations in Friday Creek. 47

Figure 9. FC concentrations and loads at 03-FRI-00.8 (Friday Creek at Bow Hill/ Prairie Rd), 2006-07.. 48

Figure 10. Seasonal longitudinal FC loading profile of Friday Creek and tributary mouths. 48

Figure 11. Longitudinal FC concentrations in Thomas Creek....49

Figure 12. Seasonal longitudinal FC loading profile of Thomas Creek. 49

Figure 13. FC loading at 03-THO-00.3 (Thomas Creek at Hwy 99), 2006-07. 50

Figure 14. FC concentrations at 03-THO-00.3 (Thomas Creek at Hwy 99), 2006-07. 50

Figure 15. DOH's most recent five-year trend in FC pollution at Samish Bay station 82. 51

Figure 16. DOH of Health classifications for harvesting shellfish in Samish Bay (DOH, 2005). DOH FC sampling sites are also shown. 52

Figure 17. Samish Bay at station 82 geometric mean FC concentrations from DOH's 1995 to 2007 monitoring data....56

Figure 18. Samish River at RM 4.6 (Thomas Road) FC loads from Skagit County's 2000 to 2007 monitoring data....56

Figure 19. Samish River at RM 10.3 (Hwy 99) FC loads from Ecology's monthly Ambient Monitoring Program, 1995 to 2008. 57

Figure 20. Samish River at RM 0.7 (Bayview/Edison Road) FC loads from Ecology's TMDL study, 2006 to 2007. 57

Figure 21. USGS hydrograph showing July 12 and August 10, 2006 rain event discharge (cfs) spikes...60

Figure 22. A comparison of 40 paired FC samples that were analyzed using the most probable number (MPN) and membrane filter (MF) techniques during the 2006-07 TMDL study...63

Figure 23. A comparison of the 42 paired FC and *E. coli* samples collected from various sites during the 2006-07 Samish Bay bacteria TMDL study.. 64

Figure 24. Samish Bay watershed with recommended FC reduction targets. 72

Figure 25. Estimated average annual discharge from tributaries to Samish Bay during the 2006-07 TMDL study. 73

Figure 26. Estimated average annual loading from tributaries to Samish Bay during the 2006-07 TMDL study. 74

List of Tables

Page

Table 1. Fixed network of sampling site locations and descriptions in the Samish Bay watershed.......19

Table 2. Investigatory, add-on, and special survey sampling site locations and descriptions.......20

Table 3. Study area waterbodies on the 2004 303(d) list for FC bacteria. 21

Table 4. Additional 303(d) listings not addressed by this report.......21

Table 5. Duplicate laboratory sample statistics. 39

Table 6. Replicate field sample statistics.......40

Table 7. Summary statistics for FC bacteria at regularly sampled sites in the Samish Bay watershed during the 2006-07 TMDL study. Storm event data were not included in the analysis.......42

Table 8. DOH's 2005 to 2007 summary of shellfish growing areas. FC study results for Samish Bay, 05/20/2005 to 12/11/2007. 53

Table 9. Average wet, intermediate, and dry season discharge from all tributaries to Samish Bay during the 2006-07 TMDL study. Wet, intermediate, and dry season average percent of total discharge is also shown. 54

Table 10. Average wet, intermediate, and dry season loading from all tributaries to Samish Bay during the 2006-07 TMDL study. Wet, intermediate, and dry season average percent of total load is also shown.......55

Table 11. Precipitation at WSU's Sakuma weather station (northwest of Burlington) and USGS daily mean discharge at Samish River mile 10.3 from October 30 to November 14, 2006 (WSU, 2008). 58

Table 12. Precipitation at WSU's Sakuma weather station (northwest of Burlington) from July 6 to 16, 2006 (WSU, 2008).......59

Table 13. Precipitation at WSU's Sakuma weather station (northwest of Burlington) from August 3 to 13, 2006 (WSU, 2008).......60

Table 14. Recommended Samish River and tributary FC reductions and target concentrations to meet load capacities based on *Primary Contact* criteria and to protect shellfish harvesting in Samish Bay. 69

Table 15. Recommended Friday Creek and tributary FC reductions and target concentrations to meet load capacities based on *Primary Contact* criteria. 70

Table 16. Recommended Thomas Creek and tributary FC reductions and target concentrations to meet load capacities based on *Primary Contact* criteria. 70

Table 17. Recommended Samish Bay tributary FC reductions and target concentrations to meet load capacities based on *Primary Contact* criteria and to protect shellfish harvesting in Samish Bay. 71

Table 18. Recommended Samish River and tributary FC load reductions based on critical condition data meeting water quality criteria for *Primary Contact* uses. 75

Table 19. Recommended Friday Creek and tributary FC load reductions based on critical condition data meeting water quality criteria for *Primary Contact* uses. 75

Table 20. Recommended Thomas Creek and tributary FC load reductions based on critical condition data meeting water quality criteria for *Primary Contact* uses. 76

Table 21. Recommended FC load reductions for other tributaries to Samish Bay, based on critical condition data meeting water quality criteria for *Primary Contact* uses. 76

Abstract

The Washington State Department of Ecology (Ecology) is required, under section 303(d) of the federal Clean Water Act and U.S. Environmental Protection Agency regulations, to develop and implement Total Maximum Daily Loads (TMDLs) for impaired waters. A TMDL analyzes how much pollution a waterbody can assimilate without violating Washington State water quality standards.

The Samish River, Samish Bay, and sloughs to Samish Bay were listed by Ecology for not meeting fecal coliform bacteria (FC) criteria. The listings were based on sampling done by Ecology, the Washington State Department of Health, and the Skagit Stream Team since 1993.

Due to nonpoint (diffuse) pollution sources, FC levels did not meet freshwater quality criteria at most of the sites sampled by Ecology from 2006-07.

Data from Ecology 2006-07 field surveys showed that reductions in FC bacteria levels are necessary in the Samish River and its tributaries, in Colony Creek, and in all sloughs to the bay. These reductions are needed to protect the public from pathogens in freshwater and to protect marine water and shellfish harvesting in Samish Bay.

The goal of this study is to provide the technical analysis necessary to develop a TMDL for the Samish Bay watershed. The TMDL will be written to achieve compliance with the state's water quality standards for FC bacteria. Identifying and eliminating sources of FC contamination in the Samish River and other tributaries to Samish Bay, as well as cleaning up the Friday Creek and Thomas Creek subbasins, will be essential for the success of the TMDL.

Acknowledgements

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

- Rick Haley, Skagit County Public Works
- Steve Olson, Skagit County Public Health Department
- Cara McKinnon, Washington State Department of Agriculture
- Mike Shelby and Mike Rundlett, Western Washington Agricultural Association
- Kristi Carpenter and John Schuh, Skagit County Conservation District
- Jon-Paul Shannahan, Upper Skagit Indian Tribe
- Bill Dewey, Taylor Shellfish Company
- Suzanne Shull, David Henry, and Doug Bulthuis, Padilla Bay National Estuarine Research Reserve
- Christine Woodward, Samish Tribe

Staff with the Department of Ecology, Environmental Assessment Program:

- Jim Carroll and Joe Joy, Eastern Operations Section
- Brandon Slone, Chad Brown, Nuri Mathieu, Tanya Roberts, Teizeen Mohamedali, Christopher Moore, Debby Sargeant, Paul Anderson, Chuck Springer, Don Watt, Joan LeTourneau and Cindy Cook
- Statewide Coordination Section
- Nancy Jensen, Pam Covey, Leon Weiks, Dean Momohara, and Stuart Magoon, Manchester Environmental Laboratory
- Bernie Strong, Operations Center Manager

Staff with the Department of Ecology, Water Quality Program:

- Sally Lawrence, Craig Homan, DouGlas Palenshus, Dave Garland, Ken Ziebart, and Ken Koch

Staff with the Department of Health, Office of Shellfish and Water Protection:

- Debby Sargeant, Don Lennartson, Lawrence Sullivan, Bob Woolrich, and Greg Combs

Executive Summary

What is a Water Quality Plan or Total Maximum Daily Load (TMDL)?

The Federal Clean Water Act established a process to identify and clean up polluted waters. Each state is required to have water quality standards designed to protect, restore, and preserve water quality. Every two years states are required to prepare a list of waterbodies that do not meet water quality standards. This list is called the 303(d) list.

The Clean Water Act requires that a TMDL be developed for each of the waterbodies on the 303(d) list. A TMDL identifies how much pollution needs to be reduced or eliminated to achieve clean water. This process starts with a technical study and analysis of pollution levels and sources. Then the Washington State Department of Ecology (Ecology) works with the local community to develop (1) a strategy to control the pollution and (2) a monitoring plan to assess effectiveness of the water quality improvement activities.

Why is Ecology conducting a TMDL in this watershed?

The Samish River, Samish Bay, Friday Creek, Thomas Creek, Edison Slough, and an unnamed slough to Samish Bay are on Ecology's 2004 303(d) list for FC bacteria (Ecology, 2005).

Reducing FC bacteria in the river, creeks, and sloughs draining to Samish Bay will help keep important commercial and recreational shellfish beds available for harvest and will improve water quality of the bay for both aquatic life and human uses.

Goals and objectives

The goal of this TMDL is to develop a plan to meet water quality standards for fecal coliform bacteria. The following technical analysis will help accomplish this goal by:

- Providing a comprehensive evaluation of data.
- Identifying and characterizing FC concentrations and loads from all tributaries, point sources, and drainages to Samish Bay under various seasonal and hydrological conditions.
- Identifying relative contributions of FC loading to the bay so that cleanup activities can focus on the largest sources.
- Recommending FC load and wasteload allocations to protect beneficial uses, including primary and secondary contact and shellfish harvesting.

Watershed description

Samish Bay is located in northwestern Skagit County and southern Whatcom County, north of Padilla Bay and south of Bellingham Bay. Samish Bay is within Water Resource Inventory Area (WRIA) 03.

The Samish River is the largest tributary to Samish Bay, but Colony Creek, Oyster Creek, and several sloughs and drainage ditches, including Edison Slough, also contribute fresh water to the bay. Friday Creek, a major tributary to the Samish River and an important salmon spawning stream, flows from Samish, Cain, and Reed Lakes in Whatcom County.

The Samish River watershed drains 123 square miles and covers parts of Skagit and Whatcom Counties (Figure 1). The watershed consists of three major subbasins; the Samish River (62%), Friday Creek (30%) and Thomas Creek (8%) (Palmer et al., 1996). The mainstem Samish River runs along a low gradient valley, but many small tributaries flow into the main channel from surrounding steep slopes.

About 75% of the lower Samish River basin is used for agriculture, including dairy and cattle operations. The mainstem Samish River is extensively channelized and diked.

About 1,100 acres of Samish Bay's tide flats are currently farmed for the commercial production of shellfish, primarily Pacific Oysters, Manila Clams, mussels, and geoduck.

TMDL analysis

Data from Ecology 2006-07 field surveys showed that reductions in FC bacteria levels are necessary in the Samish River and its tributaries, Colony Creek, and all sloughs to the bay. These reductions are needed to protect the public from pathogens in freshwater and to protect marine water and shellfish harvesting in Samish Bay.

A geometric mean fecal coliform bacteria target of 10 colony forming units (cfu)/100 mL and a 90^{th} percentile of 43 cfu/100 mL is recommended for the Samish River at river mile (RM) 0.7. The recommended bacteria target near the mouth of the Samish River is lower than the freshwater fecal coliform standard because the river has a large impact on the bay.

The Samish River contributes an average of 83% of the total water to the bay and 70% of the FC loading annually.

A 72% reduction in fecal coliform bacteria is needed at the mouth of the Samish River to meet the recommended target concentration. Targets at RM 4.6 and 6.5 have been adjusted so that the target at RM 0.7 can be met. Reductions necessary for the rest of the Samish River, and all streams and sloughs studied in the Samish Bay watershed, are shown in ES Tables 1-4.

Table ES-1. Recommended Samish River and tributary FC reductions and target concentrations to meet load capacities based on *Primary Contact* criteria and to protect shellfish harvesting in Samish Bay.

Site ID w/River Mile	Site Location	Number of Samples	Critical Period	Critical Period FC (cfu/100 mL)		FC Reduction	FC Target Capacity (cfu/100 mL)	
				90th %tile	Geo-mean		90th %tile	Geo-mean
03-SAM-00.7	Bayview/ Edison Rd	25	none	156	35	72%	43	10
03-SAM-04.6	Thomas Rd	25	none	243	56	72%	67	15
03-SAM-06.5	Chuckanut Dr	25	none	226	65	73%	62	18
03-THO-00.3	Thomas Ck at Old Hwy 99	24	May-Sep	920	254	78%	200	55
03-SAM-10.3	Hwy 99	24	May-Oct	428	181	53%	200	85
03-FRI-00.8	Friday Ck at Bow Hill / Prairie Rd	24	Jun-Sep	936	174	79%	200	37
03-SAM-13.1	F&S Grade Rd	24	May-Oct	380	130	47%	200	69
03-SWE-00.0	Swede Ck at Grip Rd	24	Apr-Sep	828	157	76%	200	38
03-SKA-00.5	Skarrup Creek at first road crossing	21	none	750	170	73%	200	45
03-SAM-15.0	2nd Prairie Rd crossing from Hwy 99	24	May-Aug	572	97	65%	200	34
03-PAR-00.0	Parson Ck at confluence w/Samish R	24	July-Oct	3605	1976	95%	182	100
03-SAM-16.5	Off Prairie Rd upstream of Parson Ck	24	May-Aug	356	87	44%	200	49
03-SAM-20.7	3rd Prairie Rd crossing from Hwy 99	24	May-Aug	372	74	46%	200	40
03-SAM-22.0	Hwy 9	24	none	--	--	--	200	100
03-SAM-26.6	Wickersham Rd	24	none	--	--	--	200	100
03-ENN-00.0	Ennis Ck at mouth, Wickersham Rd	21	none	--	--	--	200	100
03-SAM-28.8	Innis Ck Rd (in Doran)	24	none	1604	149	88%	200	19

Table ES-2. Recommended Friday Creek and tributary FC reductions and target concentrations to meet load capacities based on *Primary Contact* criteria.

Site ID w/River Mile	Site Location	Number of Samples	Critical Period	Critical Period FC (cfu/100 mL)		FC Reduction	FC Target Capacity (cfu/100 mL)	
				90th %tile	Geo-mean		90th %tile	Geo-mean
03-FRI-00.8	Friday Ck at Bow Hill/ Prairie Rd	24	Jun-Sep	936	174	79%	200	37
03-FRI-03.8	Friday Ck at Friday Ck Rd	24	Jun-Sep	911	159	78%	200	35
03-SIL-00.4	Silver Creek at Friday Ck Rd	24	none	--	--	--	200	100
03-FRI-06.5	Friday Ck at Lake Samish Rd	24	none	--	--	--	200	100

Table ES-3. Recommended Thomas Creek and tributary FC reductions and target concentrations to meet load capacities based on *Primary Contact* criteria.

Site ID w/River Mile	Site Location	Number of Samples	Critical Period	Critical Period FC (cfu/100 mL)		FC Reduction	FC Target Capacity (cfu/100 mL)	
				90th %tile	Geo-mean		90th %tile	Geo-mean
03-THO-00.3	Old Hwy 99	24	May-Sep	920	254	78%	200	55
03-WIL-00.0	Off F&S Grade Rd above Thomas Ck	17[1]	none	2327	234	91%	200	20
03-THO-03.6	Off F&S Grade Rd above Willard Ck	24	May-Sep	3105	399	94%	200	26

[1]Some samples were taken during the dry period, but not used because there was no streamflow.

Table ES-4. Recommended Samish Bay tributary FC reductions and target concentrations to meet load capacities based on *Primary Contact* criteria and protect shellfish harvesting in Samish Bay.

Site ID w/ River Mile	Site Location	Number of Samples	Critical Period	Critical Period FC (cfu/100 mL)		FC Reduction	FC Target Capacity (cfu/100 mL)	
				90th %tile	Geo-mean		90th %tile	Geo-mean
03-COL-00.0	Colony Ck near mouth, up of tidegates	25	May-Oct	244	103	18%	200	85
03-ALI-PUMP	Drainage to Alice Bay	25	none	127	16	66%	43	5
03-NED-PUMP	N Edison drainage at Key Ave.	17[1]	none	330	109	39%	200	66
03-SED-PUMP	S Edison drainage near liquor store	21	none	601	167	67%	200	56
03-BAY-GATE	Drainage W of Sam. R mouth	25	none	342	52	42%	200	30
03-MCE-GATE	Tidegate to McElroy/ Col. Slough	25	Apr-Sep	836	196	76%	200	47
03-WED-GATE	W Edison drainage near Edison Slough	15[1]	none	428	41	53%	200	19
03-SMI-GATE	Drain to Edison Slough at Smith Rd	4	none	--	--	NA[2]	NA[2]	NA[2]
03-EDI-01.2	Edison Slough up of gates in Edison	24	Apr-Jul	846	129	76%	200	31
03-EDI-01.6	Edison Slough just up of school	25	Apr-Jul	960	153	79%	200	32
03-OYS-00.0	Oyster Ck near mouth	25	none	--	--	--	NA	NA

[1]Some samples were taken during the dry period, but not used because there was no flow.
[2]SMI-GATE reductions will occur as NED-PUMP's reduction targets are met. They are fed through the same slough system.

Conclusions and recommendations

The following is a summary of conclusions and recommendations based on this 2006-07 fecal coliform (FC) TMDL evaluation:

Conclusions

- The geographic extent of FC problems is much wider than indicated by the 303(d) listings.
- The Samish River is the largest contributor of FC, with 83% of the total freshwater and 70% of the total loading to Samish Bay.
- Storm events can result in elevated FC levels, especially if they occur after a dry period.
- Higher streamflows and associated loadings influence the bay's FC more than concentrations alone.
- Highest FC loads occur in the wet season and during storm events.
- Highest freshwater FC concentrations occur mostly in the dry season.
- Implementing the recommended 72% FC load reduction at Samish RM 0.7 as well as various reductions at Colony Creek and all sloughs to Samish Bay, should be adequate to protect shellfish harvesting and other beneficial uses in Samish Bay.
- The sources of FC contamination in the watershed are not obvious, but probably include surface flow from areas where livestock or manure application is occurring during storm events, malfunctioning on-site septic systems, waterfowl and wildlife, stormwater runoff, pets, non-commercial farm animals, and recreational users.

Recommendations

- Cleaning up direct sources of FC to the bay is the highest priority. Since the Samish River is the largest FC source; cleanup should begin there.
- Priority should also be given to the sloughs in south Edison, north Edison, Alice Bay, and Colony Creek since they contribute the highest loads (other than the Samish River) to the bay.
- Other priority sites should include upper Samish River, upper Thomas Creek, lower Friday Creek, and Parson, Skarrup, and Swede Creeks.
- Most stream reaches require more intensive spatial and temporal monitoring to better identify sources of FC contamination.
- Septic system inspections and repairs should be completed in a timely manner to eliminate human waste as a source of FC to the bay.

This page is purposely left blank

What is a Total Maximum Daily Load (TMDL)?

Federal Clean Water Act requirements

The Clean Water Act established a process to identify and clean up polluted waters. Under the Clean Water Act, each state is required to have its 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, as well as criteria (usually numeric) 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, 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 the data are used to develop the 303(d) list. The 303(d) list is part of the larger Water Quality Assessment.

The Water Quality Assessment is a list that tells a more complete story about the condition of Washington's water. This list divides waterbodies into five categories:

Category 1 – Meets standards for parameter(s) for which it has been tested.

Category 2 – Waters of concern.

Category 3 – Waters with no data available.

Category 4 – Polluted waters that do not require a TMDL because:

- 4a. – Has an approved TMDL and it is being implemented.
- 4b. – Has a pollution control program 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 TMDL -- the 303(d) list.

TMDL process overview

The Clean Water Act requires that a TMDL be developed for each of the waterbodies on the 303(d) list. A TMDL identifies how much pollution needs to be reduced or eliminated to achieve clean water. Then Ecology works with the local community to develop (1) a strategy to control the pollution and (2) a monitoring plan to assess effectiveness of the water quality improvement activities. The document that combines all of these elements is called a water quality implementation report.

Elements required in a TMDL

The goal of a TMDL is to ensure the impaired water will attain Washington State water quality standards. 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 (point) source regulated by a National Pollution Discharge Elimination System (NPDES) permit, such as a municipal or industrial facility's discharge pipe, that facility's share of the loading capacity is called a *wasteload allocation*. If the pollutant comes from a set of diffuse (nonpoint) sources such as general urban, residential, or farm runoff, 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.

TMDL = Loading Capacity = sum of all wasteload allocations + sum of all load allocations + margin of safety

Total Maximum Daily Load analyses: Loading capacity

Identification of the contaminant loading capacity for a waterbody is an important step in developing a TMDL. Environmental Protection Agency defines the loading capacity as "the greatest amount of loading that a waterbody can receive without violating water quality standards" (EPA, 2001). The loading capacity provides a reference for calculating the amount of pollution reduction needed to bring a waterbody into compliance with the standards. The portion of the receiving water's loading capacity assigned to a particular source is a load or wasteload allocation. By definition, a TMDL is the sum of the allocations, which must not exceed the loading capacity.

Why is Ecology conducting a TMDL study in this watershed?

Overview

Section 303(d) of the federal Clean Water Act periodically requires Washington State to prepare a list of all surface waters in the state that do not meet water quality standards and are not expected to improve within the next two years. The Samish River, Samish Bay, Friday Creek, Thomas Creek, Edison Slough, and an unnamed slough to Samish Bay are on the Washington State Department of Ecology's (Ecology's) 2004 303(d) list for fecal coliform (FC) bacteria (Ecology, 2005).

Total Maximum Daily Load (TMDL) evaluations are required to identify the maximum amount of each pollutant to be allowed into these waterbodies so as not to impair beneficial uses of the water. The TMDL is then used to determine the wasteload allocations among sources with wastewater and stormwater permits, and load allocations among various nonpoint sources that do not have permits.

This technical report will be used to develop FC bacteria TMDLs in the Samish River and its tributaries and other tributaries to Samish Bay. The TMDLs will set water quality targets to meet FC bacteria standards, identify key reaches for source reduction, and allocate pollutant loads to nonpoint sources. The study was conducted by Ecology's Environmental Assessment Program in cooperation with Ecology's Water Quality Program at the Northwest Regional Office, the Washington State Department of Health, Skagit County, and other local governments.

Study area

Samish Bay is located in northwestern Skagit County and southern Whatcom County, north of Padilla Bay and south of Bellingham Bay within Water Resource Inventory Area (WRIA) 03 (Figure 1). Sampling site locations and descriptions referencing the numbers in Figure 1 can be found in Table 1 and Table 2.

The Samish River is the largest tributary to Samish Bay, but Colony Creek, Oyster Creek, and several sloughs and drainage ditches, including Edison Slough, also contribute freshwater to the bay. Friday Creek, a major tributary to the Samish River and an important salmon spawning stream, flows from Samish, Cain, and Reed Lakes in Whatcom County.

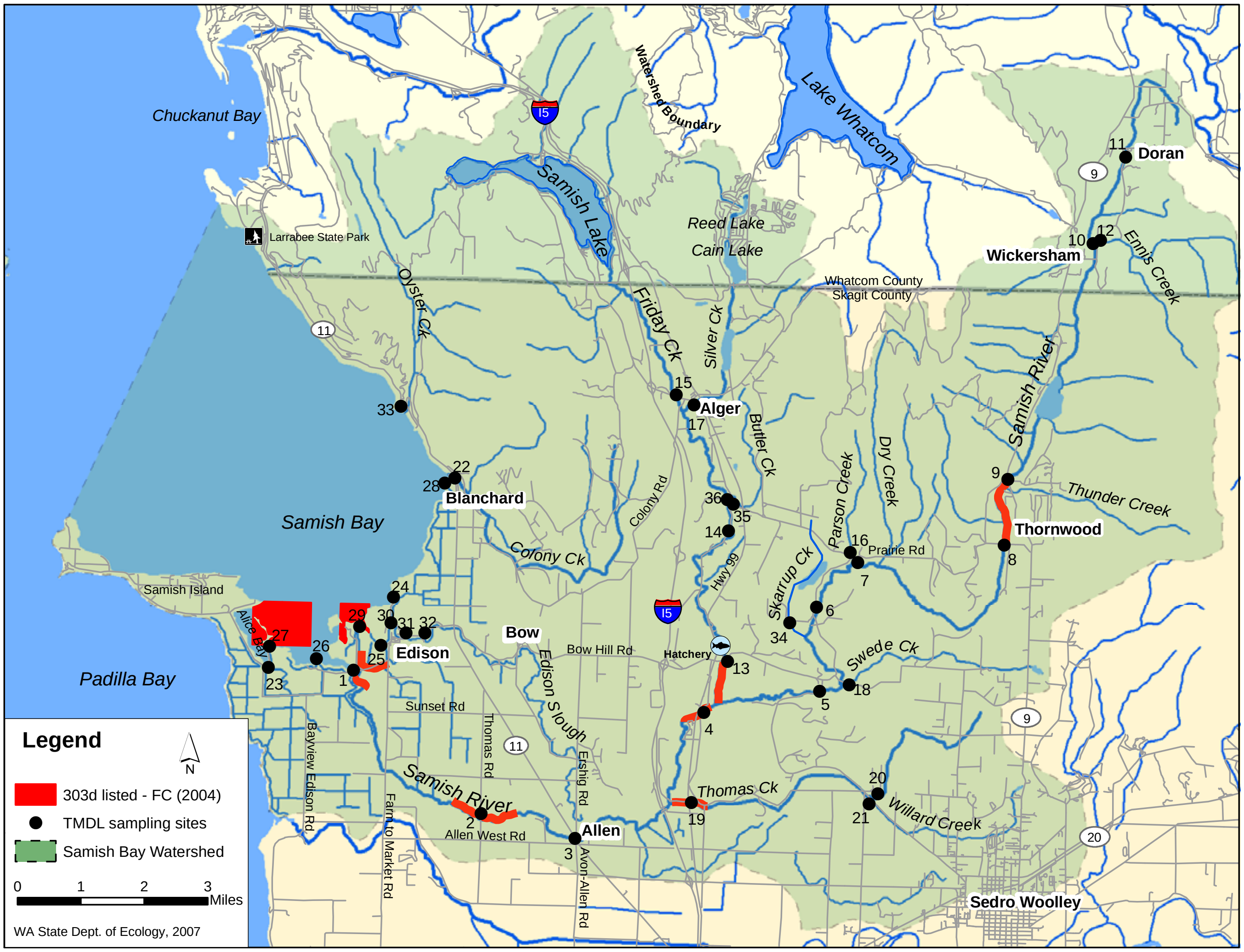


Figure 1. Map of the Samish Bay watershed showing 303(d) listed areas and sampling sites. Numbers reference site descriptions in Table 1 and Table 2.

Table 1. Fixed network of sampling site locations and descriptions in the Samish Bay watershed. Numbers reference Figure 1.

Field ID with River Mile	Map #	Watershed or Subwatershed and Site Location
Samish River		
03-SAM-00.7	1	At Bayview/ Edison Rd
03-SAM-04.6	2	Thomas Rd
03-SAM-06.5	3	Chuckanut Dr
03-SAM-10.3	4	Hwy 99
03-SAM-13.1	5	F&S Grade Rd
03-SAM-15.0	6	2nd Prairie Rd crossing from Hwy 99
03-SAM-16.5	7	Off Prairie Rd upstream of Parson Ck
03-SAM-20.7	8	3rd Prairie Rd crossing from Hwy 99
03-SAM-22.0	9	Hwy 9
03-SAM-26.6	10	Wickersham Rd
03-SAM-28.8	11	Innis Ck Rd (in Doran)
Samish River Tributaries		
03-ENN-00.0	12	Ennis Ck at mouth, Wickersham Rd
03-FRI-00.8	13	Friday Ck at Bow Hill / Prairie Rd (below Hatchery)
03-FRI-03.8	14	Friday Ck at Friday Ck Rd
03-FRI-06.5	15	Friday Ck at Lake Samish Rd / Alger Cain Lk Rd
03-PAR-00.0	16	Parson Ck at confluence with Samish R
03-SIL-00.4	17	Silver Creek at Friday Ck Rd
03-SWE-00.0	18	Swede Ck at Grip Rd
03-THO-00.3	19	Thomas Ck at Old Hwy 99
03-THO-03.6	20	Thomas Ck off F&S Grade Rd above Willard Ck confluence
03-WIL-00.0	21	Willard Ck off F&S Grade Rd above Thomas Ck confluence
Samish Bay Tributaries		
03-COL-00.0	22	Colony Ck near mouth, upstream of tidegates
03-ALI-PUMP	23	Drainage to Alice Bay
03-NED-PUMP	24	N Edison drainage at Key Ave., off Smith Rd
03-SED-PUMP	25	S Edison drainage near liquor store
03-BAY-GATE	26	Drainage west of Samish River mouth, to Samish Bay
03-ALI-GATE	27	Drainage to Alice Bay
03-MCE-GATE	28	Tidegate to McElroy/Colony Slough
03-WED-GATE	29	W Edison drainage near Edison Slough mouth
03-SMI-GATE	30	Drainage to Edison Slough at Smith Rd near NED-PUMP
03-EDI-01.2	31	Edison Slough just upstream of tidegates in Edison
03-EDI-01.6	32	Edison Slough at private drive upstream of school
03-OYS-00.0	33	Oyster Ck near mouth

Table 2. Investigatory, add-on, and special survey sampling site locations and descriptions. Numbers reference Figure 1.

Field ID w/ River Mile	Map #	Investigatory, Add-on, and Special Survey Sites
03-DRY-00.0	-	Dry Creek at mouth
03-SKA-00.5	34	Skarrup Creek at first road crossing
03-SAM-WF	-	Samish River "West Fork" at Doran Rd
03-BUT-00.0	35	Butler Ck at mouth
03-FRI-04.3	36	Friday Ck just above Butler confluence
03-VER-00.3	-	Vernon Ck near mouth at Upper Samish Rd
03-SAM-28.8	-	Innis Ck Rd (in Doran)
03-SAM-HW1	-	About 0.1 RM upstream from SAM-28.8, just upstream from Doran Rd bridge
03-SAM-HW2	-	About 0.1 RM upstream from SAM-HW1
03-SAM-HW3	-	About 0.1 RM upstream from SAM-HW2
03-SAM-HW4	-	About 0.1 RM up from SAM-HW3, above pool and below a pipe from hillside
03-WIL-00.0	21	Willard Ck Off F&S Grade Rd above Thomas Ck confluence
03-WIL-DIT	-	Unnamed tributary flowing through cow pasture (wet season only)
03-WIL-00.2	-	Willard Ck just above unnamed tributary flowing through cow pasture
03-WIL-DIT2	-	Ditch draining hillside upstream of 03-WIL-00.2
03-WIL-01.3	-	Willard Ck at corner of Westerman Rd
03-WIL-01.6	-	Willard Ck at Garden of Eden Rd
03-WIL-01.7	-	Willard Ck at Birch St
03-SAM-09.2	-	Samish River below ditch on private property
03-DIT-00.0	-	Ditch flowing through private property
03-SAM-09.6	-	Samish River below Bobcat Ck and above DIT-00.0
03-BOB-00.0	-	Bobcat Creek near mouth
03-SAM-10.0	-	Samish River above Bobcat Ck and private property
03-COL-00.0	-	Colony Ck near mouth, just before tidegates
03-COL-00.3	-	Colony Ck at Flinn Rd
03-COL-00.9	-	Colony Ck at S. Blanchard Rd; past slough
03-COL-01.2	-	Colony Ck at bridge 0.5 to 0.75 mi downstream of Colony Mountain Rd
03-COL-01.8	-	Colony Creek 500 feet upstream of Colony Mountain Rd

Pollutants addressed by this TMDL

This TMDL addresses FC bacteria concentrations and loads in tributaries to Samish Bay, including the Samish River and its major tributaries, and other creeks and drainages to Samish Bay. Analysis of FC in Samish Bay is also included (Department of Health data). Additional 303(d) listings not addressed by this report are listed in Table 4.

Impaired beneficial uses and waterbodies on Ecology's 303(d) list of impaired waters

The main beneficial uses to be protected by this TMDL are primary contact recreation and shellfish protection. Table 3 shows reaches of the Samish River, Samish Bay, Friday Creek, Thomas Creek, and an unnamed slough with Clean Water Act Section 303(d) listings (2004 list) that do not meet FC standards and are addressed in the Samish Bay FC TMDL Study.

Table 3. Study area waterbodies on the 2004 303(d) list for FC bacteria.

Waterbody	Waterbody ID	Listing ID	Latitude/Longitude or Section, Township, Range	Marine Grid Cell
Samish Bay	390KRD TMKY HEWJ	40585 40583 40584	48.565 122.475 48.565 122.455 48.565 122.485	48122F4G7 48122F4G5 48122F4G8
Samish River	NN50EA	16412	35N 04E 06	
Samish River	NN50EA	16413 16414 39646	35N 03E 15 36N 04E 24 35N 03E 99	
Friday Creek	NI79KV	16409	35N 04E 05	
Thomas Creek	IO78KZ	39658	35N 04E 18	
Edison Slough	TR24JW	39604	36N 03E 33	
unnamed slough	AU64DK	39671	35N 03E 05	

At both the 303(d) and non-303(d) locations, where exceedances of the water quality criteria for FC were observed, load allocations were recommended. Additional 303(d) listings not addressed by this report are listed in Table 4.

Table 4. Additional 303(d) listings not addressed by this report.

Waterbody	Parameter	Medium	Waterbody ID	Listing ID	Section, Township, Range
Samish River Samish River	Turbidity Turbidity	Water Water	NN50EA NN50EA	15910 15911	35N 03E 15 35N 04E 06
Samish Lake	Total PCBs	Tissue	O54FYG	17366	37N 03E 26
Edison Slough	D.O.	Water	TR24JW	39605	36N 03E 33
Unnamed slough Unnamed slough Unnamed slough	D.O. Temperature D.O.	Water Water Water	SN87OD SN87OD AU64DK	39666 39669 39673	35N 03E 06 35N 03E 06 35N 03E 05

D.O. = Dissolved Oxygen.

Why are we doing this TMDL now?

Reducing FC bacteria in the river, creeks, and sloughs draining to Samish Bay will (1) help keep important commercial and recreational shellfish beds available for harvest, and (2) improve water quality of the bay for both aquatic life and human uses.

Samish Bay shellfish are an important economic resource, with annual sales of oysters and clams totaling three to four million dollars. The shellfish are also harvested recreationally.

In December 2003, the Washington State Department of Health (DOH) closed Samish Bay to commercial harvest for three weeks following an outbreak of Norovirus, which causes severe gastrointestinal illness. Twenty-one people who had eaten raw Samish Bay oysters in Seattle-area restaurants became ill. The closure cost the local industry tens of thousands of dollars and resulted in the layoff of several workers. It was this temporary closure, as well as information from DOH indicating that additional closures could follow if bacteria loadings to the bay were not reduced, that spurred local and state interest in developing a TMDL assessment for bacteria in the Samish Bay watershed.

The December 2003 closure was frustrating for shellfish growers and for residents who had participated in earlier efforts to reduce FC levels in the watershed following an illness outbreak in August 1994. In response to this earlier outbreak, the Samish watershed Plan (1995) was prepared as a Final Closure Response Strategy. The plan outlined objectives for addressing nonpoint pollution problems in the watershed. In 1998, individual septic systems in Blanchard were replaced or repaired, and a community sewer was installed in Edison. These efforts resulted in a small amount of the original 2700 acres of closed shellfish beds upgrading to “approved” and “conditionally approved.”

Also in response to the 1994 illness outbreak and subsequent cleanup efforts, water quality data for 24 sites in the Samish watershed was collected by Skagit County Public Works from May 2000 to May 2003 (Haley, 2004). While the study pointed to the Samish River as the largest source of loading to the bay, it showed that bacteria were present throughout the watershed at levels that exceeded parts of the state standard and varied with season, with highest concentrations usually occurring in late spring and early summer.

This 2006-07 study was designed to further locate sources of bacteria so that appropriate actions could be taken to remove or reduce pollution sources.

Water Quality Standards and Beneficial Uses

The Washington State Water Quality Standards, set forth in Chapter 173-201A of the Washington Administrative Code (WAC), include designated beneficial uses, waterbody classifications, and numeric and narrative water quality criteria for surface waters of the state.

Freshwater and marine waterbodies are required to meet water quality standards based on the beneficial uses of the waterbody. Numeric criteria for specific water quality parameters are intended to protect designated uses. Samish Bay and its tributaries, including the Samish River and Friday Creek and their tributaries, are classified as Primary Contact waters.

Bacteria

WAC 173-201A-060 describes the application of freshwater and marine water quality standards on the basis of salinity. Where 95% of the salinity values are less than ten parts per thousand (ppt), the freshwater standards apply. The marine water quality standard applies where salinity is 10 ppt or greater. If data show a 95^{th} percentile conductivity of 17,700 micromhos, equivalent to a salinity greater than 10 ppt, marine FC standards apply.

The FC criteria have two statistical components: a geometric mean and an upper limit value that 10% of the samples cannot exceed. Fecal coliform samples collected randomly follow a log-normal distribution. In Washington State FC TMDL studies, the upper limit statistic (i.e., not more than 10% of the samples shall exceed) has been interpreted as a 90^{th} percentile value of the log-normalized values (Cusimano, 1997; Joy, 2000; Sargeant, 2002).

Reaches of the Samish River and Samish Bay are available to the public for primary (e.g., swimming) and secondary (e.g., sport fishing) recreation. Fishing is allowed in the Samish River and Samish Bay during specific times of the year. Hunters, recreational fishermen, agricultural workers, and adventurous children have limited contact with waters of the Samish Bay watershed. Commercial shellfish workers and salmon fisherman have more regular contact with the waters of Samish Bay.

Freshwaters

Bacteria criteria are set to protect people who work and play in and on the water from waterborne illnesses. In Washington State water quality standards, FC is used as an “indicator bacteria” for the state’s freshwaters (e.g., lakes and streams). Fecal coliform bacteria in water “indicates” the presence of waste from humans and 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 FC criteria are set at levels that have been shown to maintain low rates of serious intestinal illness (gastroenteritis) in people.

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 also 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% 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 (for example, dry-season versus wet-season) data sets.

The criteria for FC are based on allowing no more than the pre-determined risk of illness to humans that work or recreate in a waterbody. The criteria used in Washington 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 FC 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 FC concentrations back into compliance with the standard.

If natural levels of FC (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 (particularly those that are managed by humans and thus exposed to human-derived pathogens as well as those of animal origin) are a common source of serious waterborne illness for humans.

Marine waters

In marine (salt) waters, bacteria criteria are set to protect shellfish consumption and people who work and play in and on the water. Two bacterial indicators are used in the state's marine waters: (1) in waters protected for both primary contact recreation and shellfish harvesting, FC bacteria are used as indicator bacteria to gauge the risk of waterborne diseases and (2) in water protected only for secondary contact, enterococci bacteria are used as the indicator bacteria.

The presence of these bacteria in the water indicates the presence of waste from humans 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.

To protect *Shellfish Harvesting* and *Primary Contact Recreation* (swimming or water play): *"Fecal coliform organism levels must not exceed a geometric mean value of 14 colonies/100 mL, with not more than 10% of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 43 colonies/100mL"* [WAC 173-201A-210(3)(b), 2003 edition].

The criterion level set to protect shellfish harvesting and primary contact recreation is consistent with federal shellfish sanitation rules. Fecal coliform concentrations in our marine waters that meet shellfish protection requirements also meet the federal recommendations for protecting people who engage in primary water contact activities. Thus the same criterion is used to protect both "shellfish harvesting" and "primary contact" uses in Washington State standards.

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 must be used in combination to ensure that the bacterial pollution in a waterbody will be maintained at levels that will not cause a greater risk to human health. While some discretion exists for selecting sample averaging periods, compliance will be evaluated for both monthly (if five or more samples exist) and seasonal (for example, dry-season versus wet-season) data sets.

Once the concentration of FC in the water reaches the numeric criterion, human activities that would increase the concentration above that criterion are not allowed. If the criterion is exceeded, the state will require that human activities be conducted in a manner that will bring bacteria concentrations back into compliance with the standards.

If natural levels of bacteria (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 (particularly those that are managed by humans and thus exposed to human-derived pathogens as well as those of animal origin) are a common source of serious waterborne illness for humans.

This page is purposely left blank

Watershed Description

Samish Bay

Towns and communities in the Samish Bay watershed are generally low density. These include Edison and Bow in the Edison Slough drainage area; Allen on the lower Samish River; Blanchard near Colony Creek; north Sedro Woolley in the upper Thomas Creek area; Alger and developments around Cain, Reed, and Samish Lakes in the upper Friday Creek subbasin; and Thornwood, Wickersham, and Doran in the upper Samish River watershed (Figure 1).

Samish Bay contains important habitat for many marine species and juvenile anadromous (sea-run) fish. The bay and surrounding valley also provide valuable wintering ground for many raptors and waterfowl. Activities in the area include fishing, shellfish harvesting, bird watching, duck hunting, windsurfing, kite boarding, kayaking, hang gliding, parasailing, hiking, horseback riding, and boating.

Of Samish Bay's 340 miles of tributary streams, approximately 100 miles are used by anadromous fish species including fall chinook, coho, chum, sockeye, winter steelhead, smelt, and sea-run cutthroat trout. Resident species include cutthroat and eastern brook trout, kokanee, mountain whitefish, pike minnow, pea-mouthed chub, and sculpin (Skagit Stream Team, 2004).

Much of the lower Samish Valley, including Samish Bay and the Samish River, has been diked and drained to limit the potential for flooding and to open land for farming and agriculture. The communities of Edison, Bow, and Blanchard, and the lower Samish River and Edison Slough, lie on land that was historically covered by tidally influenced wetlands and is only a few feet above sea level. An extensive system of drainage ditches and sloughs with tidegates and pumps is now in place, keeping the valley relatively dry.

The Washington State Department of Health (DOH), and Skagit County Public Works, and other governing agencies and organizations have documented high fecal coliform concentrations in the Samish Bay watershed. Outbreaks of gastroenteritis led to restrictions of shellfish beds in 1994 and 2004. A new community on–site septic system in Edison, and repaired or replaced individual systems in Blanchard, lowered FC concentrations enough for parts of the shellfish beds to be upgraded in 2001. Recent FC monitoring has shown high levels of FC throughout much of the watershed.

The water quality characteristics of the streams and drainages are influenced by the various uses of the water, along with wastewater additions and runoff from adjacent land. Most of the Samish Valley drainages and waterbodies have been monitored and have FC bacteria concentrations that do not meet state or federal water quality standards. These reaches were included on Washington State's 2004 303(d) list (Table 3).

Samish River and tributaries

The Samish River watershed drains 123 square miles and covers parts of Skagit and Whatcom Counties (Figure 1). The watershed consists of three major subbasins: the Samish River (62%), Friday Creek (30%), and Thomas Creek (8%) (Palmer et al., 1996). Eighty percent of the upper Samish Basin is dominated by forests, and about 10% is used for commercial agriculture. There are also many small hobby and subsistence farms. The mainstem Samish River runs along a low gradient valley, but many small tributaries flow into the main channel from surrounding steep slopes.

Forests dominate the Friday Creek subbasin. Alger and Samish, Cain, and Reed Lakes have some concentrated developments. The Lake Samish area is partly sewered. Interstate 5 and state highways 9 and 11 run nearly the entire length of the basin. Small farms are scattered throughout the basin as well.

Commercial agriculture comprises about 35% of the Thomas Creek subbasin, and forests cover about 40%. A 200-acre golf course and parts of north Sedro Woolley are also located in the Thomas Creek subbasin. Lower Thomas Creek is low gradient with extensive diking and channelization (Palmer et al., 1996).

About 75% of the lower Samish River basin is used for agriculture, including dairy and cattle operations. The mainstem Samish River is extensively channelized and diked.

Shellfish

About 1,100 acres of Samish Bay's tide flats are currently farmed for the commercial production of shellfish, primarily Pacific oysters, Manila clams, mussels, and geoduck. The county park on Samish Island and Larrabee State Park on the very northern end of Samish Bay are the only places where there is public access for recreational shellfish harvesting (Lennartson, 2005). Along the shores of Samish Island, there is also significant recreational shellfish harvesting by upland owners of adjacent tidelands. Government Bar in the middle of Samish Bay, while largely privately owned by Taylor Shellfish, has not been farmed in recent years. The bar is popular with locals who harvest geoduck, horse, butter, and cockle clams there. Recreational shellfish harvesting also occurs in the southern portion of the bay where tidelands are owned by duck hunting clubs and other private landowners.

In 2004, Samish Bay shellfish companies grossed over 3.25 million dollars and employed the equivalent of 36 full-time workers, paying them over 1.13 million dollars in wages. Retail stores, restaurants, and festivals and other public events also depend on shellfish resources. In addition, the bay supports natural populations of crab and other shellfish important to the area.

DOH monitors water quality in Samish Bay near shellfish beds and classifies these areas as approved, conditionally approved, restricted, or prohibited. Figure 2 shows the current classifications in Samish Bay. DOH also certifies commercial operators to ensure they adhere to the National Shellfish Sanitation Program guidelines.

The two largest commercial shellfish beds belong to Taylor Shellfish Farms and Blau Oyster Company; Acme is the third largest. A few one-person operations exist, but are largely inactive.

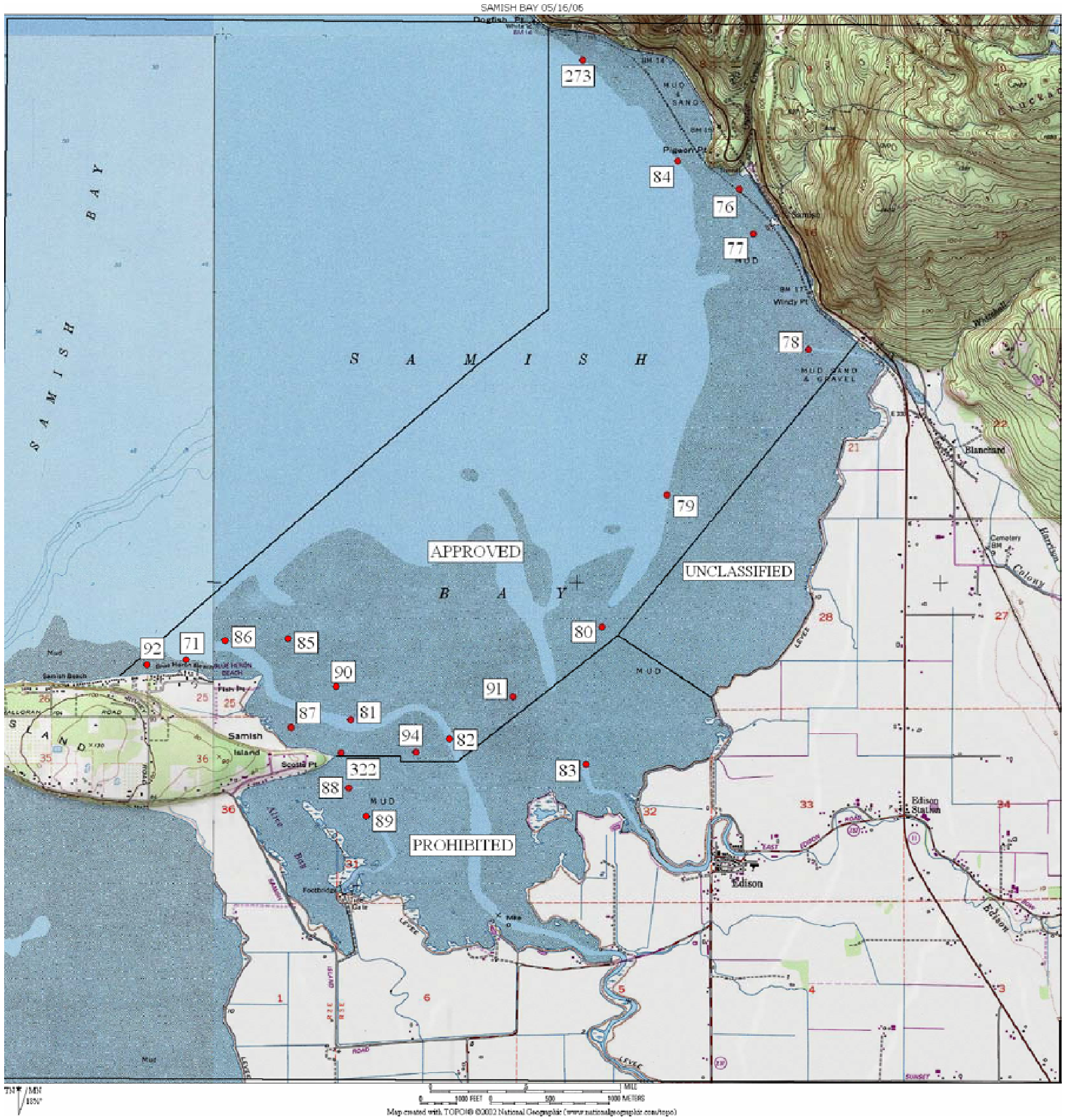


Figure 2. Washington State Department of Health classifications for harvesting shellfish in Samish Bay (DOH, 2005). DOH FC sampling sites are also shown.

This study area is in Water Resource Inventory Area (WRIA) 03.

Potential sources of bacteria

Permit holders

Fecal coliform (FC) bacteria can be present in a wide variety of municipal and industrial wastewater and stormwater sources. The disinfection methods used by these sources are not 100% effective at removing FC all of the time, so FC bacteria can enter the receiving waters from these sources. Fecal coliform bacteria and other potential contaminants from industrial and municipal sources are regulated by various individual and general NPDES permits from Ecology.

Virtually all homes in the unincorporated community of Edison, including the Edison elementary school, discharge to a wastewater collection system built in 1996. Wastewater is treated biologically in a recirculating gravel filter, followed by post-treatment ultraviolet disinfection. Treated and disinfected wastewater is discharged below ground via infiltrating trenches located approximately 750 feet south of, and not tributary to, Edison Slough. The Washington State Department of Health is responsible for issuing the ground discharge permit. Skagit County will be the permit holder (Ziebart, 2008).

The Samish Bay watershed has a number of dairies and commercial livestock operations as well as small non-commercial farms. Most of these are non-permitted facilities; however, all Class A dairies are required to operate in accordance with the state Dairy Nutrient Management Act. These dairies are inspected periodically by the Washington State Department of Agriculture (WSDA). New Concentrated Animal Feeding Operations (CAFO) regulations are under development and will be administered by WSDA. The only active CAFO in the Samish Bay watershed is Dynes Egg Processor (permit to be issued soon). Dairy and livestock operations with water quality impacts are subject to review for compliance with the county's Critical Area Ordinance for ongoing agricultural activities (Skagit County Code 14.24.120).

The Friday Creek fish hatchery is regulated by an Upland Fin-Fish Hatching and Rearing General NPDES permit issued by Ecology. The hatchery is likely not a significant contributor of FC to Friday Creek since fish are cold-blooded, but birds attracted by small fish may contribute small amounts of FC to the area at times.

Several gravel pits are located near the confluences of Swede and Thomas Creeks and the Samish River, but likely do not contribute FC to these streams. Gravel pit operations are regulated by a Sand and Gravel General Permit issued by Ecology.

The two shellfish processing plants on the shores of Samish Bay have NPDES permits for discharged water used to wash their oysters and clams. Taylor Shellfish had problems recently with FC bacteria levels in their wastewater discharge. The source was traced to gulls perching on the building peak and subsequent rain events washing the gull feces onto the concrete pads, which drain with the process water. The problem was resolved by stringing wire on the building peak to prevent gulls from perching.

Wildlife and background sources

Migratory and other birds are often seen in fields and in the bay itself. Birds, elk, deer, beaver, muskrat, and other wildlife in the headwater and rural valley areas are potential sources of FC bacteria. The open fields and areas where corn is grown to attract birds for hunting become feeding grounds for some birds whose presence can increase FC counts in runoff.

Usually these sources are dispersed and do not elevate FC counts over Washington State criteria. However, sometimes animals are locally concentrated and can cause elevated counts.

Nonpoint sources

Agriculture

Nonpoint sources of pollution are dispersed and not controlled by discharge permits. Several types of potential nonpoint sources are present in the study area. Range and pastured livestock with direct access to streams can be a source of FC contamination. Poor livestock or pet manure management is another source, if stormwater can wash contaminants into receiving waters.

Fecal coliform bacteria from nonpoint sources are transported to the creeks by direct and indirect means. Manure that is spread over fields during certain times of the year can enter streams via surface runoff or fluctuating water levels. Also, often livestock have direct access to water. Manure is deposited in the riparian area of the access points where fluctuating water levels, surface runoff, or constant trampling can bring the manure into the water. Swales, sub-surface drains, and flooding through pastures and near homes can carry FC bacteria from sources to waterways.

Septic systems

Malfunctioning or inadequate on-site sewage systems can release FC bacteria into waterways. The older residences in Blanchard and Edison were documented to have wastewater piped directly to adjacent waterways prior to repairs in 1994 and 1995 (Dewey, 2005). Other residences in the watershed with improperly maintained septic systems may be a source of FC bacteria to Samish Bay as well, including several boats used as homes at the mouth of the Samish River.

Recreation

Recreational opportunities in the Samish watershed are extensive. Duck hunting, fishing, shellfish harvesting, birding, boating, hang gliding, horseback riding, windsurfing, kite boarding, and parasailing are all common in the area. Unfortunately there are few toilet facilities for public usage. As such, human feces may be disposed of inappropriately, potentially entering Samish waters.

To partially address this risk, the shellfish industry has sponsored a portable toilet each year during the fall chinook salmon run near the mouth of the Samish River. The Skagit Conservation Education Alliance has a *Sanican Timeshare* program which is attempting to place more portable toilets at critical recreational access points (Dewey, 2005).

Other nonpoint sources

Road runoff, pet waste, and other nonpoint sources can potentially add FC bacteria to the waters flowing to Samish Bay as well.

Goals and Objectives

The results of this 2006-07 TMDL study will help Ecology and interested parties focus efforts on prioritizing pollution sources within the Samish Bay watershed study area. The goals of the TMDL are:

- Collect high quality FC data that promote confidence in the TMDL process.
- Increase public awareness on the level of FC bacteria reductions required and why.
- Manage resources to control nonpoint pollution.
- Attain Washington State water quality standards for FC bacteria.

Objectives of the study are:

- Identify and characterize FC bacteria concentrations and loads from all tributaries, point sources, and drainages into Samish Bay under various seasonal or hydrological conditions, including stormwater contributions.
- Recommend FC load and wasteload allocations to protect beneficial uses, including primary and secondary contact recreation, and shellfish harvesting.
- Identify relative contributions of FC loading to the bay so cleanup activities can focus on the largest sources.
- Identify FC loading capacities of streams and sloughs in the study area.

This page is purposely left blank

Study Methods

The Quality Assurance (QA) Project Plan (Swanson, 2006) for this study describes procedures used to collect and analyze field parameters and laboratory samples. Sampling site locations are shown in Figure 1 and described in Table 1 and Table 2.

Monitored field parameters included:

- Temperature
- Conductivity
- Dissolved oxygen

Laboratory parameters included:

- Fecal coliform bacteria using the membrane filter (MF) and most probable number (MPN) methods
- *E. coli* (EC)
- Percent *Klebsiella*, *Enterobacter,* and *Serratia* (%KES)
- Turbidity

Thirty-three fixed sites in the Samish Bay watershed were sampled for FC bacteria twice monthly from February 2006 through February 2007 (Table 1). Several sampling sites were added when necessary to investigate possible sources of FC bacteria (Table 2).

Bacteria grab samples were collected directly into pre-cleaned containers supplied by the laboratory and described in the Manchester Environmental Laboratory (MEL) User's Manual (MEL, 2005).

Samples were collected from the stream thalweg (center of flow) whenever possible. Samples taken in freshwaters were collected at approximately six inches below the surface of the water, with the sampler standing downstream from the collection point. Caution was exercised not to stir up sediment in streams with slow current velocities or shallow channels. In stratified sloughs, drainages, and at mouths of streams, conductivity samples were taken at two to three depths in the water column.

Each bacteria sample was labeled, transferred to a cooler as soon as possible, placed in crushed or cube ice, and kept at greater than 0°C and no more than 4°C until the sample coolers were opened by the laboratory.

Laboratory analyses for FC bacteria were performed in accordance with MEL protocols. All samples were analyzed using the MF method, and several were analyzed using the MPN method for comparison purposes. The QA Project Plan for this project describes measurement quality objectives (MQOs) for this project.

All laboratory results, including case narratives, numerical results, and data qualifiers, were reported to the project manager. Field and laboratory data were compiled and organized using Microsoft Excel® spreadsheet software as the primary project data management system. Data verification, validation, and QA evaluation were performed by staff before final data entry into the Ecology's Environmental Information Management (EIM) database.

Statistical calculations were made using Microsoft Excel® software. Data analysis in this report is limited to the evaluation of FC bacteria.

Only one storm event was captured that met criteria set forth in the QA Project Plan. This storm event will help to better characterize potential sources of FC loading to the bay. Other rain events occurred during the study that will also help characterize FC loading that did not meet QA Project Plan criteria.

The QA Project Plan (Swanson, 2006) stated that a time-of-travel study may be performed during the course of the project. Since the simple mass balance calculations and subsequent derivation of target values in freshwater assumed no FC die-off, a time-of-travel study was deemed unnecessary.

The Samish Bay watershed was sampled over the course of two days during each survey. The lower Samish River and all sloughs and creeks flowing to Samish Bay were sampled on "day 1," and the upper Samish River and its tributaries were sampled on "day 2." To link conditions in the upper watershed to the lower watershed, the Samish River at river mile 04.6 (Thomas Rd.) was sampled both days. A t-test was performed on FC data from 03-SAM-04.6 to determine if data from day 1 and day 2 were significantly different. No significant difference was found ($p<0.05$), so FC data from both days were averaged to calculate the site's geometric mean, 90th percentile, and loading.

A t-test was performed on FC data from ALI-GATE (tidegates to Alice Bay) and ALI-PUMP (pump station to Alice Bay) to evaluate differences in FC concentrations over the period they were both sampled (February through August 2006). No significant difference was found ($p<0.05$) between data from the two sites. ALI-PUMP's results were used to calculate loading and necessary load reductions. It was easier to sample and had a more complete dataset. Both ALI-GATE and ALI-PUMP flows were averaged to calculate total discharge to the bay from the slough.

Streamflows

Tidegates

Because of widely varying tidal and hydrological patterns in the bay, streams, and drainages, FC loads at tidally influenced sites were calculated using the average discharge over a four-month period of similar flow conditions.

From February 2006 to February 2007, the three flow "seasons" in the Samish Basin were:

- November 1 to February 28 (high flows)
- March 1 to June 30 (medium flows)
- July 1 to October 31 (low flows)

Special streamflow surveys were conducted in addition to regular sampling surveys. All Samish Bay tidegates were surveyed during high-flow (February 2007) and low-flow (October 2006) conditions to help determine the tide height they opened and closed. Flows were measured one to three times over the course of each gate's discharge period and averaged (if more than one flow was measured). The results for each four-month period were then multiplied by the total time the gates were open and discharging to the bay, then divided by the number of days in each period to get average daily flow (cfs) for each low-, medium-, and high-flow periods.

Pump stations

Discharge was measured and calculated at all pump station outlets using a full-pipe flow calculator if the pipe was full or an on-line open channel calculator if the pipe was partially full (Marsh McBirney, 2008). Since the pumps discharged at a consistent rate during all seasons, discharge was measured only once at each pump station. Notes taken during pump station and tidegate surveys allowed Ecology to determine approximately what percentage of the time the pumps were on or off. The resulting averaged discharge (cfs) was added to the tidegate flow if a tidegate was present. Small adjustments were made if any contrary evidence or data were recorded during the regular sampling surveys. Finally, FC loading was calculated for each site and day that bacteria was sampled, using the averaged cfs value.

Upstream sites

Streamflows for non-tidally influenced sites were measured per Ecology protocols (Ecology, 1993) using a flowmeter and wading rod. When flows could not be taken, staff gage numbers were recorded and regression was used to calculate streamflow. If staff gages were not available or an appropriate rating curve was not developed, sites were regressed with a similar site where flow was taken. Results were marked as estimates.

Sites that recorded streamflow every 15 minutes throughout the course of the project included Ecology stream gaging stations at:

- Silver Creek near the mouth
- Friday Creek near the mouth
- Samish River miles 15 and 26.6

The U.S. Geological Survey (USGS) gaging station was at Samish River mile 10.3 (Hwy 99).

Data analysis methods

The Statistical Rollback Method (Ott, 1997) was used to determine if fecal coliform distribution statistics for individual sites met the water quality criteria in the Samish Bay watershed. The method has been applied by Ecology in other FC bacteria TMDL evaluations (Cusimano and Giglio, 1995; Pelletier and Seiders, 2000; Joy, 2000; Coots, 2002: and Joy and Swanson, 2005).

The method is applied as follows:

The geometric mean (approximately the median in a log-normal distribution) and 90th percentile statistics are calculated and compared to the FC criteria. If one or both do not meet the criteria, the whole distribution is "rolled-back" to match the most restrictive of the two criteria. The 90th percentile criterion usually is the most restrictive.

The rolled-back geometric mean or 90th percentile FC value then becomes the recommended "target" FC value for the site. (The term "target" is used to distinguish these estimated numbers from the actual water quality criteria). The amount a distribution of FC counts is "rolled-back" to the target value is stated as the estimated percent of FC reduction required to meet the FC water quality criteria and *Contact Recreation* water quality standards. For more details of the statistical rollback method, see Appendix B.

The geometric mean and 90th percentile statistics for various subsets of data were calculated and compared to determine a critical season at each site and to calculate the target TMDL values.

The FC TMDL targets are only in place to assist water quality managers in assessing the progress toward compliance with the FC water quality criteria. Compliance is measured as meeting water quality criteria. Any waterbody with FC TMDL targets is expected to (1) meet both the applicable geometric mean and "not more than 10% of the samples" criteria, and (2) protect beneficial uses for the category.

Long-term trend analyses for data collected by Ecology's ambient river monitoring program at Samish River mile 10.3 was performed using WQHydro, a statistical software package for environmental data analysis (Aroner, 2003). This station has been monitored from 1959 to the present.

Study Quality Assurance Evaluation

Streamflow measurements and membrane filtered fecal coliform (FCMF) and conductivity samples met the quality criteria outlined in the QA Project Plan (Swanson, 2006) and are of adequate quality to use in the TMDL analysis. Temperature, dissolved oxygen, and turbidity measurements (Appendix D) also met quality criteria but were not analyzed in this TMDL.

Laboratory duplicates

Duplicate laboratory analysis refers to analyzing duplicate aliquots from a single sample container. The results for laboratory duplicates provide an estimate of analytical precision, including the homogeneity of the sample matrix (MEL, 2005).

The measurement quality objective (MQO) used by MEL for membrane filtered bacteria duplicates is 40% relative percent difference (RPD). For turbidity, the MQO is 20% RPD.

Each parameter's RPD met the MQOs for lab duplicates, except membrane filtered *E. coli* (ECMF) and percent *Klebsiella*, *Enterobacter,* and *Serratia* (%KES) (Table 5). Fecal coliform samples, analyzed using the most probable number method (FCMPN), were not duplicated at MEL.

Table 5. Duplicate laboratory sample statistics.

Parameter	Average %RSD	Average RPD	MQO precision standard (RPD)	Number of duplicates taken	Total # of samples less duplicates	Total # of samples including duplicates	Percent of total samples duplicated
FCMF	24.6	34.9	40	89	1100	1189	8
ECMF	36.9	52.2	40	7	50	57	14
%KES	20.2	28.6	40	7	36	43	19
Turbidity	1.3	1.9	20	10	135	145	7

Field replicates

Field replicate samples are two samples collected from the same location at the same time and submitted to MEL as blind pairs (no identification provided). Collecting field replicates is a method of looking at the precision of the entire process of sampling and analysis. Differences between the results of replicate samples can arise from variations in the sample location, collection process, sample containers, and/or analytical procedures (MEL, 2005).

The QA Project Plan for this study set a 30% relative standard deviation (RSD) precision target for all replicated membrane-filtered bacteria samples (Swanson, 2006). Table 6 shows that these targets were met.

Ecology's new MQO for analyzing precision in replicated FC samples requires that at least 50% of the samples be below a 20% RSD and that at least 90% of the samples be below a RSD of 50% (Mathieu, 2006). The RSD is defined as the percent standard deviation divided by the mean or percent coefficient of variation for the replicated QA samples. None of the samples used to assess the MQO should have a mean concentration of 20 cfu/100 mL or less.

Ecology collected 200 membrane-filtered fecal coliform (FCMF) replicates in 2006 and 2007 for the Samish Bay TMDL project. Of the 158 FCMF samples with a mean concentration above 20 cfu/100 mL, 69% of the replicate pairs were below 20% RSD and 100% were below 50% RSD (Table 6). Membrane filtered FC samples met Ecology's MQO QA precision criteria.

Table 6. Replicate field sample statistics.

<table>
<tr><th>Parameter</th><th>Average percent RSD</th><th>MQO Precision Standard</th><th>Meets MQO criteria?</th><th>Number of replicates taken</th><th>Total # of samples less replicates</th><th>Total # of samples including replicates</th><th>Percent of total samples replicated</th></tr>
<tr><td>FCMF <20 cfu/100 mL</td><td>23.2</td><td>NA</td><td>NA</td><td>42</td><td>900</td><td>942</td><td rowspan="2">22</td></tr>
<tr><td>FCMF >20 cfu/100 mL</td><td>16.8</td><td>at least 50% of rep. samples must be <20% RSD and 90% <50% RSD</td><td>Yes</td><td>158</td><td>900</td><td>1058</td></tr>
<tr><td>FCMPN</td><td>46.4</td><td>40% RSD</td><td>No</td><td>7</td><td>42</td><td>49</td><td>17</td></tr>
<tr><td>ECMF</td><td>18.1</td><td>30% RSD</td><td>Yes</td><td>9</td><td>41</td><td>50</td><td>22</td></tr>
<tr><td>%KES</td><td>37.4</td><td>30% RSD</td><td>No</td><td>6</td><td>30</td><td>36</td><td>20</td></tr>
<tr><td>Turbidity</td><td>2.9</td><td>15% RSD</td><td>Yes</td><td>13</td><td>132</td><td>145</td><td>10</td></tr>
</table>

E. coli and turbidity samples met Ecology's MQO QA precision criteria (Table 6).

Fecal coliform samples analyzed using the MPN method and percent KES samples did not meet Ecology's MQO QA precision criteria (Table 6).

Fecal coliform samples analyzed using the MPN method, percent KES, and *E. coli* bacteria samples were used as appropriate to help further characterize sources of fecal matter, identify problem areas, and in some cases, compare FCMF and FCMPN data. They were not used to calculate TMDL allocations.

Results and Discussion

All bacteria data collected during the 2006-07 monitoring period are in Appendix C, Tables C-1 to C-3. Conductivity, temperature, dissolved oxygen, turbidity, and flow data are in Appendix D. Station locations are described in Table 1 and Table 2 and shown in Figure 1.

Table 7 shows the geometric mean and 90th percentile for all data collected at each station. The 90th percentiles for stations with less than five samples were not estimated. November 6 and 7, 2006 storm-event results were not included in the data used to calculate geometric means, 90^{th} percentiles, or necessary load reductions. The Samish Basin experienced much higher than average rainfall during this time, and the data do not reflect typical rain-event conditions.

Data for this project are also available at Ecology's (EIM) website at www.ecy.wa.gov/eim/index.htm. Search User Study ID, TSWA0001.

Table 7. Summary statistics for FC bacteria (cfu/100 mL) at regularly sampled sites in the Samish Bay watershed during the 2006-07 TMDL study. Storm event data were not included in the analysis. Shaded cells indicate sites where freshwater standards were not met.

Field ID w/ River Mile	map #	Site Location	n	Min	Max	Geo-metric mean	90th percentile
Samish River							
03-SAM-00.7	1	At Bayview/ Edison Rd	25	2	220	35	156
03-SAM-04.6	2	Thomas Rd (average of both days)	25	6	385	56	243
03-SAM-06.5	3	Chuckanut Dr	25	11	330	65	226
03-SAM-10.3	4	Hwy 99	24	4	510	62	322
03-SAM-13.1	5	F&S Grade Rd	24	6	410	58	277
03-SAM-15.0	6	2nd Prairie Rd crossing from Hwy 99	24	5	950	34	177
03-SAM-16.5	7	Off Prairie Rd upstream of Parson Ck	24	3	650	30	154
03-SAM-20.7	8	3rd Prairie Rd crossing from Hwy 99	24	1	560	13	114
03-SAM-22.0	9	Hwy 9	24	1	800	11	103
03-SAM-26.6	10	Wickersham Rd	24	1	210	10	92
03-SAM-28.8	11	Innis Ck Rd (in Doran)	24	7	3000	149	1604
Samish River Tributaries							
03-ENN-00.0	12	Ennis Ck at mouth, Wickersham Rd	21	1	470	5	80
03-FRI-00.8	13	Friday Ck at Bow Hill / Prairie Rd (below Hatchery)	24	4	840	39	283
03-FRI-03.8	14	Friday Ck at Friday Ck Rd	24	4	1400	34	257
03-FRI-06.5	15	Friday Ck at Lake Samish Rd / Alger Cain Lk Rd	24	1	130	11	82
03-PAR-00.0	16	Parson Ck at confluence Samish R	24	1	3200	105	2839
03-SIL-00.4	17	Silver Creek at Friday Ck Rd	24	2	620	11	59
03-SWE-00.0	18	Swede Ck at Grip Rd	24	9	1200	75	441
03-THO-00.3	19	Thomas Ck at Old Hwy 99	24	8	1800	96	488
03-THO-03.6	20	Thomas Ck off F&S Grade Rd abv. Willard Ck confluence	24	22	5700	399	3105
03-WIL-00.0	21	Willard Ck off F&S Grade Rd abv. Thomas Ck confluence	17	13	15000	234	2327
03-SKA-00.5	34	Skarrup Creek at first road crossing	17	22	2400	170	750
Samish Bay Tributaries							
03-COL-00.0	22	Colony Ck near mouth, upstream of tidegates	25	6	310	52	189
03-ALI-PUMP	23	Drainage to Alice Bay	25	1	170	16	127
03-NED-PUMP	24	N Edison drainage at Key Ave., off Smith Rd	24	1	330	109	330
03-SED-PUMP	25	S Edison drainage near liquor store	21	32	2400	167	601
03-BAY-GATE	26	Drainage west of Samish River mouth, to Samish Bay	25	5	810	52	342
03-ALI-GATE	27	Drainage to Alice Bay	12	3	230	21	96
03-MCE-GATE	28	Tidegate to McElroy/Colony Slough	25	1	970	65	542
03-WED-GATE	29	W Edison drainage near Edison Slough mouth	15	1	610	41	428
03-SMI-GATE	30	Drainage to Edison Slough at Smith Rd nr. NED-PUMP	4	3	400	too few samples	
03-EDI-01.2	31	Edison Slough just upstream of tidegates in Edison	24	5	830	30	188
03-EDI-01.6	32	Edison Slough at private drive upstream of school	25	1	870	24	222
03-OYS-00.0	33	Oyster Ck near mouth	25	1	50	4	23

Samish River

Mainstem Samish River fecal coliform concentrations were highest at river mile (RM) 28.8 and lowest at RM 26.6, probably due to wetland attenuation, bacteria die-off, and dilution from groundwater between these sites (Figure 3). Geometric mean FC concentrations increased downstream from RM 26.6 to RM 6.5, and then decreased slightly downstream to RM 00.7 near the mouth of the river. Some bacteria die-off may have occurred at RM 0.7 due to salty bay water mixing with river water during high tides.

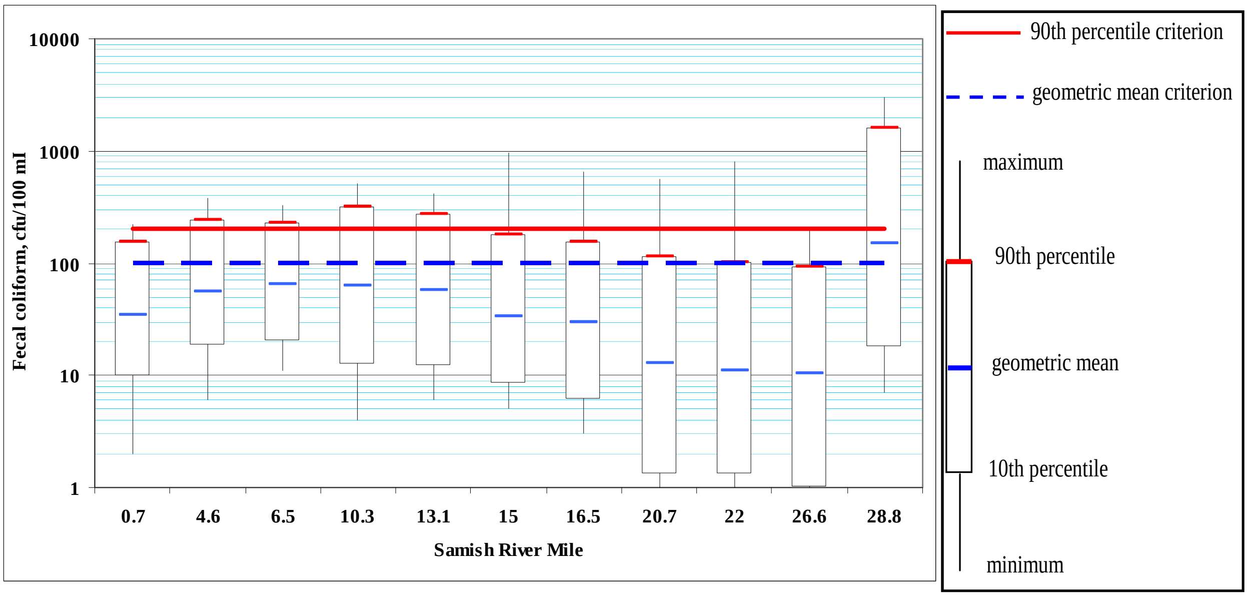


Figure 3. Samish River longitudinal FC concentration profile from data collected during the 2006-07 TMDL study. All sites were sampled 24 to 25 times.

The largest percent increase in geometric mean FC concentrations occurred between RMs 20.7 and 16.5 (131%) and RMs 15.0 and 13.1 (71%). Percent increases in 90th percentiles between the same RMs were 35% and 56%, respectively. Swede and Skarrup Creeks enter the river between RMs 15.0 and 13.1. Dry Creek enters the river between RMs 20.7 and 16.5, but is not suspected to contribute to FC problems. River access is restricted between RMs 20.7 and 16.5.

Mainstem FC loading showed similar longitudinal patterns, except loads at RM 28.8 were not the highest in the river because of low streamflow there. Loads were lowest at RM 26.6 and generally increased downstream to RM 10.3 and RM 06.5 (Figure 4). Loads increased the most between RMs 20.7 and 16.5 (281% increase) and RMs 15.0 and 13.1 (61% increase). Figure 4 also shows creeks that enter the Samish River and their corresponding load contributions.

Fecal coliform loads varied by season in the Samish River watershed. November through June was the wet season, and July through October was the dry season. Loads were averaged for each season in Figure 4.

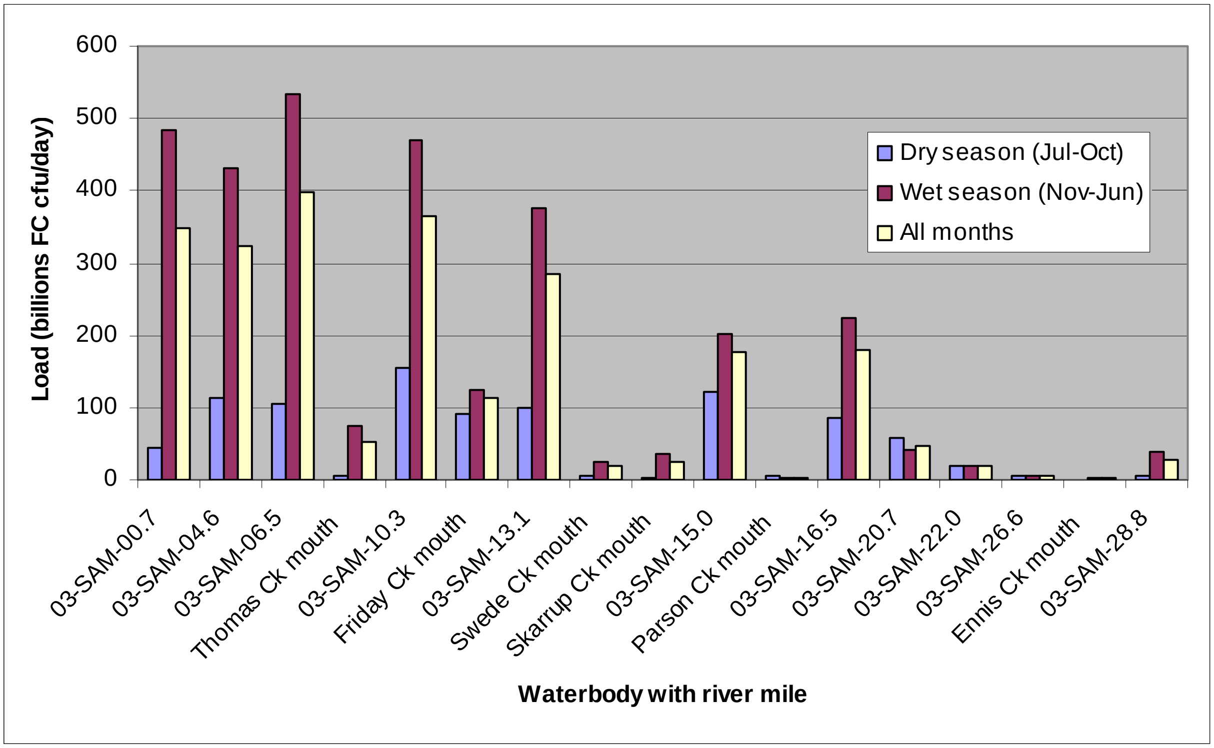


Figure 4. Seasonal longitudinal FC loading profile of the Samish River and tributary mouths.

Average monthly FC concentrations at Samish River mile 0.7 (Bayview/Edison Road) were highest from late spring through early fall, and lowest from late fall through early spring, with the exception of January (Figure 5). Very little rain fell in October 2006.

Loading at the same location shows a slightly different seasonal pattern. The Samish River at RM 0.7 carried higher loads to the bay from November through February, even though concentrations were generally lower during these months (except January) due to higher streamflows. Loads were also higher in May and June because the river was still flowing well and concentrations were high. Figure 6 shows the relationship between flow and loading during the February 2006 through February 2007 TMDL study.

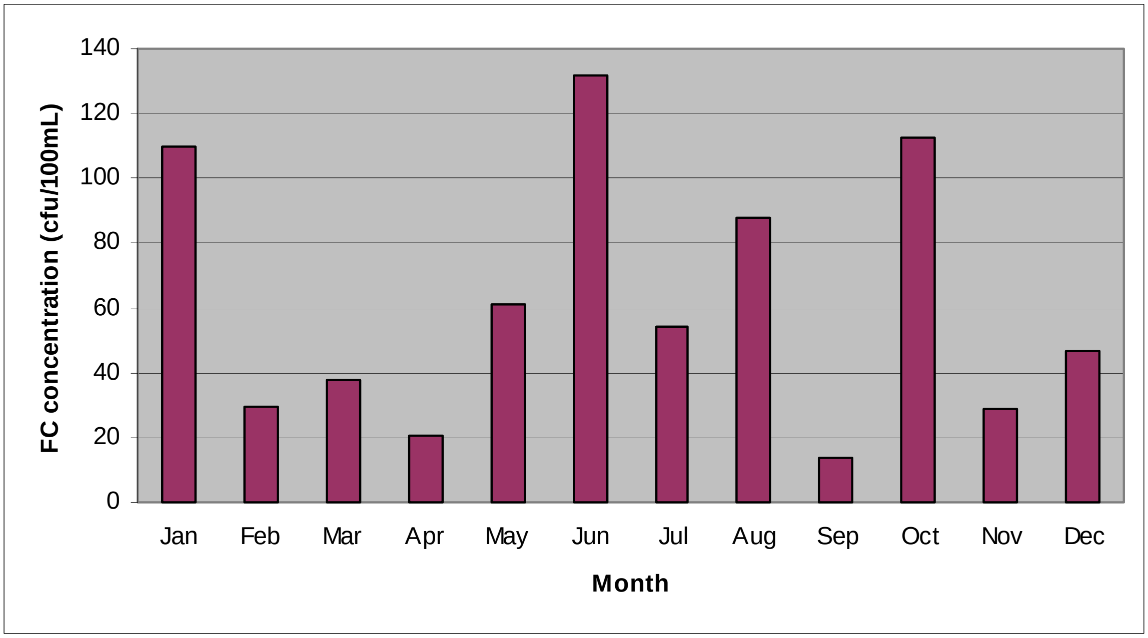


Figure 5. Average monthly FC concentrations at Samish River mile 0.7 (Bayview/Edison Road), 2006-07.

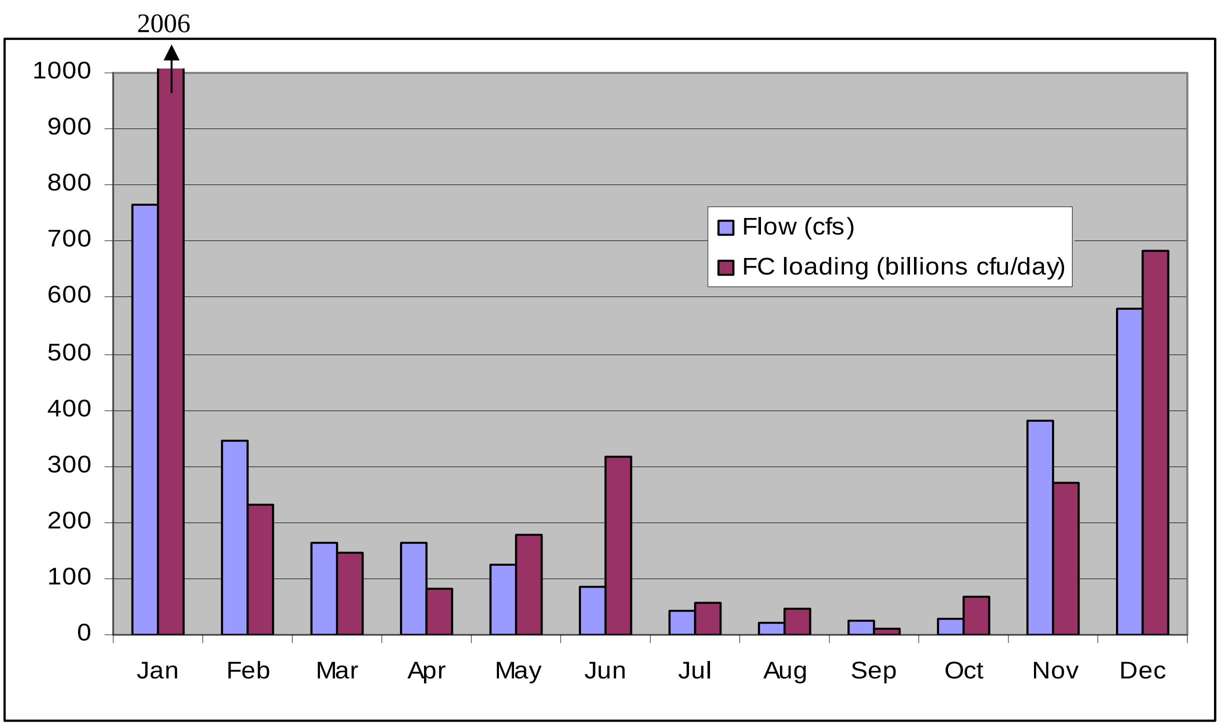


Figure 6. Average monthly loading and flows at Samish River mile 0.7 (Bayview/Edison Road), 2006-07.

Annual trends in the Samish River

Ecology's ambient monitoring station at Samish RM 10.3 has a record of monthly FC and flow data from 1976 to 2008. A Seasonal Kendal trend analysis was performed using WQHydro Software (Aroner, 2003) to determine the historical trend. Results of the trend analysis, provided in Figure 7, have a slope of -1.3 and a significance of 99%. These results indicate a statistically significant decrease in FC bacteria levels over the period of record. To confirm that this decreasing trend was also present in more recent years, the same trend analysis was performed on data collected from 1998 to 2008. Results showed a slope of -1.7 and a significance of 95%, which also indicate decreasing FC bacteria levels during the last ten years.

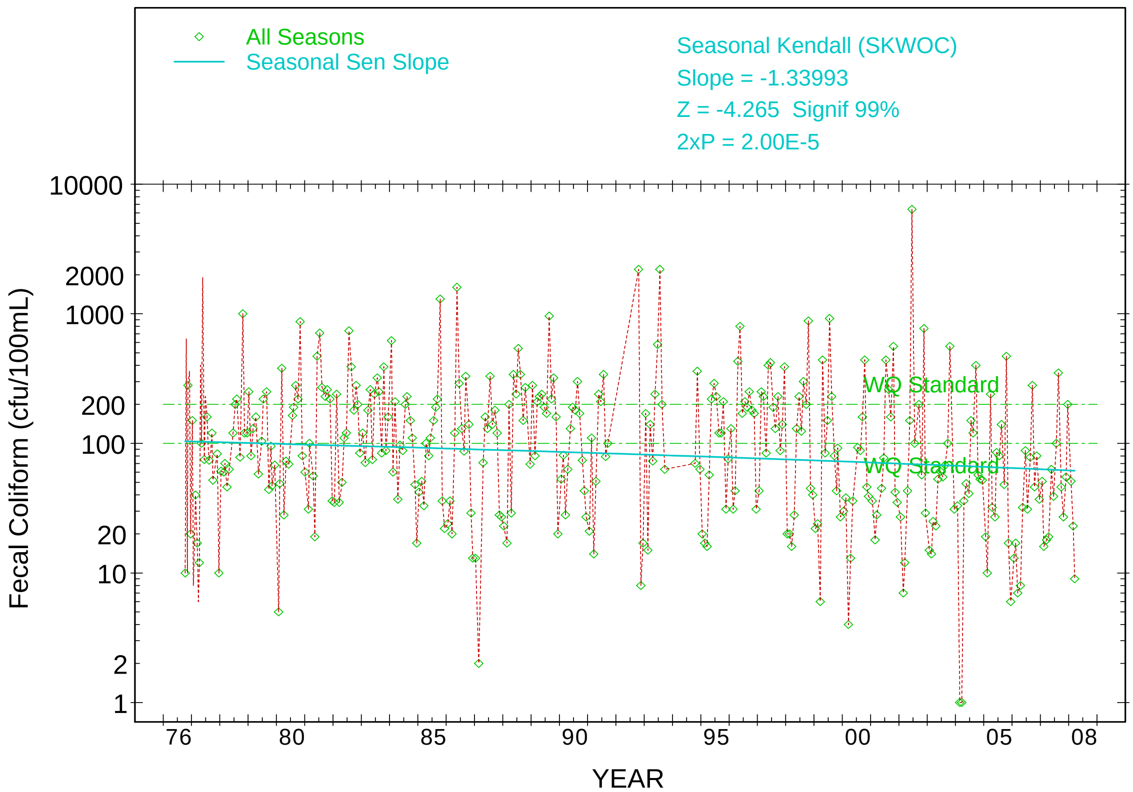


Figure 7. Results of Seasonal Kendall trend test at Samish RM 10.3, 1976 to 2008.

Loading data from the same dataset were also analyzed using WQHydro. Results indicate a statistically significant decrease in FC bacteria loading from 1976 to 2008, with a slope of -4.0 and a significance of 99%. To confirm that this decreasing trend was also present in more recent years, the same trend analysis was performed on data collected from 1998 to 2008. Results showed a slope of -19.3 and a significance of 99%, indicating an even greater decrease in FC bacteria loading during the last ten years.

Friday Creek

Friday Creek FC concentrations and loads increased between RMs 6.5 and 0.8 (Figure 8 and Figure 10). The largest increase in FC concentrations occurred between RMs 6.5 and 3.8.

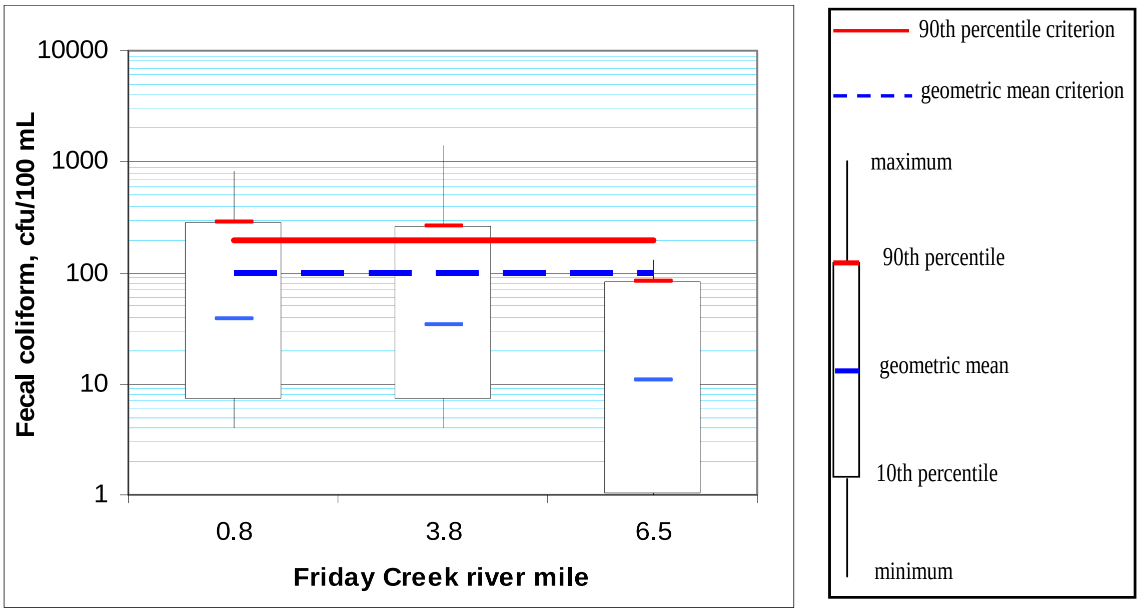


Figure 8. Longitudinal FC concentrations in Friday Creek. All sites were sampled 24 or 25 times.

Data showed higher FC concentrations from June through August (Figure 9). Loading data were similar; however, December results also showed high loading.

Butler Creek, and Friday Creek just above Butler Creek (03-FRI-04.3), were sampled from September 2006 to February 2007. Loading data suggest that sources between 03-FRI-04.3 and 03-FRI-06.5, including Butler Creek, contribute to loading at RM 03.8 (Figure 10). Figure 10 also shows a significant increase in loading between RM 3.8 and RM 0.8, near the mouth of Friday Creek.

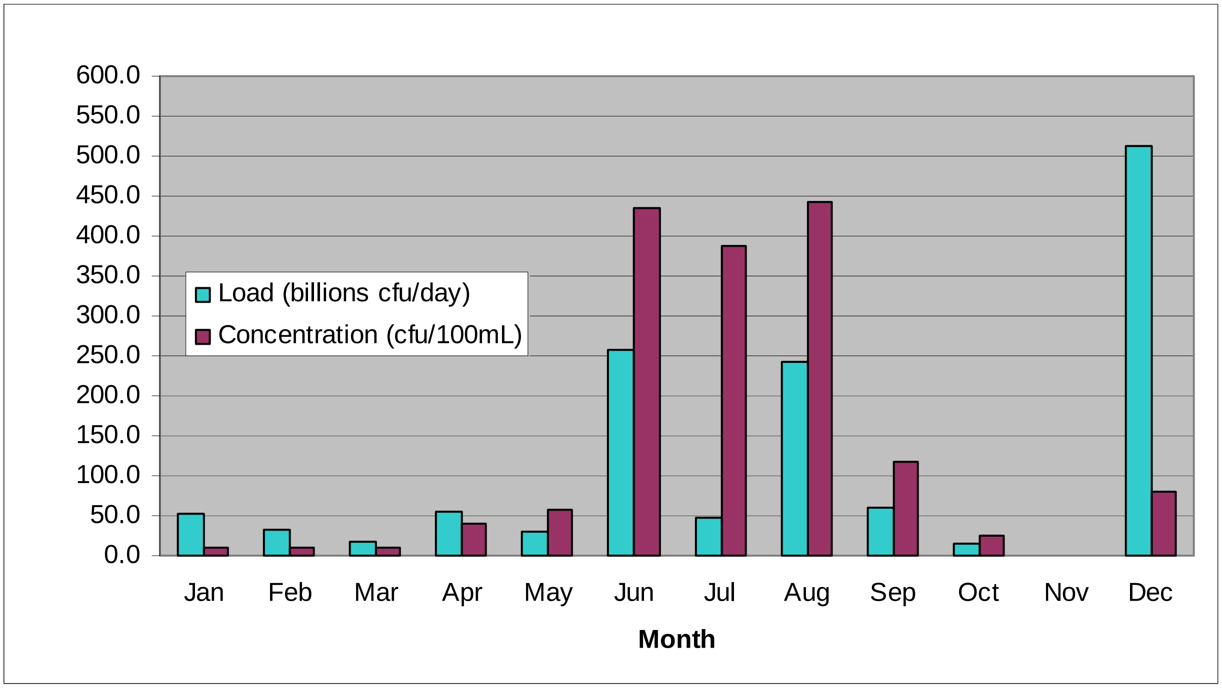


Figure 9. FC concentrations and loads at 03-FRI-00.8 (Friday Creek at Bow Hill/Prairie Rd), 2006-07. No samples were taken in November, except November rain event samples, which are not shown. Bars represent two-sample averages.

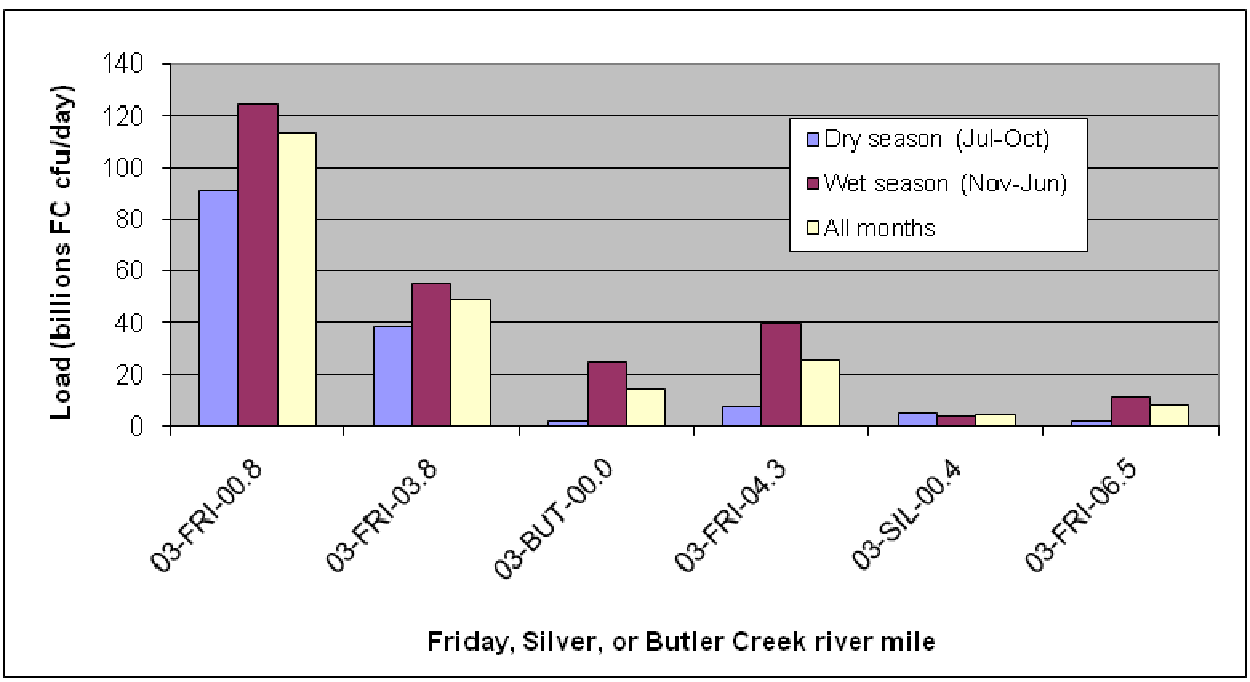


Figure 10. Seasonal longitudinal FC loading profile of Friday Creek and tributary mouths.

Thomas Creek

Thomas Creek FC concentrations and loads decreased from creek mile 3.6 (F&S Grade Road) to creek mile 0.3 (HWY 99) (Figure 11 and Figure 12). There are few inputs downstream of the Willard Creek confluence, especially in the dry season. Groundwater dilution and die-off are likely the primary factors reducing FC concentrations downstream of the F&S Grade Road. The slight loading decrease from RM 3.6 to RM 0.3 is probably due to bacteria die-off in the exposed channel of Thomas Creek.

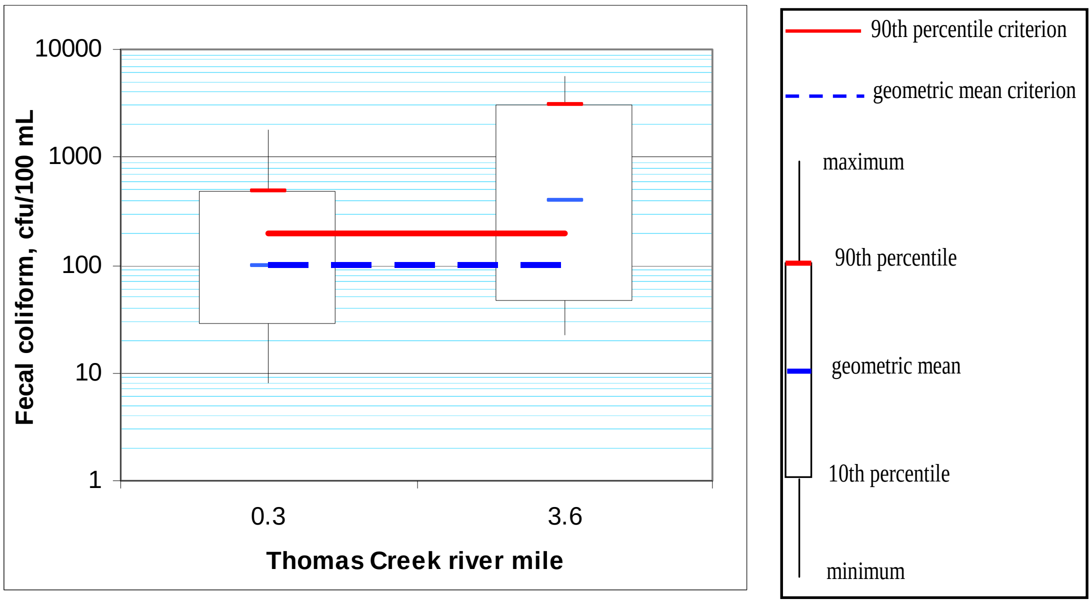


Figure 11. Longitudinal FC concentrations in Thomas Creek. Both sites were sampled 24 times.

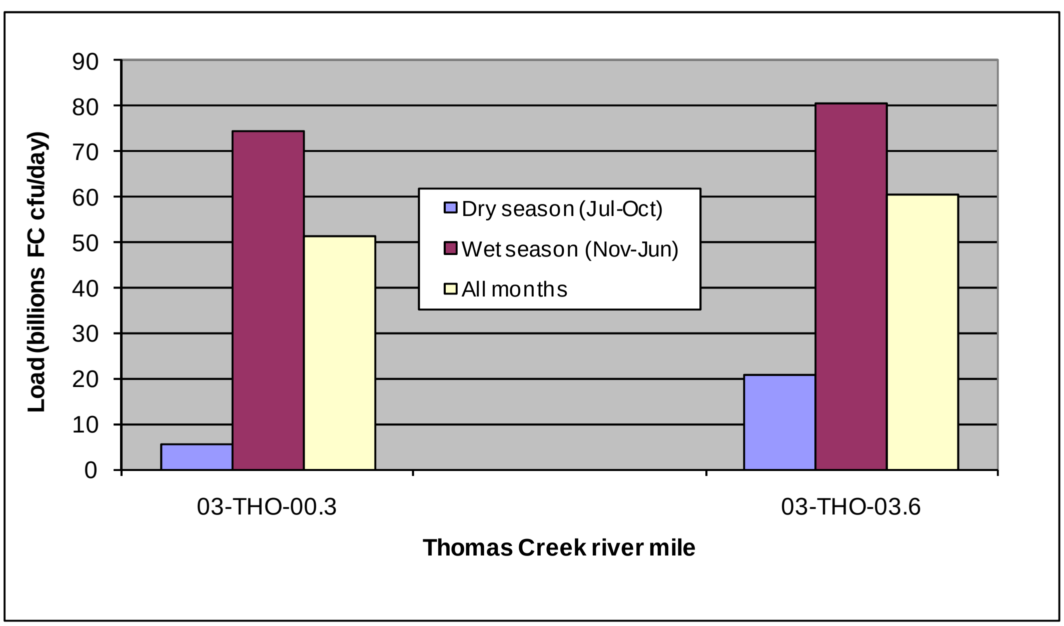


Figure 12. Seasonal longitudinal FC loading profile of Thomas Creek.

Seasonal data showed that higher FC loading generally occurred during the wet months, but higher FC concentrations occurred during the dryer months (Figure 13 and Figure 14).

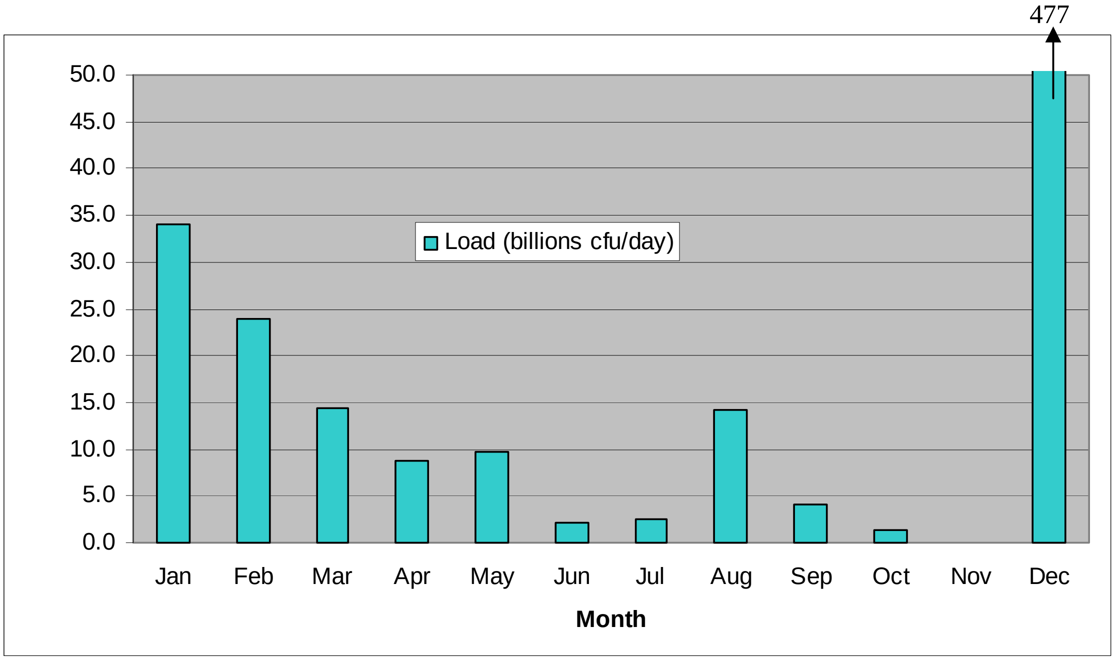


Figure 13. FC loading at 03-THO-00.3 (Thomas Creek at Hwy 99), 2006-07. No samples were taken in November, except November rain event samples, which are not shown. Bars represent two-sample averages.

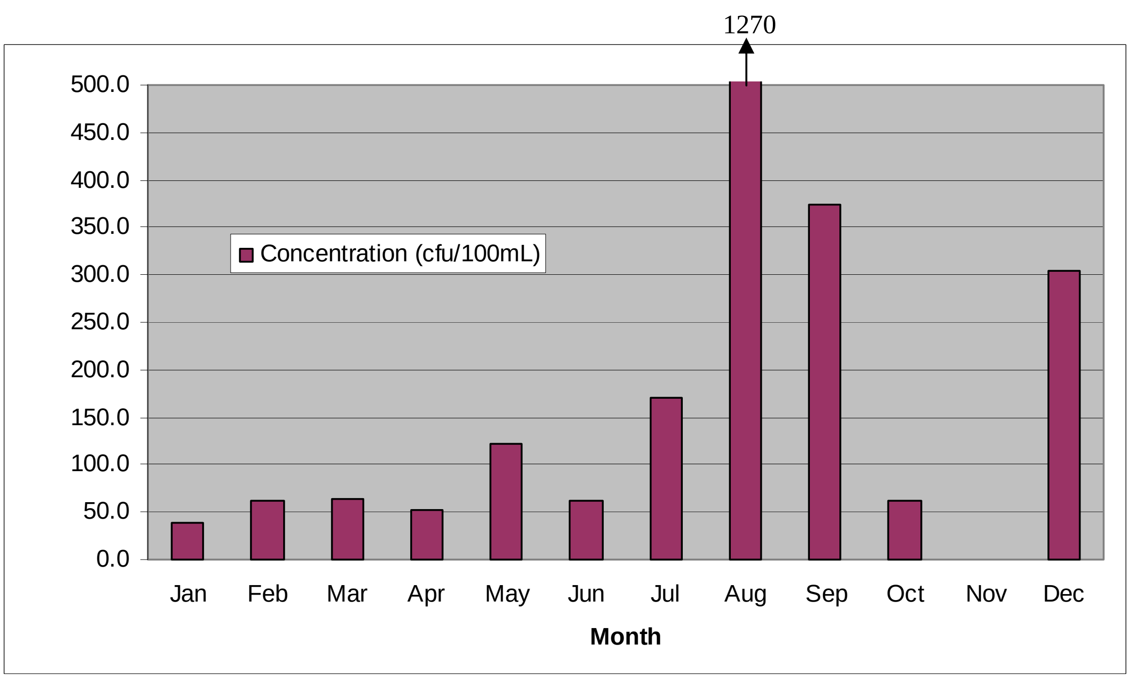


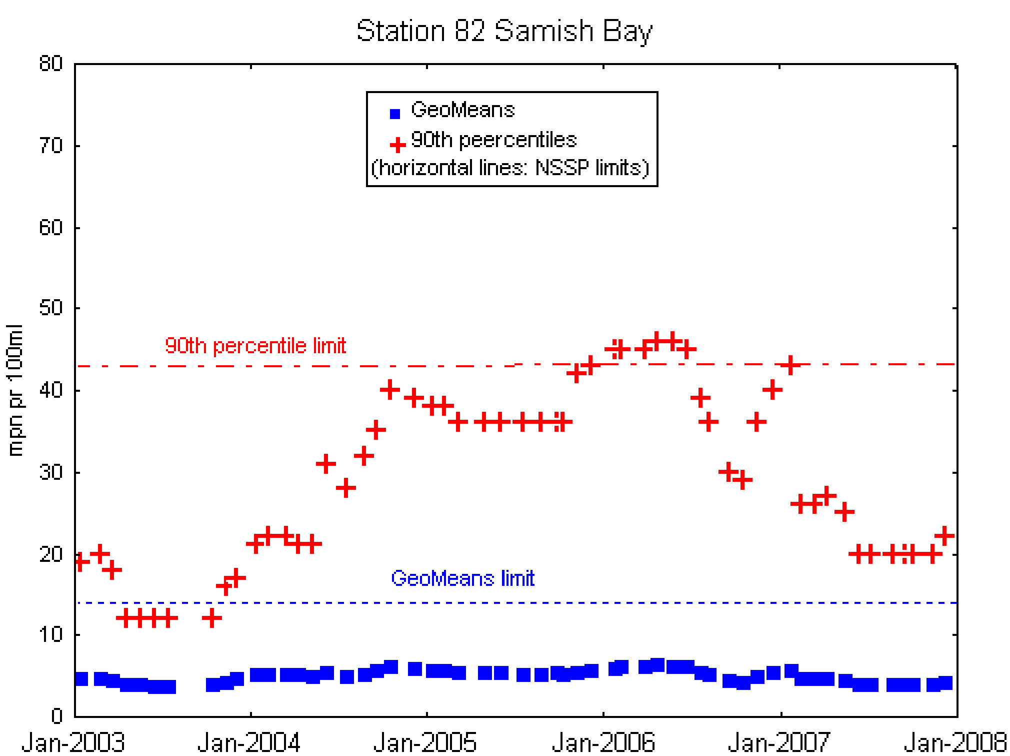
Figure 14. FC concentrations at 03-THO-00.3 (Thomas Creek at Hwy 99), 2006-07. No samples were taken in November, except November rain event samples, which are not shown. Bars represent two-sample averages.

Samish Bay fecal coliform – Washington State Department of Health

The National Shellfish Sanitation Program (NSSP) prescribes methods to evaluate FC levels at water sampling stations to classify growing areas. The Department of Health (DOH) uses Systematic Random Sampling (SRS), which uses a minimum of the last 30 samples for FC analysis. With the SRS method, the 90th percentile cannot exceed 43 fc/100 mL. If this standard is exceeded, no shellfish can be directly harvested from the area of that station (DOH, 2007).

Threatened or concerned status is generally based on water quality, but may also be based on the identification of pollution sources. *Threatened* status is assigned in SRS growing areas when a water sampling station's 90th percentile is between 30 and 43 fc/100 mL. *Concerned* status is assigned where a water sampling station's 90th percentile is greater than 20, but less than 30.

During 2008, Samish Bay was taken off DOH's threatened list due to improving water quality in 2007. Sites 82 and 94 were on DOH's list of threatened stations while 71, 81, and 91 were stations of concern in 2007 (Figure 16). As of 2008, no stations were listed as threatened and only station 82 was listed as a station of concern, based on 2007 water quality data (Sullivan, 2008). Figure 15 shows the most recent (2003-2007) five-year trend in FC pollution at station 82.



Source: DOH; Annual Growing Area Review

Figure 15. DOH's most recent five-year trend in FC pollution at Samish Bay station 82.

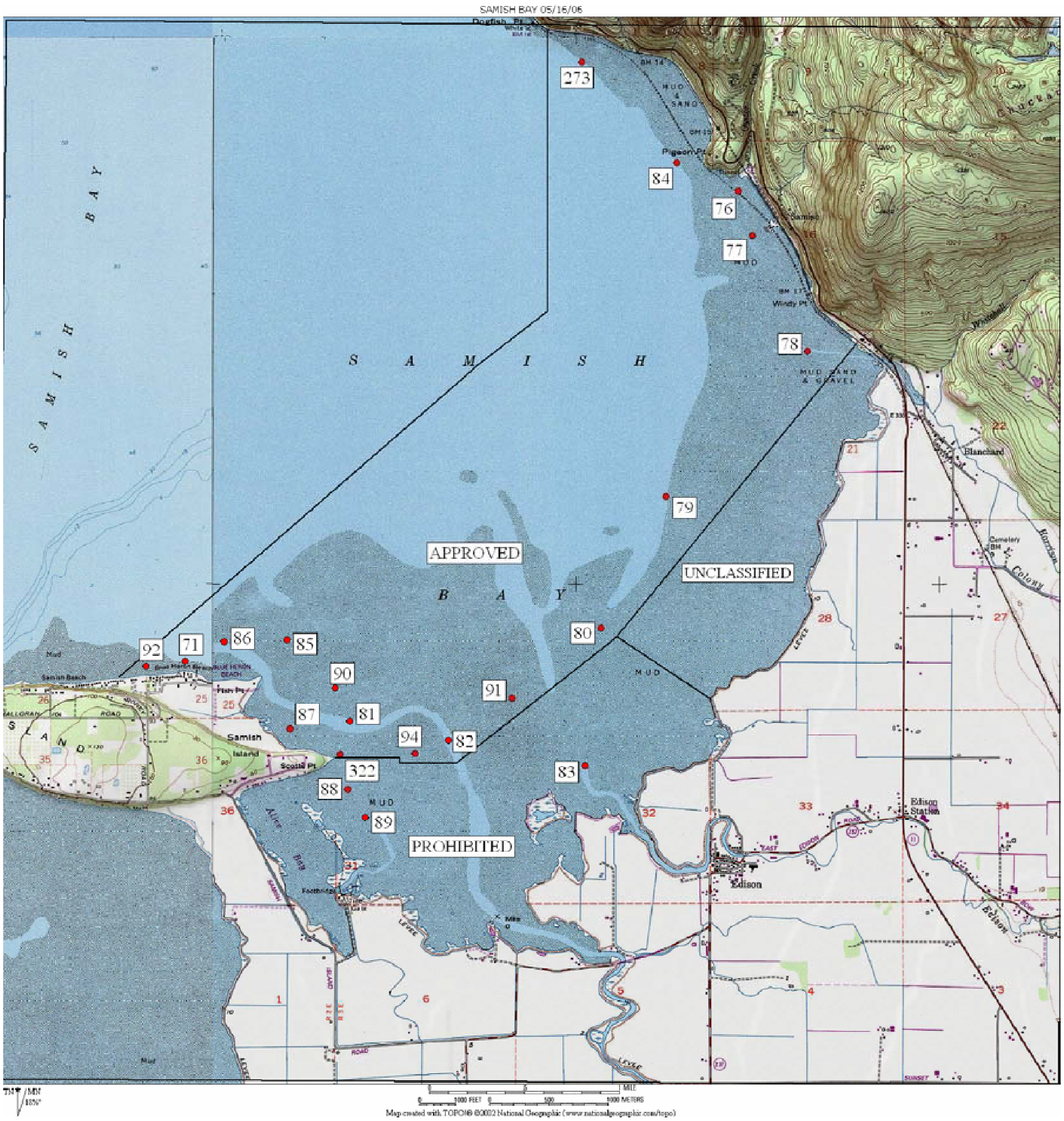


Figure 16. DOH of Health classifications for harvesting shellfish in Samish Bay (DOH, 2005). DOH FC sampling sites are also shown.

DOH collects FC samples at least six times per year. Since 2003, 10 or more samples per year were taken at stations in Samish Bay. DOH samples Samish Bay during flood or ebb periods of high tides. Stations near freshwater inputs had higher FC 90th percentiles than stations that were farther away from freshwater sources (Table 8). Data collected between 2005 and 2007 showed that the highest 90th percentile value was at station 82, where the Samish River flows through the bay's mudflats at low tide. The stations closest to 82 (94, 91, and 81) also had high 90th percentiles when compared to other stations in the approved growing area (Table 8).

Table 8. DOH's 2005 to 2007 summary of shellfish growing areas. FC study results (#/100 mL) for Samish Bay, 05/20/2005 to 12/11/2007.

Station Number	Classification	Number of Samples	Range	Geometric Mean	Est. 90th Percentile	Meets Std.
71	Approved	31	1.7 - 33.0	2.5	6	Yes
76	Approved	31	1.7 - 79.0	3.1	11	Yes
77	Approved	31	1.7 - 17.0	1.9	3	Yes
78	Approved	31	1.7 - 220.0	2.5	10	Yes
79	Approved	31	1.7 - 130.0	2.6	9	Yes
80	Approved	31	1.7 - 33.0	2.6	7	Yes
81	Approved	31	1.7 - 280.0	2.9	12	Yes
82	Approved	31	1.7 - 170.0	4.0	21	Yes
84	Approved	30	1.7 - 27.0	2.0	4	Yes
85	Approved	31	1.7 - 23.0	2.0	4	Yes
86	Approved	31	1.7 - 4.5	1.9	2	Yes
87	Approved	31	1.7 - 33.0	2.5	6	Yes
90	Approved	31	1.7 - 31.0	2.5	7	Yes
91	Approved	31	1.7 - 110.0	3.2	14	Yes
92	Approved	31	1.7 - 23.0	2.4	6	Yes
94	Approved	31	1.7 - 130.0	3.3	16	Yes
273	Approved	31	1.7 - 79.0	2.1	5	Yes
83	Prohibited	31	1.7 - 79.0	3.4	13	Yes
88	Prohibited	31	1.7 - 240.0	3.7	16	Yes
89	Prohibited	31	1.7 - 130.0	3.5	17	Yes
322	Unclassified	22	1.7 - 130.0	2.8	11	*N/A

*SRS criteria require a minimum of 30 samples from each station.
Source: DOH; Annual Growing Area Review.

Comparison of critical periods for Samish Bay and the Samish River

Samish Bay is shallow and highly influenced by freshwater inputs. Fecal coliform survival rates increase in the bay as it becomes less saline. During the dry season, when FC concentrations are typically higher in the river and loading and discharge is much lower, better mixing occurs and the saline water of the bay kills most of the FC that enter the bay. Increased solar radiation and other factors may also contribute to FC die-off during the dry period. This is reflected in DOH's dry season FC sampling results at station 82 (Figure 17).

As discharge from the Samish River increases, freshwater is more quickly pushed farther out into the bay. Mixing and dilution occur more slowly than during times of lower discharge. Consequently, bacteria are likely killed more slowly by the marine environment. Even slightly elevated (over the marine standard of 43 cfu/100 mL) wet season bacteria concentrations from the river have the potential to affect FC bacteria concentrations in the bay, especially if mixing is not complete and a freshwater surface lens develops. Stations 81, 82, 91, and 94, where higher

FC concentrations were found, were more influenced by the Samish River than other sites, likely because of their proximity to out-flowing river water (Table 8).

The Samish River's annual contribution to the total amount of freshwater entering the bay is about 83%. Table 9 shows seasonal differences in discharge from all freshwater sources.

Table 9. Average wet, intermediate, and dry season discharge from all tributaries to Samish Bay during the 2006-07 TMDL study. Wet, intermediate, and dry season average percent of total discharge is also shown.

Site	Wet season average flow (Nov 1 - Feb 28)	Intermediate season average flow (Mar 1 - Jun 30)	Dry season average flow (Jul 1 - Oct 31)	Wet season percent of total flow	Intermediate season percent of total flow	Dry Season percent of total flow
	$ft.^3/sec.$	$ft.^3/sec.$	$ft.^3/sec.$	%	%	%
03-SAM-00.7	468	149	33	78.3	80.0	91.3
03-ALI-PUMP	20	6	0.5	3.3	3.2	1.4
03-SED-PUMP	20	8	0.5	3.3	4.3	1.4
03-WED-GATE	6.8	0.2	0	1.1	0.1	0.0
03-EDI-01.2	17.4	1.0	0.2	2.9	0.5	0.6
03-BAY-GATE	2.5	0.5	0.2	0.4	0.3	0.6
03-MCE-GATE	6.9	1.0	0.5	1.2	0.5	1.4
03-NED-PUMP	10	5	0	1.7	2.7	0.0
03-SMI-GATE	0.5	0.1	0.1	0.1	0.1	0.3
03-COL-00.0	23.8	9.4	0.9	4.0	5.1	2.5
03-OYS-00.0	21.9	5.9	0.2	3.7	3.2	0.6
Total (all sites)	597.8	185.6	35.7	100.0	100.0	100.0
Total (minus Samish)	129.8	37.1	3.1	21.7	20.0	8.7
Total (sloughs only)	84.1	21.8	2.0	14.1	11.7	5.6

Loading followed a similar seasonal pattern as discharge. From 2006 to 2007, the Samish River contributed about 70% of the total FC load to the bay. The sloughs and creeks of Samish Bay made up almost 46% of the total load during the intermediate season (March 1 to June 30), and the pump station in south Edison accounted for over 30% of the load during this time.

Table 10. Average wet, intermediate, and dry season loading from all tributaries to Samish Bay during the 2006-07 TMDL study. Wet, intermediate, and dry season average percent of total load is also shown.

Site	Wet season load (Nov 1 - Feb 28) billions cfu/day	Intermediate season load (Mar 1 - Jun 30) billions cfu/day	Dry season load (Jul 1 - Oct 31) billions cfu/day	Percent of total wet season load %	Percent of total intermediate season load %	Percent of total dry season load %
03-SAM-00.7	2044.6	181	45	70.1	54.2	86.9
03-ALI-PUMP	357.7	10.2	0.4	12.3	3.1	0.7
03-SED-PUMP	104.6	101.8	2.3	3.6	30.5	4.4
03-WED-GATE	48.1	0.3	0.0	1.7	0.1	0.0
03-EDI-01.2	41.7	6.6	0.1	1.4	2.0	0.2
03-BAY-GATE	27.3	1.9	0.8	0.9	0.6	1.6
03-MCE-GATE	6.9	1.0	0.5	0.2	0.3	1.0
03-NED-PUMP	191.7	17.0	0	6.6	5.1	0.0
03-SMI-GATE	3.3	0.1	0.1	0.1	0.0	0.1
03-COL-00.0	61.5	13.2	2.6	2.1	3.9	4.9
03-OYS-00.0	30.3	0.9	0.1	1.0	0.3	0.2
Total	2917.8	333.9	52.1	100.0	100.0	100.0
Total (minus Samish)	873.2	152.9	6.8	29.9	45.8	13.1
Total (sloughs only)	781.4	138.9	4.1	26.8	41.6	8.0

The following figures show FC concentrations in the bay, and loading in the river, at their highest at the beginning of the wet season, then tapering off as the wet season progressed into early spring. Some of the figures also show a spike in FC pollution in late spring, possibly due to rain events during times of manure application or other newly arrived FC sources. Fecal coliform pollution generally was at its lowest in late winter/early spring, after heavy rainfalls flushed the system, and in summer, when wet season inputs to the Samish River dried up.

DOH geometric mean FC MPN data show that the beginning of the rainy season, November through January, is the critical season for FC concentrations in Samish Bay at station 82 (Figure 17).

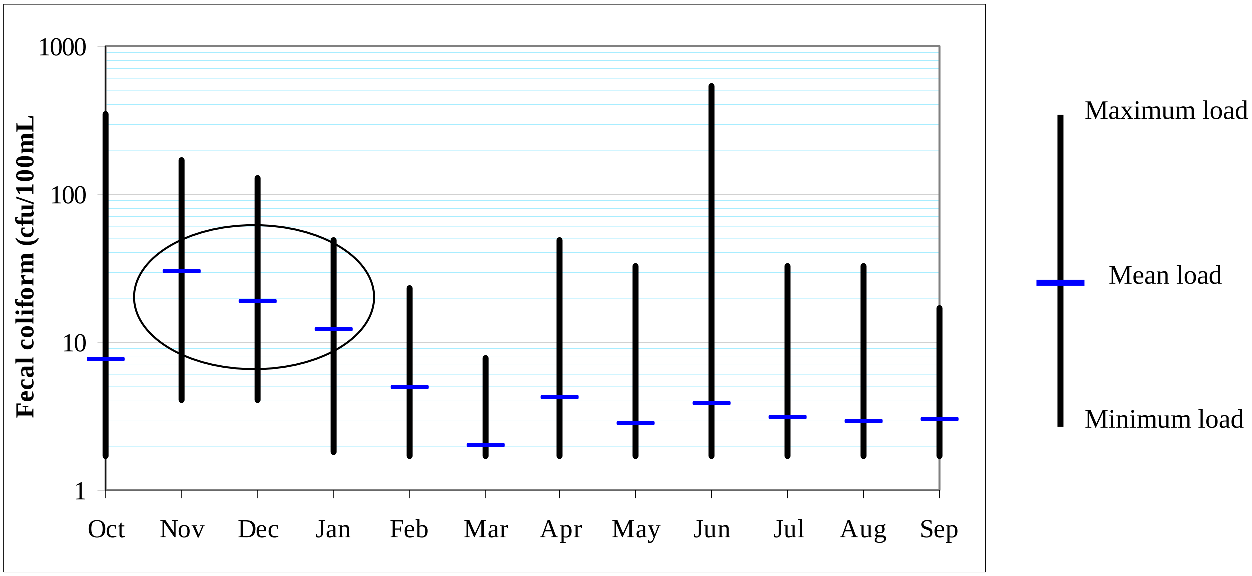


Figure 17. Samish Bay at station 82 geometric mean FC concentrations from DOH's 1995 to 2007 monitoring data.

Skagit County's 2000 to 2007 geometric mean FC loading data also show that November through January is the critical season for loading in the Samish River at RM 4.6 (Thomas Road) (Figure 18).

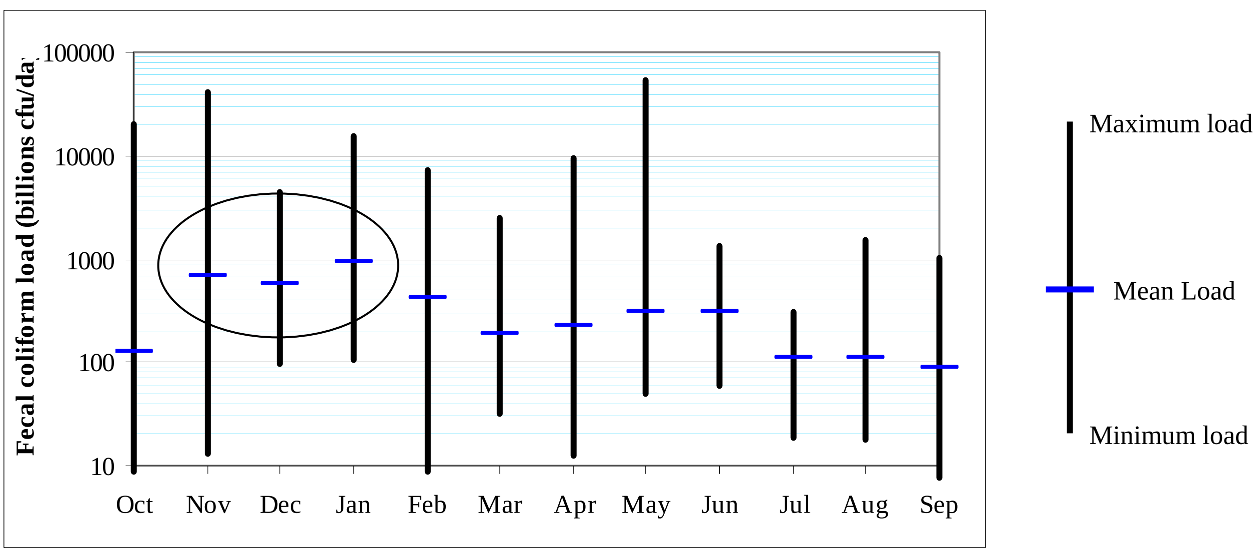


Figure 18. Samish River at RM 4.6 (Thomas Road) FC loads from Skagit County's 2000 to 2007 monitoring data.

Ecology's 1995 to 2008 monthly Ambient Monitoring Program data also show a similar pattern in seasonal FC loading in the Samish River at RM 10.3 (Hwy 99). October through January is the critical season, with a noticeable increase in late spring as well (Figure 19).

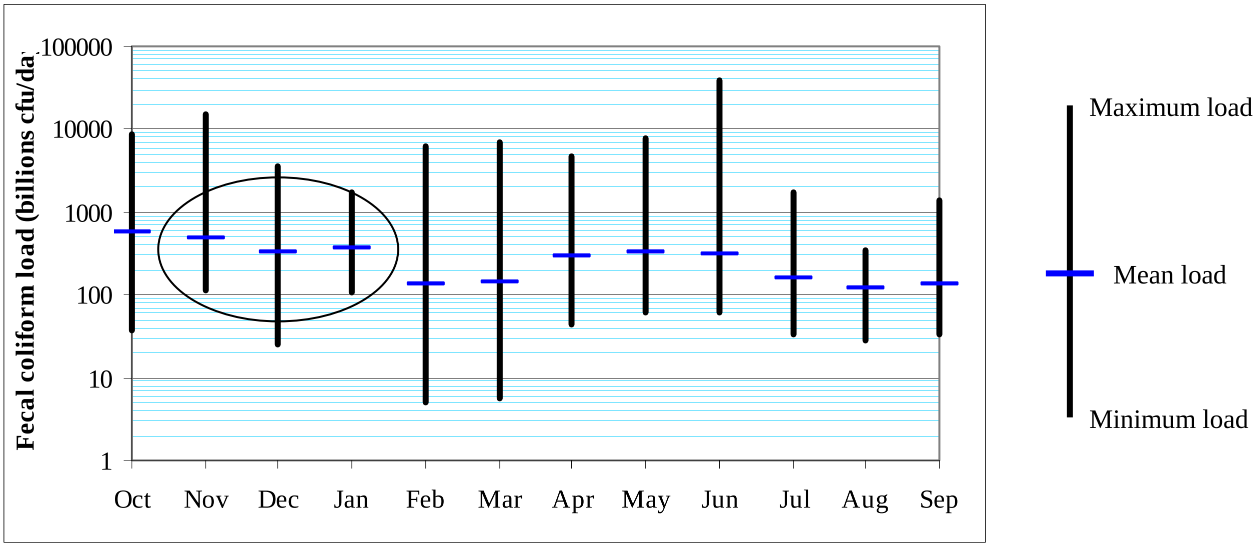


Figure 19. Samish River at RM 10.3 (Hwy 99) FC loads from Ecology's monthly Ambient Monitoring Program, 1995 to 2008.

Ecology's 2006 to 2007 TMDL data show a rougher, yet comparable pattern (Figure 20). November through January is the critical period. June also had higher FC loading.

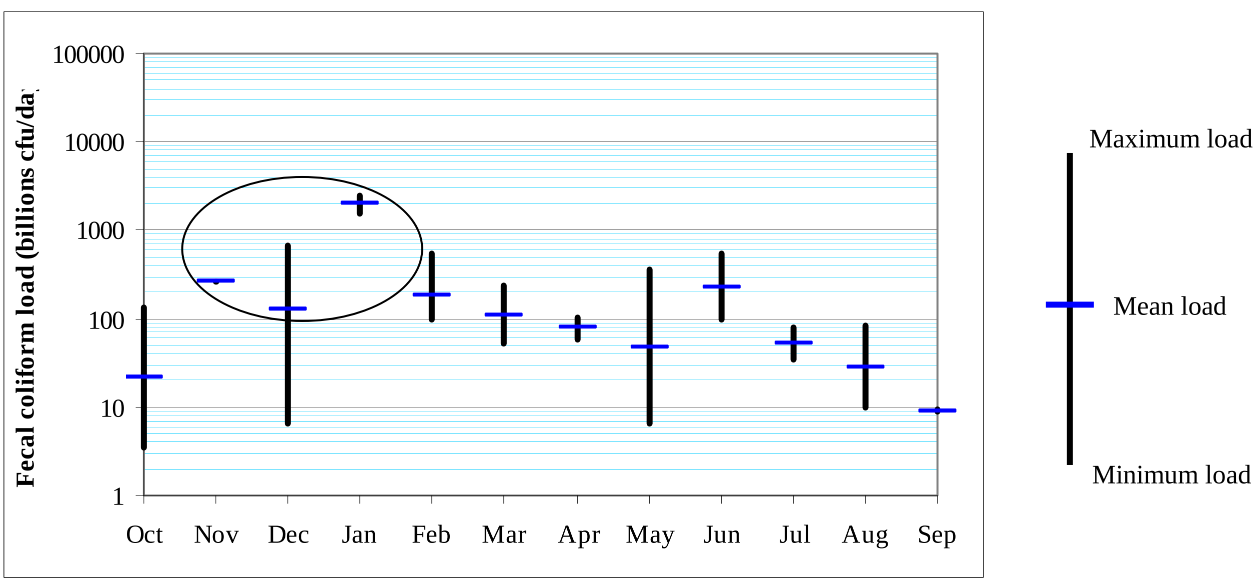


Figure 20. Samish River at RM 0.7 (Bayview/Edison Road) FC loads from Ecology's TMDL study, 2006 to 2007.

Regression analysis was not used to compare river loading and bay FC concentrations because DOH often sampled on different days than Ecology or Skagit County, rendering most results incomparable. Confidence with regression results would have been low due to the limited amount of data used.

Rain events

Samish River and tributaries

Fecal coliform can be directly transported to streams via overland flow during rain events. Extended preceding dry periods often create the potential for FC to accumulate and then wash into streams during intense rainfall. Ecology's November 6 and 7, 2006 sampling results reflect how FC in Samish Basin streams increased in response to heavy rains after such a dry period. Although some rain fell in the preceding days (Table 11), much of it infiltrated the dry, unsaturated ground. On November 6, rain intensity increased, water began to flow overland, and streamflows increased rapidly. Data show how FC concentrations were higher on November 6 as flows increased, and then decreased at most stream sites on November 7 as streams crested and rains lightened (Appendix C, Tables C-1 and C-2).

USGS daily mean discharge at Samish RM 10.3 increased 847% from November 5 to 6 in response to the rain event. Discharge increased 95% from November 12 to13 (Table 11). On November 14, DOH sampled FC in Samish Bay. At station 82, FC results were higher than the water quality criterion (79 FC/100 mL).

Table 11. Precipitation at WSU's Sakuma weather station (northwest of Burlington) and USGS daily mean discharge at Samish River mile 10.3 from October 30 to November 14, 2006 (WSU, 2008).

Date	Precip. (in.)	Accumulation (since 10/30/06)	USGS daily mean (cfs)
10/30/2006	0	0	32
10/31/2006	0	0	29
11/1/2006	0	0	26
11/2/2006	0.33	0.33	27
11/3/2006	0.39	0.72	35
11/4/2006	0.50	1.22	80
11/5/2006	0.21	1.43	114
11/6/2006	1.32	2.75	1080
11/7/2006	0.41	3.16	1150
11/8/2006	0.04	3.20	639
11/9/2006	0.1	3.30	401
11/10/2006	0.28	3.58	331
11/11/2006	0.16	3.74	527
11/12/2006	0.88	4.62	776
11/13/2006	0.32	4.94	1510
11/14/2006	0	4.94	959

November 6 FC concentrations in sloughs were generally lower than November 7 concentrations, likely because slough flows took longer to respond to the rain events (Appendix C, Table C-1).

Although Ecology only sampled once specifically for rain event FC data, two smaller dry-period rain events occurred that influenced FC concentrations as well.

Ecology sampled the Samish River from RM 0.7 to RM 6.5 on July 11, 2006 and upstream of RM 6.5 and all Samish River tributaries on July 12, 2006. Ecology sampled Samish RM 4.6 again on July 12 to compare both days' FC results. Fecal coliform concentrations at Samish RM 4.6 increased from 57 cfu/100 mL on July 11 to 210 cfu/100 mL on July 12. Higher than normal FC concentrations were found basin-wide on July 12, likely due to rainfall washing FC into the streams (Appendix C, Tables C-1 and C-2). Daily precipitation and Samish River discharges are shown in Table 12 and Figure 21.

Table 12. Precipitation at WSU's Sakuma weather station (northwest of Burlington) from July 6 to 16, 2006 (WSU, 2008).

Date	Precip. (in.)	Accumulation (since 7/6/06)
7/6/2006	0	0
7/7/2006	0	0
7/8/2006	0	0
7/9/2006	0	0
7/10/2006	0	0
7/11/2006	0.05	0.05
7/12/2006	0.23	0.28
7/13/2006	0.08	0.36
7/14/2006	0	0.36
7/15/2006	0	0.36
7/16/2006	0	0.36

Ecology sampled the Samish River from RM 0.7 to RM 4.6 on August 9, 2006 and upstream of RM 4.6 and all Samish River tributaries on August 10, 2006. Ecology sampled Samish RM 4.6 again on August 10 to compare both days' FC results. Fecal coliform concentration at Samish RM 4.6 increased from 100 cfu/100 mL on August 9 to 310 cfu/100 mL on August 10. Higher than normal FC concentrations were found basin-wide on August 10, likely due to rainfall washing FC into the streams (Appendix C, Tables C-1 and C-2). Daily precipitation and Samish River discharge can be seen in Table 13 and Figure 21.

Sloughs did not appear to respond to the two dry-period rain events, probably because not enough rain fell to produce overland flow and increase FC in these areas.

Table 13. Precipitation at WSU's Sakuma weather station (northwest of Burlington) from August 3 to 13, 2006 (WSU, 2008).

Date	Precip. (in.)	Accumulation (since 8/3/06)
8/3/2006	0	0
8/4/2006	0	0
8/5/2006	0	0
8/6/2006	0	0
8/7/2006	0	0
8/8/2006	0.02	0.02
8/9/2006	0.09	0.11
8/10/2006	0.17	0.28
8/11/2006	0	0.28
8/12/2006	0	0.28
8/13/2006	0	0.28

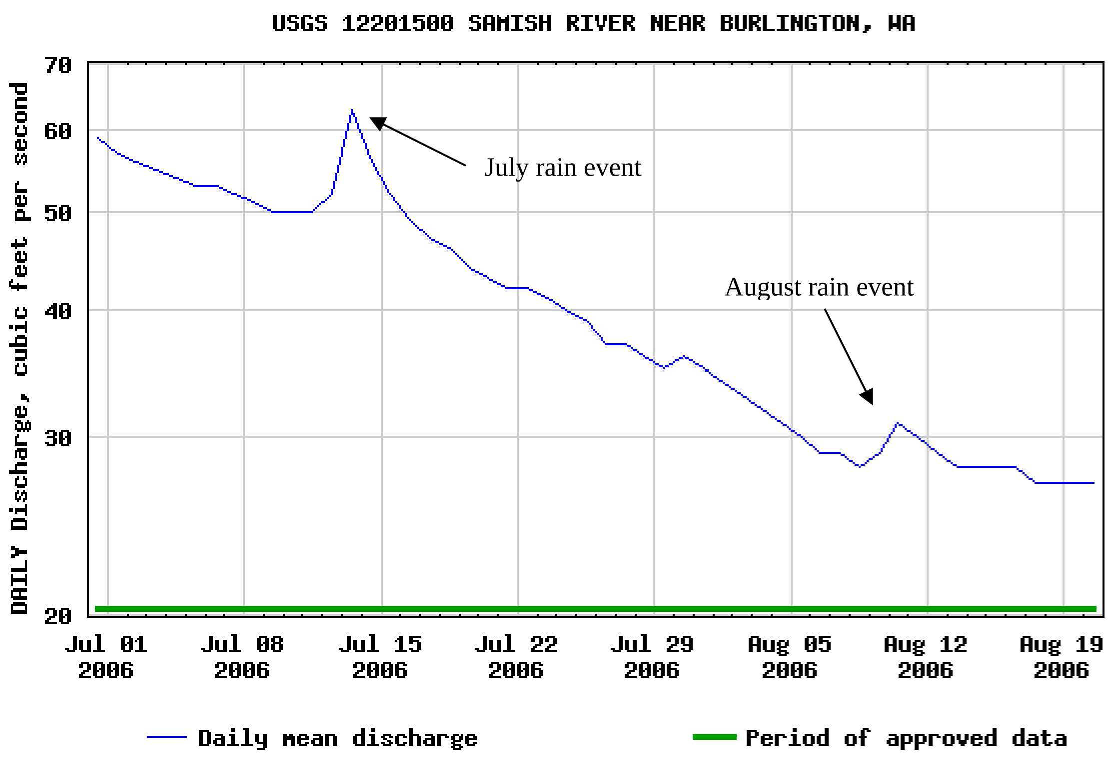


Figure 21. USGS hydrograph showing July 12 and August 10, 2006 rain event discharge (cfs) spikes.

Samish Bay

The following were separately regressed with DOH's station 82 FC concentrations: Day of bay sampling rainfall total, one day prior to bay sampling rainfall total, two days prior to bay sampling rainfall total, and the sum of all three day's rainfall from WSU's Sakuma and Mt. Vernon weather stations (1995 through 2007). No significant correlation was found.

Samish River discharge at RM 10.3 was regressed with DOH FC results from station 82. No significant correlation was found.

The percent increase of Samish River streamflows (RM 10.3) from two days prior, to one day prior, to DOH sampling was regressed with DOH FC results (1996 to 2007 data). Results showed a weak correlation between percent increase of streamflow and bay FC (R^2=0.25). Data from 2004 through 2007 showed a stronger correlation between percent increase of streamflow and Samish Bay FC (R^2=0.62).

Special surveys

Several synoptic surveys were conducted in the upper Samish River and Willard and Colony Creeks during the TMDL study to further bracket sources of fecal pollution. Bird abundance was also noted during the 2006-07 sampling period of the study.

Upper Samish River

Samples taken at Samish RM 28.8 suggest a significant source of FC exists above RM 28.8. At this site, the Samish River had a geometric mean of 149 FC cfu/100 mL and a 90^{th} percentile of 1,604 FC cfu/100 mL.

On June 28, 2006, Ecology crews sampled FC at four locations while walking upstream from 03-SAM-28.8 to the headwaters of the Samish River, approximately 0.5 mile northeast of 03-SAM-28.8. Fecal coliform counts increased from RM 28.8 (150 cfu/100 mL) to 03-SAM-HW4 (320 cfu/100 mL), the most upstream site. Water percolating from a hillside and draining from a pipe formed the headwaters of the Samish River at 03-SAM-HW4. Bacteria results, other parameter results, and a map of the sites are in Appendices C, D, and E, respectively.

Willard Creek

Samples taken in Willard Creek near its confluence with Thomas Creek also suggest upstream sources of FC pollution. At this site, Willard Creek had a geometric mean of 234 FC cfu/100 mL and a 90^{th} percentile of 2,327 FC cfu/100 mL.

On December 13, 2006, Ecology crews sampled FC at four locations while traveling downstream from the headwaters of Willard Creek, 1.7 creek miles southeast of 03-WIL-00.0. Fecal coliform levels increased considerably from creek mile 1.7 (16 cfu/100 mL) downstream to mile 1.3 (1000 cfu/100 mL) and then remained high downstream to the mouth of Willard Creek at creek mile 0 (730 cfu/100 mL). Combined groundwater from a hillside and field formed the headwaters of Willard Creek near creek mile 1.7 (Birch Road). Bacteria results and a map of the sites are in Appendices C and E, respectively.

Willard Creek was investigated again on January 10, 2007. While FC concentrations generally increased from the headwaters to the mouth, results were somewhat inconclusive due to the low FC concentration values (Appendix C, Table C-2).

Colony Creek

Four investigatory samples were taken in Colony Creek on February, 2007 up to creek mile 1.8. Although there was a significant increase in FC concentrations between creek mile 0.3 (12 cfu/100 mL) and 0.6 (81 cfu/100 mL), FC concentrations never exceeded criteria in the creek during the special survey. Bacteria results and a map of the sites are in Appendices C and E, respectively.

Birds

Various species of non-migratory birds were present throughout the Samish Bay Basin at all times of the year. Migratory birds such as ducks and geese were abundant in fall and early winter when they grazed in fields and temporary puddles and pools. Bird numbers and species changed from location to location, day to day, and year to year, making them nearly impossible to accurately enumerate or to predict their bacterial contribution. However, bacteria results suggest birds did not cause FC criteria to be exceeded in the lower Samish River. Rather, FC from upstream sources was likely the largest contributor of FC downstream of RM 10.3 (Hwy 99).

Geometric mean and 90th percentile FC concentrations generally decreased from Samish RM 10.3 to 0.7 where most of the bird presence was noted. Fecal coliform loading stabilized downstream of Samish RM 10.3.

It could not be determined if birds contribute significantly to slough and drainage FC bacteria pollution. However, since migratory waterfowl were more commonly seen on land and not in the sloughs themselves, and slough FC was generally lower during the migratory season than during the spring, it is unlikely that birds contributed the majority of FC pollution to sloughs and drainages.

If natural levels of FC (from birds and wildlife) do cause criteria to be exceeded, no allowance exists for human sources to measurably increase bacterial pollution further. Since human-caused FC pollution is evident in the Samish River Basin, target FC reductions will remain the same.

Bacterial comparisons

All of the bacteria samples collected during the 2006-07 TMDL study were analyzed for FC using the membrane filter (MF) method. Fifty of those samples were also split and analyzed for FC using the most probable number (MPN) method and for *Escherichia coli* (*E. coli*) using the MF method. Thirty-six samples were also split and analyzed for percent *Klebsiella*, *Enterobacter*, and *Serratia* (%KES).

Fecal coliform analysis methods

Fecal coliform samples taken by the DOH and Skagit County are analyzed using the MPN method. Saltwater samples are analyzed using the MPN method because of regulatory reasons. Most probable number results have a wider confidence interval than MF and an inherent positive statistical bias (APHA et al., 1998). Some researchers believe the MPN method is better at enumerating injured or stressed organisms, as well as organisms in turbid or saline waters (Joy, 2000). Ecology typically uses the MF method in streams because of its practicality and precision.

The overall relationship between MPN and MF pairs shown in Figure 22 was significant after log-normal transformation, but not highly correlated (R^2=0.653). The positive bias of the MPN results is also evident in the graph.

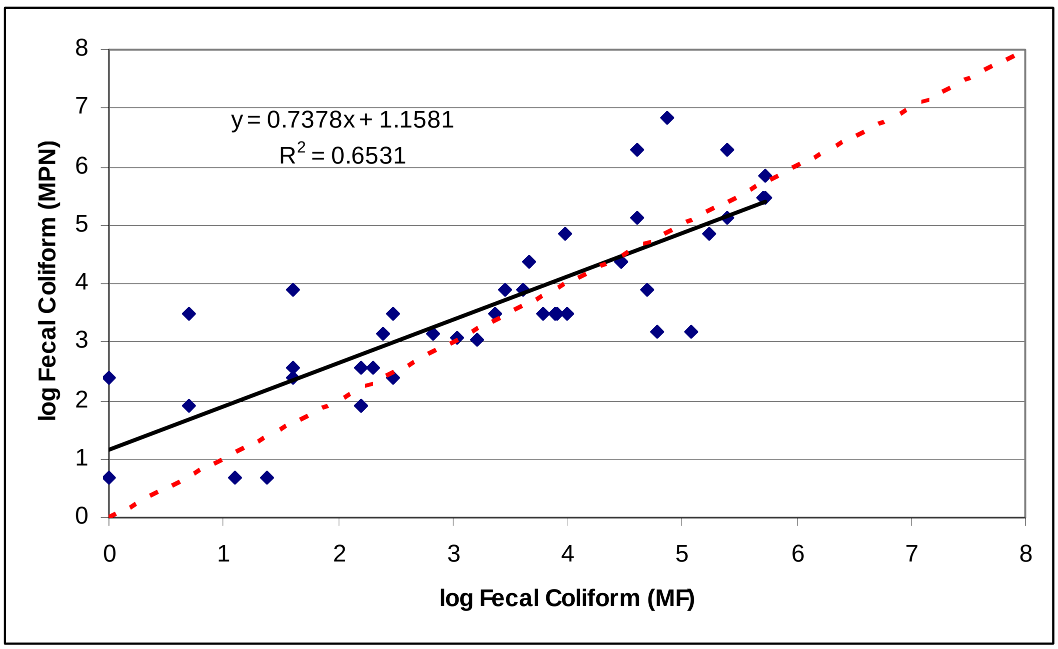


Figure 22. A comparison of 40 paired FC samples that were analyzed using the most probable number (MPN) and membrane filter (MF) techniques during the 2006-07 TMDL study. Dashed line denotes 1:1 relationship.

E. coli and other species

E. coli is the species of the FC group most commonly associated with wastes from warm-blooded animals. However, a large basin like the Samish Bay watershed could have several other members of the FC group that are not *E. coli* (e.g., members of the genus *Klebsiella*, *Enterobacter*, and *Serratia*). For example, Klebsiella *sp.* are associated more with decaying vegetation, and not necessarily an indication of fecal contamination from warm-blooded animals. State and federal FC criteria do not make allowances for the type of organisms reported as fecal coliform. Identifying specific types of organisms within the FC group is helpful for identifying probable sources and planning methods for their control.

A close correlation between *E. coli* and FC was found in TMDL survey samples. Membrane filtered *E. coli* and FC samples were highly correlated (R^2= 0.875) with a slope near 1.0. The relationship between the MF pairs is shown in Figure 23. The results show *E. coli* as the predominant FC organism in Samish Basin samples, and wastes from warm-blooded animals are the likely sources of contamination. Percent KES results also showed that most, if not all, FC came from warm-blooded animals (Appendix C, Table C-3).

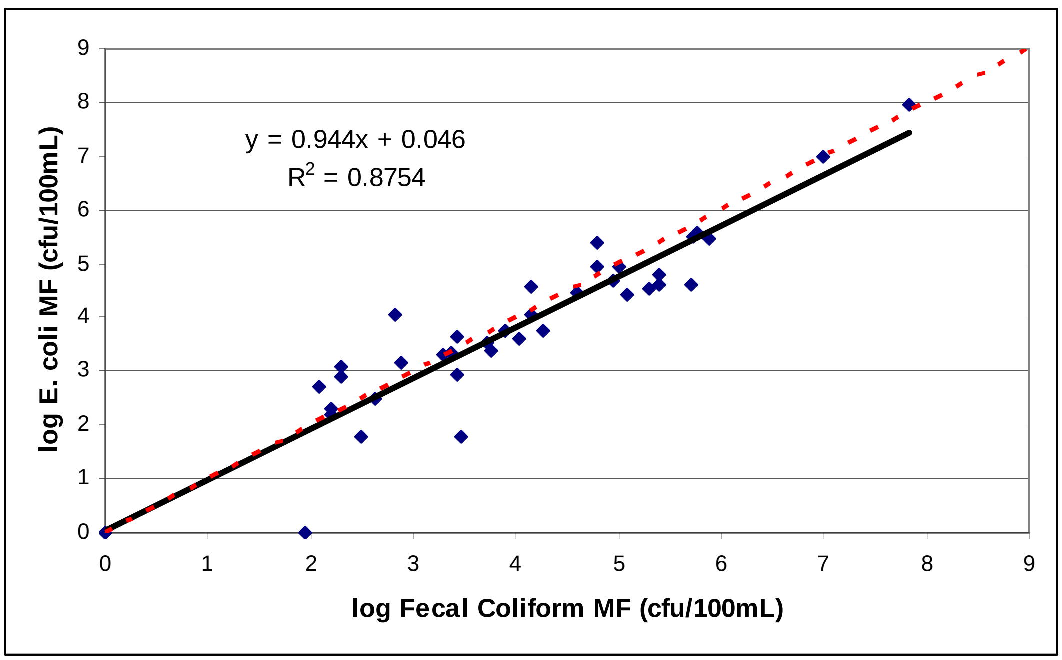


Figure 23. A comparison of the 42 paired FC and *E. coli* samples collected from various sites during the 2006-07 Samish Bay bacteria TMDL study. Dashed line denotes 1:1 relationship.

Fecal coliform bacteria

Analytical framework

Development of allowable loads for FC bacteria for the Samish River and its tributaries, and tributaries to Samish Bay, was based on an analysis of TMDL data collected in 2006 and 2007.

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

The statistical rollback method (Ott, 1997) was used to establish FC bacteria reduction targets for the Samish River mainstem and tributary segments and other Samish Bay tributaries. The rollback method simply compares monitoring data to standards, and the difference is the percent change needed to meet the standards. This method has been previously employed by Ahmed and Hempleman (2006), Sargeant et al. (2005), Roberts (2003), Joy (2000), and Pelletier and Seiders (2000).

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

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

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

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

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

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

$$90^{th} \text{ percentile} = 10^{(\mu_{\log} + 1.28\sigma_{\log})}$$

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

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

$$\left[\frac{\text{observed } 90^{\text{th}} \text{ percentile} - 90^{\text{th}} \text{ percentile criterion}}{\text{observed 90th percentile}}\right] \text{x}\,100$$

or:

$$\left[\frac{\text{observed geometric mean} - \text{geometric mean criterion}}{\text{observed geometric mean}}\right] \text{x}\,100$$

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

f) If the 90th percentile is limiting, the goal would be to meet the 90th percentile FC standard, and no goals would be set for the geometric mean since, with the implementation of the target reductions, the already low geometric mean would only get lower. Similarly, if the geometric mean is limiting, the goal would be to achieve the geometric mean standard with no goal for the already low 90th percentile concentration.

g) While percent reductions are based on the critical period, target reduction values apply year-round.

Loading capacity

Washington State fecal coliform bacteria TMDLs use a combination of mass-per-time units and statistical targets to define loading capacities. This is necessary since mass-per-time units (loads) do not adequately define periods of FC criteria violations. Fecal coliform sources are quite variable, and different sources can cause water quality violations at different times (e.g., poor dilution of contaminated sources during low streamflow conditions or increased source loading during run-off events). Loads are instructive for identifying changes in FC source intensity between sites along a river or between seasons at a site.

The statistical targets are referenced in the Washington State FC criteria and provide a better measure of the loading capacity during the most critical period. The Samish Bay watershed FC loading capacities are the applicable two statistics in the state FC criteria (e.g., the geometric mean and the value not to be exceeded by more than 10% of the samples). As discussed earlier in the *Data Analysis Methods* section, the 90th percentile value of samples is used in TMDL evaluations for the latter criterion statistic. The FC TMDL target capacities in the following tables are either the criteria or statistics that estimate the reductions necessary to meet the criteria.

The percentage reduction values in the following tables indicate the relative degree the waterbody is out of compliance with criteria (i.e., how far it is over its capacity to receive FC source loads and still provide the designated beneficial uses). Sites representing reaches or tributaries that are currently meeting their loading capacity do not have a FC reduction value. Sites that require aggressive reductions in FC sources will have a high FC percentage reduction value, while sites with minor problems will have a low FC percentage reduction value.

Since the loading capacity and statistical values are based on the critical condition, the tables include the critical period to provide water quality managers with a sense of when FC sources are violating criteria. If there is no critical period, no seasonal changes were noted and data from the entire year was used.

Target capacity and recommended reductions

Target reductions may be either in terms of concentration or load or both. For the Samish River and its tributaries, the TMDL for FC is expressed in terms of FC concentration as allowed under Federal Regulations [40 CFR 130.2(I)] as "other appropriate measures." The concentration measure is appropriate since the water quality standard can be directly compared to measured concentrations in the receiving water under all flow scenarios.

The "target reductions" show what is necessary to achieve the water quality standard. However, loads at specific locations along the river and at the mouths of tributaries have been established to provide a relative comparison of contributions of fecal coliform.

The TMDL targets and FC reductions for the Samish River need to be protective of all downstream beneficial uses. The use with the most restrictive FC criteria is shellfish harvesting in Samish Bay. DOH recently took Samish Bay off the list of threatened bays due to improving water quality in 2007. However, station 82, in the approved section of the bay, is still on DOH's list of stations of concern and lies directly in the path of outgoing Samish River water. The water quality in the harvesting area must have a 90^{th} percentile of no greater than 43 FC cfu/ 100 mL (MPN) and a geometric mean of no greater than 14 FC cfu/100 mL.

To be more protective of beneficial uses in the bay, it is recommended that the freshwater FC target capacity and load allocation at Samish RM 0.7 be replaced by the marine water criteria. It is also recommended that the freshwater FC target capacity and load allocation in the slough flowing directly into Alice Bay (sites 03-ALI-PUMP and 03-ALI-GATE) be replaced by the marine water criteria because stations 89 and 88, near the outlet of Alice Bay and the slough, have the second and third highest 90^{th} percentile FC concentrations in the bay, respectively (Figure 16 and Table 8).

Even if upstream Samish River sites met freshwater *Primary Contact* criteria, the Samish River at RM 0.7 would not meet marine criteria because the marine criteria are more stringent. Therefore, upstream sites should meet a more stringent water quality standard so the Samish River at RM 0.7 can meet marine standards.

The more stringent FC targets at the two TMDL sites upstream of RM 0.7 (Table 14) were derived by calculating the reduction in the average 90^{th} percentile FC concentration that occurs from RM 4.6 to RM 0.7 and the increase in concentration that occurs from RM 6.5 to RM 4.6. A 36% reduction in average 90^{th} percentile FC concentration occurs from RM 4.6 to RM 0.7, and an 8% increase in average 90^{th} percentile concentration occurs from RM 6.5 to RM 4.6. At the downstream site (RM 0.7), the 90^{th} percentile (43 col/100 mL) was the limiting criteria. After calculations were made, the target 90^{th} percentile for RM 4.6 became 67 cfu/100 mL, and the target 90^{th} percentile at RM 6.5 became 62 cfu/100 mL. Meeting these targets at RMs 4.6 and 6.5 will ensure that the most downstream site (RM 0.7) will meet the 90^{th} percentile marine water quality criterion. Table 14 describes recommended bacteria reductions for each site. No significant pollution sources were found between RMs 6.5 and 0.7 during the course of the TMDL study.

Conductivity in most of the sloughs to Samish Bay was high enough to impose marine water criteria (Appendix D). But as FC reductions occur throughout the rest of the basin, the further reduction of slough bacteria to meet stringent marine water criteria will become less of a priority and difficult to accomplish. Reductions based on freshwater criteria are recommended at all creek and slough mouths, except the pump station and tidegates at Alice Bay and the mouth of the Samish River as previously stated. If met, the recommended freshwater-based FC reductions will dramatically lower slough concentrations and loading, ensuring further protection of Samish Bay and its resources.

Samish River

Samish River mile 28.8, just below Doran Road in Whatcom County, had the highest FC counts in the Samish River. An 88% reduction in 90^{th} percentile FC concentrations is needed to meet the water quality criterion.

Downstream of RM 28.8, the Samish River slowly flows through interconnecting wetlands where it receives groundwater inputs as evidenced in the dry season by increasing streamflows from RM 28.8 to RM 20.7. These upper Samish River sites likely had low FC concentrations and met criteria due to wetland attenuation, groundwater dilution, and bacteria die-off. Tributaries in this stretch were mostly dry during the dry period.

The rest of the river and major tributaries did not meet the FC criteria and appropriate FC reduction percentages have been recommended to bring the Samish River into compliance (Table 14).

All TMDL data were used to calculate target reductions from RM 0.7 to RM 6.5 even though FC concentrations were generally higher from May through September at RMs 4.6 and 6.5. Since higher bay FC concentrations and river loading occurred during the wet season, and FC concentration violations occurred mostly at other times of the year, it was decided to set year-round reduction targets from RM 0.7 to RM 6.5 (Table 14). Also, setting freshwater FC reductions based on the already low marine water criteria, *and* using higher FC concentration values from the critical season to calculate reductions, would set unrealistic FC targets and load allocations.

Table 14. Recommended Samish River and tributary FC reductions and target concentrations to meet load capacities based on *Primary Contact* criteria and to protect shellfish harvesting in Samish Bay.

Site ID w/River Mile	Site Location	Number of Samples	Critical Period	Critical Period FC (cfu/100 mL)		FC Reduction	FC Target Capacity (cfu/100 mL)	
				90th %tile	Geo-mean		90th %tile	Geo-mean
03-SAM-00.7	Bayview/ Edison Rd	25	none	156	35	72%	43	10
03-SAM-04.6	Thomas Rd	25	none	243	56	72%	67	15
03-SAM-06.5	Chuckanut Dr	25	none	226	65	73%	62	18
03-THO-00.3	Thomas Ck at Old Hwy 99	24	May-Sep	920	254	78%	200	55
03-SAM-10.3	Hwy 99	24	May-Oct	428	181	53%	200	85
03-FRI-00.8	Friday Ck at Bow Hill / Prairie Rd	24	Jun-Sep	936	174	79%	200	37
03-SAM-13.1	F&S Grade Rd	24	May-Oct	380	130	47%	200	69
03-SWE-00.0	Swede Ck at Grip Rd	24	Apr-Sep	828	157	76%	200	38
03-SKA-00.5	Skarrup Creek at first road crossing	21	none	750	170	73%	200	45
03-SAM-15.0	2nd Prairie Rd crossing from Hwy 99	24	May-Aug	572	97	65%	200	34
03-PAR-00.0	Parson Ck at confluence w/Samish R	24	July-Oct	3605	1976	95%	182	100
03-SAM-16.5	Off Prairie Rd upstream of Parson Ck	24	May-Aug	356	87	44%	200	49
03-SAM-20.7	3rd Prairie Rd crossing from Hwy 99	24	May-Aug	372	74	46%	200	40
03-SAM-22.0	Hwy 9	24	none	--	--	--	200	100
03-SAM-26.6	Wickersham Rd	24	none	--	--	--	200	100
03-ENN-00.0	Ennis Ck at mouth, Wickersham Rd	21	none	--	--	--	200	100
03-SAM-28.8	Innis Ck Rd (in Doran)	24	none	1604	149	88%	200	19

Friday Creek

The loading capacity in the upper Friday Creek watershed was adequate to handle current FC source loading. Fecal coliform reductions do not appear to be necessary at this time in the reaches above RM 6.5 and in Silver Creek.

Below RM 6.5, bacteria concentrations and loading increased significantly and will require 78-79% load reductions to meet criteria (Table 15).

Table 15. Recommended Friday Creek and tributary FC reductions and target concentrations to meet load capacities based on *Primary Contact* criteria.

Site ID w/River Mile	Site Location	Number of Samples	Critical Period	Critical Period FC (cfu/100 mL)		FC Reduction	FC Target Capacity (cfu/100 mL)	
				90th %tile	Geo-mean		90th %tile	Geo-mean
03-FRI-00.8	Friday Ck at Bow Hill / Prairie Rd	24	Jun-Sep	936	174	79%	200	37
03-FRI-03.8	Friday Ck at Friday Ck Rd	24	Jun-Sep	911	159	78%	200	35
03-SIL-00.4	Silver Ck at Friday Ck Rd	24	none	--	--	--	200	100
03-FRI-06.5	Friday Ck at Lake Samish Rd	24	none	--	--	--	200	100

Thomas Creek

Both upper and lower Thomas Creek and Willard Creek require FC reductions to meet criteria. The reduction in FC concentration from Thomas Creek RM 3.6 to RM 0.3 (Table 16) is likely due to bacteria die-off in the dry season, and die-off or dilution from groundwater or small tributaries during the wet season. Willard Creek often holds water, but does not flow during the dry season. Samples taken during this time were not used in the analysis of FC in Willard Creek.

Table 16. Recommended Thomas Creek and tributary FC reductions and target concentrations to meet load capacities based on *Primary Contact* criteria.

Site ID w/River Mile	Site Location	Number of Samples	Critical Period	Critical Period FC (cfu/100 mL)		FC Reduction	FC Target Capacity (cfu/100 mL)	
				90th %tile	Geo-mean		90th %tile	Geo-mean
03-THO-00.3	Old Hwy 99	24	May-Sep	920	254	78%	200	55
03-WIL-00.0	Off F&S Grade Rd abv. Thomas Ck	17[1]	none	2327	234	91%	200	20
03-THO-03.6	Off F&S Grade Rd abv. Willard Ck	24	May-Sep	3105	399	94%	200	26

[1]Some samples were taken during the dry period, but not used because there was no flow.

Other tributaries to Samish Bay

Oyster Creek, which flows out of a mostly forested watershed, met the freshwater criteria and loading capacity during the TMDL study and requires no FC load reductions. All other sloughs and creeks tributary to Samish Bay require load reductions from 18% to 79% (Table 17).

The slough flowing into Alice Bay and Samish Bay (sites 03-ALI-PUMP and 03-ALI-GATE) met freshwater criteria, but not marine water criteria. The two DOH sampling stations nearest to the slough's pump and tidegates had the highest FC concentrations in Samish Bay, other than sites 82 and 94 (Table 8 and Figure 16). Therefore, the 90th percentile target capacity was replaced by the marine water criterion (43 cfu/100 mL), allowing better protection of beneficial uses in the bay. A load reduction of 66% on Alice Bay slough is necessary to meet the 90th percentile marine criterion.

The slough flowing into Edison Slough at Smith Rd (03-SMI-GATE) rarely opened and leaked saltwater back through the tidegate at high tides. This site should meet bacteria criteria as FC loading from the slough in north Edison (03-NED-GATE) is reduced. 03-SMITH-GATE and 03-NED-GATE are connected by the same slough system, and little to no FC pollution sources were found near 03-SMI-GATE.

Table 17. Recommended Samish Bay tributary FC reductions and target concentrations to meet load capacities based on *Primary Contact* criteria and to protect shellfish harvesting in Samish Bay.

Site ID w/ River Mile	Site Location	Number of Samples	Critical Period	Critical Period FC (cfu/100 mL)		FC Reduction	FC Target Capacity (cfu/100 mL)	
				90th %tile	Geo-mean		90th %tile	Geo-mean
03-COL-00.0	Colony Ck near mouth, up of tidegates	25	May-Oct	244	103	18%	200	85
03-ALI-PUMP	Drainage to Alice Bay	25	none	127	16	66%	43	5
03-NED-PUMP	N Edison drainage at Key Ave.	17[1]	none	330	109	39%	200	66
03-SED-PUMP	S Edison drainage near liquor store	21	none	601	167	67%	200	56
03-BAY-GATE	Drainage W of Samish R mouth	25	none	342	52	42%	200	30
03-MCE-GATE	Tidegate to McElroy/ Col. Slough	25	Apr-Sep	836	196	76%	200	47
03-WED-GATE	W Edison drainage near Edison Slough	15[1]	none	428	41	53%	200	19
03-SMI-GATE	Drain to Edison Slough at Smith Rd	4	none	--	--	NA[2]	NA[2]	NA[2]
03-EDI-01.2	Edison Slough up of gates in Edison	24	Apr-Jul	846	129	76%	200	31
03-EDI-01.6	Edison Slough just up of school	25	Apr-Jul	960	153	79%	200	32
03-OYS-00.0	Oyster Ck near mouth	25	none	--	--	--	NA	NA

[1]Some samples were taken during the dry period, but not used because there was no flow.

[2]SMI-GATE reductions will occur as NED-PUMP's reduction targets are met. They are fed through the same slough system.

Figure 24 further illustrates reaches where FC reductions are necessary to bring the Samish Bay watershed into compliance with water quality standards.

Figure 24. Samish Bay watershed with recommended FC reduction targets.

Recommended load allocations

The average annual discharge from the Samish River and other tributaries to Samish Bay during the 2006-07 TMDL study can be seen in Figure 25. The Samish River is the largest contributor of freshwater to the bay at 83% of the total discharge. For seasonal results, see Table 9.

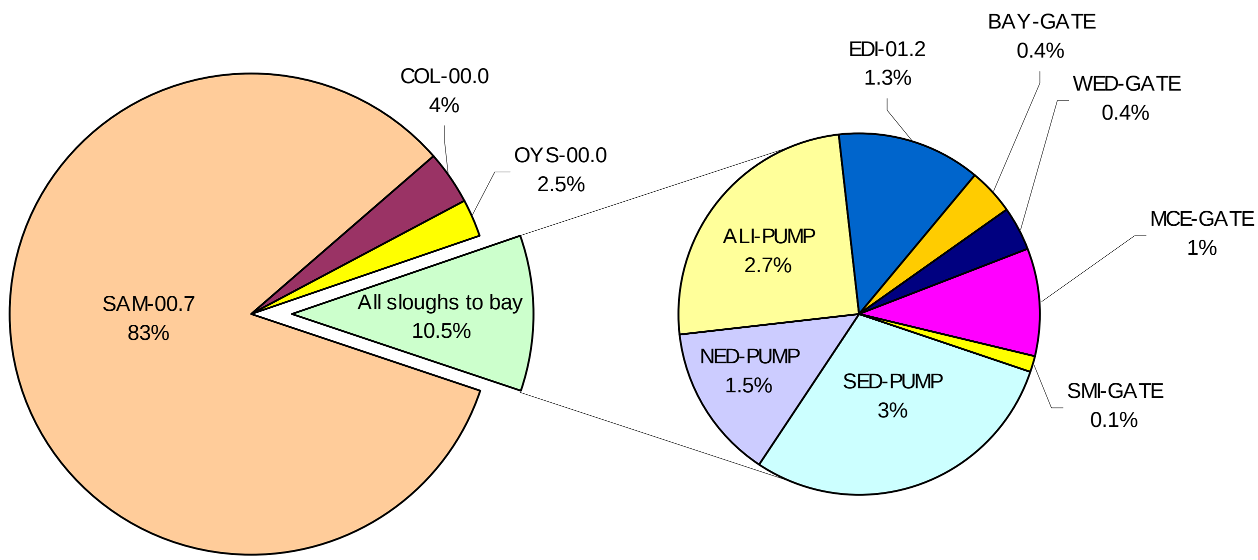


Figure 25. Estimated average annual discharge from tributaries to Samish Bay during the 2006-07 TMDL study.

Figure 26 shows the estimated average annual loading from tributaries to Samish Bay during the 2006-07 TMDL study. The Samish River is the largest contributor of FC loading to the bay at 70% of the total loading. For seasonal results, see Table 10.

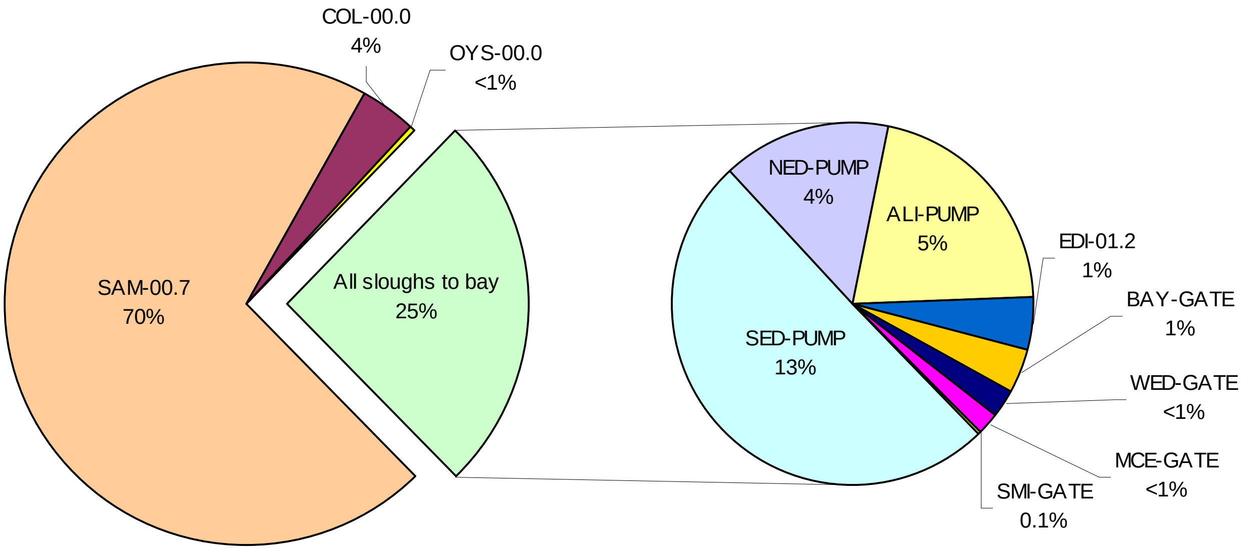


Figure 26. Estimated average annual loading from tributaries to Samish Bay during the 2006-07 TMDL study.

Table 18 through Table 21 show loads from all regularly sampled 2006-07 TMDL sites and recommended TMDL load allocations based on calculated target reductions.

Table 18. Recommended Samish River and tributary FC load reductions based on critical condition data meeting water quality criteria for *Primary Contact* uses.

Site ID w/ River Mile	Site Location	Load Allocation (cfu/day)	Current Load (cfu/day)	Target Reduction	Target Basis LA WQ criterion
03-SAM-00.7	Bayview/ Edison Rd	9.8E+10	3.5E+11	72%	90th %tile
03-SAM-04.6	Thomas Rd	9.1E+10	3.2E+11	72%	90th %tile
03-SAM-06.5	Chuckanut Dr	1.1E+11	4.0E+11	73%	90th %tile
03-THO-00.3	Thomas Ck at Hwy 99	1.1E+10	5.1E+10	78%	90th %tile
03-SAM-10.3	Hwy 99	1.7E+11	3.6E+11	53%	90th %tile
03-FRI-00.8	Friday Ck at Bow Hill / Prairie Rd (below Hatchery)	2.4E+10	1.1E+11	79%	90th %tile
03-SAM-13.1	F&S Grade Rd	1.5E+11	2.8E+11	47%	90th %tile
03-SWE-00.0	Swede Ck at Grip Rd	4.7E+09	2.0E+10	76%	90th %tile
03-SKA-00.5	Skarrup Creek at first road crossing	6.5E+09	2.4E+10	73%	90th %tile
03-SAM-15.0	2nd Prairie Rd crossing from Hwy 99	6.2E+10	1.8E+11	65%	90th %tile
03-PAR-00.0	Parson Ck at confluence w/ Samish R	1.7E+08	3.3E+09	95%	geomean
03-SAM-16.5	Off Prairie Rd upstream of Parson Ck	1.0E+11	1.8E+11	44%	90th %tile
03-SAM-20.7	3rd Prairie Rd crossing from Hwy 99	2.4E+10	4.5E+10	46%	90th %tile
03-SAM-22.0	Hwy 9	--	1.9E+10	no reduction required	
03-SAM-26.6	Wickersham Rd	--	6.0E+09	no reduction required	
03-ENN-00.0	Ennis Ck at mouth, Wickersham Rd	--	2.3E+09	no reduction required	
03-SAM-28.8	Innis Ck Rd (in Doran)	3.8E+08	3.1E+09	88%	90th %tile

Table 19. Recommended Friday Creek and tributary FC load reductions based on critical condition data meeting water quality criteria for *Primary Contact* uses.

Site ID w/ River Mile	Site Location	Load Allocation (cfu/day)	Current Load (cfu/day)	Target Reduction	Target Basis LA WQ criterion
03-FRI-00.8	Friday Ck at Bow Hill / Prairie Rd (below Hatchery)	2.4E+10	1.1E+11	79%	90th %tile
03-FRI-03.8	Friday Ck at Friday Ck Rd	1.0E+10	4.7E+10	78%	90th %tile
03-SIL-00.4	Silver Creek at Friday Ck Rd	--	4.6E+09	no reduction required	
03-FRI-06.5	Friday Ck at Lake Samish Rd / Alger Cain Lk Rd	--	7.7E+09	no reduction required	

Table 20. Recommended Thomas Creek and tributary FC load reductions based on critical condition data meeting water quality criteria for *Primary Contact* uses.

Site ID w/ River Mile	Site Location	Load Allocation (cfu/day)	Current Load (cfu/day)	Target Reduction	Target Basis LA WQ criterion
03-THO-00.3	Thomas Ck at Old Hwy 99	1.1E+10	5.1E+10	78%	90th %tile
03-WIL-00.0	Willard Ck Off F&S Grade Rd above Thomas Ck	9.8E+08	1.1E+10	91%	90th %tile
03-THO-03.6	Thomas Ck off F&S Grade Rd above Willard Ck	3.6E+09	6.0E+10	94%	90th %tile

Table 21. Recommended FC load reductions for other tributaries to Samish Bay, based on critical condition data meeting water quality criteria for *Primary Contact* uses.

Site ID w/ River Mile	Site Location	Load Allocation (cfu/day)	Current Load (cfu/day)	Target Reduction	Target Basis LA WQ criterion
03-COL-00.0	Colony Creek near mouth, upstream of tidegates	9.9E+09	1.2E+10	18%	90th %tile
03-ALI-PUMP	Drainage to Alice Bay	2.7E+09	7.9E+09	66%	90th %tile
03-NED-PUMP	North Edison drainage at Key Ave., off Smith Rd	1.7E+10	2.8E+10	39%	90th %tile
03-SED-PUMP	South Edison drainage near liquor store	2.4E+10	7.3E+10	67%	90th %tile
03-BAY-GATE	Drainage west of Samish River mouth, to Samish Bay	1.6E+09	2.8E+09	42%	90th %tile
03-MCE-GATE	Tidegate to McElroy/Colony Slough	1.3E+09	5.2E+09	76%	90th %tile
03-WED-GATE	West Edison drainage near Edison Slough mouth	7.1E+09	1.5E+10	53%	90th %tile
03-SMI-GATE	Drainage to Edison Slough at Smith Road near NED-PUMP	--	--	NA*	NA*
03-EDI-01.2	Edison Slough just upstream of tidegates in Edison	1.2E+09	5.2E+09	76%	90th %tile
03-EDI-01.6	Edison Slough at private drive upstream of school	9.1E+08	4.3E+09	79%	90th %tile
03-OYS-00.0	Oyster Creek near mouth	--	6.2E+08	no reduction required	

*SMI-GATE reductions will occur as NED-PUMP's reduction targets are met. They are fed through the same slough system.

Permitted entities in the Samish watershed

The TMDL *Implementation Plan* to follow this report will establish wasteload allocations for NPDES permittees in the Samish watershed. Based on the TMDL analysis, Samish stream reaches will meet water quality standards if the percent FC reduction developed for an individual reach applies to both point and nonpoint sources in the drainage.

Washington State Department of Transportation

The Washington State Department of Transportation (WSDOT) is covered under an NPDES municipal stormwater permit issued by Ecology. It is expected that if WSDOT were able to reduce FC discharges to Samish area streams from its stormwater drainage system by percentages equivalent to those assigned to nonpoint sources, then the streams will be able to meet water quality standards.

For example, I-5 crosses the Samish River at river mile 8.3. The percent FC load reduction necessary downstream at Chuckanut Drive (RM 6.5) is 73% (Table 14), so WSDOT will need to reduce FC loading from I-5 to the Samish River by 73%.

Chuckanut Drive (SR 11) is also managed by WSDOT and will need to reduce FC discharge by the percentage calculated for nonpoint sources to the Samish River at Thomas Rd. (RM 4.6) (72% reduction).

All WSDOT managed roads in the Samish Bay watershed where runoff flows into drainages with nonpoint sources should expect to reduce FC bacteria in their stormwater conveyance system by the same amount assigned to the nonpoint sources for that drainage. Highways managed by the WSDOT in the Samish Basin are I-5, SR 11, and SR 9.

Dynes Egg Processor

The only active Concentrated Animal Feeding Operation (CAFO) in the Samish Bay watershed is Dynes Egg Processor (permit to be issued soon). It is recommended that the Dynes permit be given an automatic wasteload allocation of zero because it is required to have no discharge of pollutants to the waters of the state, except under extreme circumstances (storm event in excess of the area's 25-year, 24-hour precipitation amount).

This page is purposely left blank

Margin of safety

The federal Clean Water Act requires that TMDLs be established with margins of safety (MOS). The MOS accounts for uncertainty in the available data, or the unknown effectiveness of the water quality controls that are put in place. The MOS can be stated explicitly (e.g., a portion of the load capacity is set aside specifically for the MOS). But implicit expressions of the MOS are also allowed, such as conservative assumptions in the use of data, application of models, and the effectiveness of proposed management practices.

Implicit MOS elements were applied to analyses to provide a large MOS for the Samish Bay fecal coliform TMDL evaluation. The recommended FC reductions and allocations are conservatively set to protect human health and beneficial uses to the fullest extent possible.

The following are conservative assumptions that contribute to the MOS.

- In most cases, the statistical rollback method was applied to FC data from the most critical season, and the resultant recommended TMDL target annual FC load reductions are more stringent than would be required under the listed Washington State *Primary Contact* and *Secondary Contact Recreation* uses.

- The rollback method assumes that the variance of the pre-management data set will be equivalent to the variance of the post-management data set. As pollution sources are managed, the occurrence of high FC values is likely to be less frequent, reducing the variance and 90^{th} percentile of the post-management condition.

- The simple mass balance calculations and subsequent derivation of target values in freshwater assumed no FC die-off. Dilution and die-off of FC in the marine water from the Samish River to Samish Bay were also not included in the analysis.

- Since the variability in FC concentrations during low-flow conditions is usually quite high, the recommended TMDL targets and percent reductions estimated by the statistical rollback method are conservative, especially if a 90^{th} percentile is the critical criterion. In these cases, the high coefficient of variation of the log-normalized data can produce a 90^{th} percentile value for the population greater than any of the sample results used to calculate the value. This is especially true at sites with fewer than 20 data.

- The cumulative tributary FC loads to the Samish River should be reduced by 80% under the recommended TMDL targets. A 72% reduction of FC is recommended at the terminal compliance site on the Samish River.

- Marine water criteria were used to calculate recommended terminal FC targets and load reductions for the Samish River and Alice Bay slough. Using marine water criteria to set terminal freshwater FC targets and load allocations ensures further protection of the Samish Bay.

- Fecal coliform targets and recommended load allocations at Samish River miles 4.6 and 6.5 were calculated to ensure that the Samish River at the lowermost site (river mile 0.7) can meet Washington State marine water criteria.

- Recommended load allocations were set downstream from suspected nonpoint sources. The reduction or elimination of FC at upstream sources will likely bring downstream sites into compliance with water quality criteria. The downstream sites add assurance that any other FC nonpoint (diffuse) sources will be identified and reduced.

Conclusions

The following is a summary of conclusions based on this 2006-07 FC TMDL evaluation:

- The geographic extent of fecal coliform (FC) bacteria problems is much wider than indicated by the 303(d) listings.
- Higher streamflows and loading influence the bay's FC more than FC concentrations alone.
- The Samish River is the largest contributor of FC, with 83% of the total freshwater discharge and 70% of the total loading to Samish Bay.
- Highest FC loads occur in the wet season (November – June) and during storm events.
- Highest freshwater FC concentrations occur mostly in the dry season (July – October).
- Storm events often result in elevated FC levels, especially if they occur after a dry period.
- The highest FC concentrations in the Samish River were found at river mile (RM) 28.8, while the lowest concentrations were found at RM 26.6.
- Samish River FC loads increase from RM 26.6 to RM 10.3 and stabilize downstream of RM 10.3 (Hwy 99).
- Implementing a 72% FC load reduction at Samish RM 0.7, and various reductions at Colony Creek and all sloughs to Samish Bay, should be adequate to protect shellfish harvesting areas and other beneficial uses in Samish Bay.
- The sources of FC contamination in the watershed are not obvious, but probably include surface flow from areas where livestock or manure application is occurring during rain events, malfunctioning on-site septic systems, waterfowl and wildlife, stormwater runoff, pets, non-commercial farm animals, and recreational users.
- Fecal coliform concentrations at Samish RM 10.3, Ecology's ambient monitoring station, are slowly decreasing over the long-term but do not yet meet Washington State water quality criteria.

Recommendations

The following is a summary of recommendations based on this 2006-07 fecal coliform TMDL evaluation:

- Cleaning up direct sources of FC bacteria to the bay is the highest priority. Since Samish River is the largest FC source; clean up should begin there.
- Priority should also be given to the sloughs in south Edison, north Edison, Alice Bay, and Colony Creek since they contribute the highest loads, other than the Samish River, to Samish Bay.
- Other priority sites should include upper Samish River, upper Thomas Creek, and lower Friday Creek, as well as Parson, Skarrup, and Swede Creeks.
- Most reaches require more intensive spatial and temporal monitoring to better identify sources of FC contamination.
- Septic inspections and repairs should be completed in a timely manner to eliminate human waste as a source of FC to the bay.
- Circulation patterns in the bay should be further studied so that FC dispersion during different hydrologic and wind conditions can be characterized.
- Birds are common in the lower Samish watershed. Performing a detailed study of temporal and spatial patterns of bird migration might help to track their waste and its effect on bay FC bacteria concentrations.
- Education and signage may increase recreational users' awareness of the importance of properly disposing human and pet waste. More toilet facilities at key recreational sites may further ensure proper disposal of human and pet waste.

References

Ahmed, A. and C. Hempleman, 2006. Tributaries to Totten, Eld, and Little Skookum Inlets – Fecal Coliform Bacteria and Temperature Total Maximum Daily Load: Water Quality Improvement Report. Washington State Department of Ecology, Olympia, WA. 98 pgs. Publication No. 06-03-007. www.ecy.wa.gov/biblio/0603007.html

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., 2003. WQHydro: Water Quality/Hydrology Graphics/Analysis System. Portland, OR.

Coots, R., 2002. Colville River Fecal Coliform Total Maximum Daily Load Study. Washington State Department of Ecology, Olympia, WA. 30 pgs + appendices. Publication No. 02-03-036. www.ecy.wa.gov/biblio/0203036.html

Cusimano, R. and D. Giglio, 1995. Salmon Creek Nonpoint Source Pollution TMDL. Washington State Department of Ecology, Olympia, WA. Publication No. 95-355. www.ecy.wa.gov/biblio/95355.html

Cusimano, R., 1997. Water Quality Assessment of Tributaries to the Snohomish River and Nonpoint Source Pollution TMDL Study. Washington State Department of Ecology, Olympia, WA. 52 pgs. Publication No. 97-334. www.ecy.wa.gov/biblio/97334.html.

Dewey, B., 2005. Electronic mail, December, 2005. Taylor Shellfish Company. Shelton, WA.

DOH, 2005. Samish Bay Shellfish Classification Map. Washington State Department of Health, Olympia, WA. www.doh.wa.gov/ehp/sf/Pubs/gareports/samish.pdf

DOH, 2007. Atlas of Fecal Coliform Pollution in Puget Sound: Year 2005. Washington State Department of Health, Olympia, WA. Publication No. 332-061.

Ecology, 1993. Field Sampling and Measurement Protocols for the Watershed Assessments Section. Washington State Department of Ecology, Olympia, WA. Publication No. 93-e04. www.ecy.wa.gov/biblio/93e04.html

Ecology, 2005. 2004 Water Quality Assessment (Final) – Category 5 Listings. Washington State Department of Ecology, Olympia, WA. Doesn't work

EPA, 2001. Overview of Current Total Maximum Daily Load - TMDL - Program and Regulations. U.S. Environmental Protection Agency. www.epa.gov/owow/tmdl/policy.html

Haley, R., 2004. Samish Bay Watershed Water Quality Monitoring Project, Final Report. Skagit County Public Works Department. Mt. Vernon, WA.

Joy, J., 2000. Lower Nooksack River Basin Bacteria Total Maximum Daily Load Evaluation. Washington State Department of Ecology. Olympia, WA. 60 pgs. Publication No. 00-03-006. www.ecy.wa.gov/biblio/0003006.html

Joy, J. and T. Swanson, 2005. Walla Walla River Basin Fecal Coliform Total Maximum Daily Load Study. Washington State Department of Ecology. Olympia, WA. 76 pgs. Publication No. 05-03-041. www.ecy.wa.gov/biblio/0503041.html

Lennartson, D., 2005. Personal communication, June-November, 2005. Public Health Advisor, Office of Food, Safety, and Shellfish Programs. Division of Environmental Health, Washington State Department of Health, Olympia, WA.

Marsh McBirney, 2008. FlowCalculator.com. www.marsh-mcbirney.com/flowcalculator/

Mathieu, N., 2006. Replicate Precision for 12 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, 2005. Lab User's Manual, Eighth Edition. Manchester Environmental Laboratory, Environmental Assessment Program, Washington State Department of Ecology, Manchester, WA.

Ott, W., 1997. Environmental Statistics and Data Analysis. Lewis Publishers, New York, NY.

Palmer, R., Knable, R., and Pfaff, B., 1996. Storm Event Monitoring in the Lower Samish Watershed. Skagit County Health Department, Skagit County Conservation District, Skagit County Planning and Permit Center, and Washington State Department of Ecology. Mt. Vernon, WA.

Pelletier, G. and K. Seiders, 2000. Grays Harbor Fecal Coliform Total Maximum Daily Load Study. Washington State Department of Ecology, Olympia, WA. 110 pgs. Publication No. 00-03-020. www.ecy.wa.gov/biblio/0003020.html

Roberts, M., 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

Samish Watershed Management Committee, 1995. Skagit County Department of Planning and Community Development and Washington State Department of Ecology, 1995. Samish Bay Watershed Nonpoint Action Plan and Final Closure Response Strategy. December 1995.

Sargeant, D., 2002. Dungeness River and Matriotti Creek Fecal Coliform Bacteria Total Maximum Daily Load Study. Washington State Department of Ecology, Olympia, WA. 46 pgs. Publication No. 02-03-014. www.ecy.wa.gov/biblio/0203014.html.

Sargeant, D., M. Roberts, and B. Carey, 2005. Nisqually River Basin Fecal Coliform and Dissolved Oxygen Total Maximum Daily Load Study. Washington State Department of Ecology, Olympia, WA. 89 p. + app. Publication No. 05-03-002. www.ecy.wa.gov/biblio/0503002.html

Skagit Stream Team, 2004. Skagit Stream Team 2004 Water Quality Report: Citizen Monitoring Summary for the Nookachamps, Samish, and Padilla Bay Watersheds. Padilla Bay National Estuarine Reserve and Skagit Conservation District. Mt Vernon, WA.

Sullivan, L., 2008. Annual Growing Area Review. Washington State Department of Health, Office of Shellfish and Water Protection, Olympia, WA. www.doh.wa.gov/ehp/sf/Pubs/gareports/threatenedlist.pdf

Swanson, T., 2006. Quality Assurance Project Plan: Samish Bay Fecal Coliform Total Maximum Daily Load. Washington State Department of Ecology, Olympia, WA. 53 pgs. Publication No. 06-03-102. www.ecy.wa.gov/biblio/0603102.html

WAC 173-201A: Water Quality Standards for surface waters in the State of Washington Washington State Department of Ecology. www.ecy.wa.gov/laws-rules/ecywac.html

WSU, 2008. Washington State University's AgWeatherNet. Rainfall data from Sakuma and Mt. Vernon. http://weather.wsu.edu/awn.php

Ziebart, Kenneth D., 2008. Electronic mail, January, 2008. Water Quality Program, Washington State Department of Ecology, Olympia, WA.

This page is purposely left blank

Appendices

This page is purposely left blank

Appendix A. Glossary, acronyms, and abbreviations

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.

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

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 twenty-four 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.

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

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

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

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

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.

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.

Surface waters of the state: Lakes, rivers, ponds, streams, inland waters, salt waters, wetlands and all other surface waters and watercourses within the jurisdiction of Washington State.

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.

Wasteload allocation: The portion of a receiving water's loading capacity allocated to existing or future point sources of pollution. Wasteload allocations constitute 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.

Acronyms and Abbreviations

CAFO	Concentrated Animal Feeding Operation
Cfu	Colony forming units
DOH	Washington State Department of Health
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
FC	Fecal coliform
KES	Klebsiella, Enterococcus, and Serratia
MEL	Manchester Environmental Laboratory
MF	Membrane filter (method)
MPN	Most probable number (method)
MQO	Measurement quality objective
ppt	Parts per thousand
QA	Quality assurance
RM	River mile
RPD	Relative percent difference
RSD	Relative standard deviation
USGS	U.S. Geological Survey
WSDOT	Washington State Department of Transportation
WSU	Washington State University

This page is purposely left blank

Appendix B. Equations for statistical analysis – Statistical Theory of Rollback

The statistical rollback method proposed by Ott (1997) describes a way to use a numeric distribution of a water quality parameter to estimate the distribution after abatement processes are applied to sources. The method relies on basic dispersion and dilution assumptions and their effect on the distribution of a chemical or a bacterial population at a monitoring site downstream from a source. It then provides a statistical estimate of the new population after a chosen reduction factor is applied to the existing pollutant source. In the case of the Total Maximum Daily Load (TMDL), compliance with the most restrictive of the dual fecal coliform (FC) criteria will determine the reduction factor needed.

As with many water quality parameters, FC counts collected over time at an individual site usually follow a log-normal distribution. That is, over the course of sampling for a year, or multiple years, most of the counts are low, but a few are much higher. When monthly FC data are plotted on a logarithmic-probability graph, they appear to form nearly a straight line.

The 50th percentile (an estimate of the geometric mean) and the 90th percentile (a representation of the level over which 10% of the samples lie) can be located along a line plotted from an equation estimating the original monthly FC data distribution.

The following is a summary of the major theorems and corollaries for the Statistical Theory of Rollback (STR) from *Environmental Statistics and Data Analysis* by Ott (1997).

1. If Q = the concentration of a contaminant at a source, and D = the dilution-diffusion factor, and X = the concentration of the contaminant at the monitoring site, then X = Q*D.

2. Successive random dilution and diffusion of a contaminant Q in the environment often result in a log-normal distribution of the contaminant X at a distant monitoring site.

3. The coefficient of variation (CV) of Q is the same before and after applying a “rollback” (i.e., the CV in the post-control state will be the same as the CV in the pre-control state). The rollback factor = r, a reduction factor expressed as a decimal (a 70% reduction would be a rollback factor of 0.3). The random variable Q represents a pre-control source output state, and rQ represents the post-control state.

4. If D remains consistent in the pre-control and post-control states (long-term hydrological and climatic conditions remain unchanged), then CV(Q)*CV(D)=CV(X), and CV(X) will be the same before and after the rollback is applied.

5. If X is multiplied by the rollback factor, then the variance in the post-control state will be multiplied by r^2, and the post-control standard deviation will be multiplied by r.

6. If X is multiplied by the rollback factor, the quantiles of the concentration distribution will be scaled geometrically.

7. If any random variable is multiplied by r, then its expected value and standard deviation also will be multiplied by r, and its CV will be unchanged. (Ott uses “expected value” for the mean.)

This page is purposely left blank

Appendix C. Bacteria results

This page is purposely left blank

Table C-1. FC (cfu/100mL) results for regularly sampled sites from the 2006-07 TMDL study. November 6 and 7 storm event results are also shown.

Field ID w/ River Mile	map #	Feb 7-8	Feb 21-22	Mar 14-15	Mar 28-29	Apr 11-12	Apr 25-26	May 9-10	May 24-25	June 13-14	June 27-28	July 11-12	July 25-26	Aug 9-10	Aug 29-30	Sept 12-13	Sept 26-27	Oct 17-18	Oct 31-Nov 1	Nov 28	Dec 12-13	Dec 27	Jan 10-11	Jan 23-24	Feb 13-14	Feb 27-28	n	min	max	geo-metric mean	90th percen-tile	Nov 6 (storm)	Nov 7 (storm)
Samish River																																	
03-SAM-00.7	1	36	31	11	65	27	14	2	120	200	63	69	39	16	160	15	13	5	220	29	52	41	100	120	43	9	25	2	220	35	156	140	370
03-SAM-04.6	2	31	30	16	46	32	35	47	235	250	80	134	104	205	205	190	385	40	31	9	95	37	39	107	22	6	25	6	385	56	243	770	370
03-SAM-06.5	3	28	32	11	19	31	40	60	250	330	140	77	110	300	240	77	150	80	83	23	150	39	22	140	41	18	25	11	330	65	226	1600	350
03-SAM-10.3	4	34	10	4	80	33	32	89	200	250	220	180	80	510	120	220	200	210	20		210	23	12	20	36	14	24	4	510	62	322	1700	280
03-SAM-13.1	5	27	27	30	10	48	29	46	200	260	140	220	71	310	88	150	120	410	23		270	17	8	29	42	6	24	6	410	58	277	1100	270
03-SAM-15.0	6	24	11	5	8	16	30	9	90	100	67	400	54	950	69	27	51	47	13		150	17	6	16	46	14	24	5	950	34	177	900	
03-SAM-16.5	7	32	19	16	3	5	17	33	85	150	46	650	31	230	37	40	14	48	16		190	6	16	12	43	6	24	3	650	30	154	400	
03-SAM-20.7	8	4	1	24	1	14	1	9	45	49	100	560	54	290	51	17	2	14	12		20	6	7	10	3	3	24	1	560	13	114	280	
03-SAM-22.0	9	2	4	1	2	31	4	7	35	33	28	170	69	800	77	12	8	49	8		11	3	12	1	2	1	24	1	800	11	103	200	
03-SAM-26.6	10	1	1	2	1	2	8	14	92	51	20	190	46	210	80	68	7	14	20		7	1	2	4	7	6	24	1	210	10	92	92	
03-SAM-28.8	11	280	310	1100	140	1200	2500	1100	1800	450	150	390	54	3000	8	51	35	130	54		390	17	7	22	19	22	24	7	3000	149	1604	2800	
Samish River Tributaries																																	
03-ENN-00.0	12	1	1	1	1	1	1	1	7	22	35	470	200	310				8	2		35	3	1	1	1	8	21	1	470	5	80	69	
03-FRI-00.8	13	7	7	16	4	34	44	25	92	800	69	730	46	840	44	77	160	40	9		130	31	4	15	9	20	24	4	840	39	283	2100	200
03-FRI-03.8	14	4	10	4	7	41	16	19	75	220	150	1400	110	920	38	45	52	33	49		120	9	7	9	7	15	24	4	1400	34	257	1500	
03-FRI-06.5	15	1	1	1	4	99	7	11	47	56	41	92	34	130	37	12	33	12	18		9	6	4	5	1	1	24	1	130	11	82	430	
03-PAR-00.0	16	3	290	17	340	37	88	37	68	59	76	2700	2100	2500	2800	1700	770	3200	1400		25	1	6	1	65	8	24	1	3200	105	2839	10000	
03-SIL-00.4	17	7	6	2	2	5	17	19	25	63	25	620	31	64	7	4	9	13	4		9	6	18	5	2	3	24	2	620	11	59	360	
03-SWE-00.0	18	45	43	9	99	260	34	16	230	240	230	1200	38	800	85	290	140	170	31		210	69	14	15	14	11	24	9	1200	75	441	1700	
03-THO-00.3	19	8	150	77	49	37	67	160	84	43	80	200	140	740	1800	450	300	100	23		530	80	11	67	44	45	24	8	1800	96	488	1000	1500
03-THO-03.6	20	760	1100	71	470	1900	64	590	2600	900	2700	2400	1500	1900	5700	380	180	150	310		630	130	22	36	31	85	24	22	5700	399	3105	3500	480
03-WIL-00.0	21	220	71	140	140	240	120	250	340	830	7000	15000									730	200	23	38	170	13	17	13	15000	234	2327	9400	1900
Samish Bay Tributaries																																	
03-COL-00.0	22	6	18	21	56	36	73	55	140	100	210	140	190	84	92	39	110	310	34	88	13	34	37	51	7	34	25	6	310	52	189	200	40
03-ALI-PUMP	23	30	49	120	29	40	29	41	96	160	40	6	9	4	33	3	6	3	170	9	5	1	100	35	1	1	25	1	170	16	127	2800	5000
03-NED-PUMP	24	27	300	44	180	190	69	36	230	330	31		12	6	10	1	7	1	15	250	83	88	190	310	51	110	24	1	330	109	330	2400	4800
03-SED-PUMP	25	32	320	49	180	330	37	110	530	2400		260		230	200	84	170			88	59	120	300	330	100	310	21	32	2400	167	601	220	470
03-BAY-GATE	26	6	390	12	28	40	380	14	460	210	120	34	810	31	10	9	27	200	220	31	41	13	160	46	80	5	25	5	810	52	342	930	2700
03-ALI-GATE	27		230		26	26	15	16	72	52	33	5	3	9	9												12	3	230	21	96		
03-MCE-GATE	28	4	9	14	12	230	34	51	240	580	480	400	220	970	120	380	31	110	56	88	47	49	17	100	1	54	25	1	970	65	542	1600	43000
03-WED-GATE	29	20	32	1	2	3	65	160	80											610	46	200	220	100	51	80	15	1	610	41	428	320	1500
03-SMI-GATE	30													9				3	51					400			4	3	400			110	290
03-EDI-01.2	31	11	14	5	13	55	160	130	830	610	360	15	25	13	10	6		10	63	9	26	29	32	27	9	10	24	5	830	30	188	550	360
03-EDI-01.6	32	12	12	27	15	59	8	220	870	440	300	150	170	74	9	2	4	1	4	11	9	13	43	12	17	9	25	1	870	24	222	140	160
03-OYS-00.0	33	2	1	1	11	1	1	4	17	25	16	14	50	33	20	7	6	12	1	2	1	2	1	3	1	1	25	1	50	4	23	140	27

Table C-2. FC (cfu/100mL) results for investigatory, add-on, and special survey sites from the 2006-07 TMDL study. November 6 and 7 storm event results are also shown.

Field ID w/ River Mile	map #	Feb 7-8	Feb 21-22	Mar 14-15	Mar 28-29	Apr 11-12	Apr 25-26	May 9-10	May 24-25	June 13-14	June 27-28	July 11-12	July 25-26	Aug 9-10	Aug 29-30	Sept 12-13	Sept 26-27	Oct 17-18	Oct 31-Nov 1	Nov 28	Dec 12-13	Dec 27	Jan 10-11	Jan 23-24	Feb 13-14	Feb 27-28	n	min	max	geo-metric mean	90th percen-tile	Nov 6 (storm)
Investigatory, Add-on, and Special Survey Sites																																
03-DRY-00.0		7																														
03-SKA-00.5	**34**				100	190	140	73	640	800	430	480	220	2400	120	200	100	80	39		580	180	150	27	88	22	**21**	**22**	**2400**	**170**	**750**	3800
03-SAM-WF								31																			**1**					
03-BUT-00.0	**35**															220	40	92	80		140	39		27	21	30	**9**	**21**	**220**			900
03-FRI-04.3	**36**															43	80	13	77		49	8		2	4	3	**9**	**2**	**80**			970
03-SAM-28.8											150																**1**					
03-SAM-HW1											200																**1**					
03-SAM-HW2											180																**1**					
03-SAM-HW3											320																**1**					
03-SAM-HW4											320																**1**					
03-WIL-00.0	**21**																				730			38			**2**					
03-WIL-DIT																					1300			70			**2**					
03-WIL-00.2																					690			30			**2**					
03-WIL-DIT2																								14			**1**					
03-WIL-01.3																					1000			1			**2**					
03-WIL-01.6																								34			**1**					
03-WIL-01.7																					16			5			**2**					
03-SAM-09.2																					31						**1**					
03-DIT-00.0																					320						**1**					
03-SAM-09.6																					17						**1**					
03-BOB-00.0																					26						**1**					
03-SAM-10.0																					26						**1**					
03-COL-00.0																										34	**1**					
03-COL-00.3																										81	**1**					
03-COL-00.9																										12	**1**					
03-COL-01.2																										9	**1**					
03-COL-01.8																										5	**1**					

Table C-3. FC membrane filter (FCMF), FC most probable number (FCMPN), percent *Klebsiella*, *Enterococcus*, and *Serratia* (%KES), and *E. coli* membrane filter (ECMF) results from the 2006-07 TMDL study. All numbers except %KES are cfu/100mL.

Field ID w/River Mile	Feb 21 - 22			Mar 14		Apr 26			May 9		June 27-28			July 25		Aug 29-30			Oct 17		Oct 31 - Nov 1			Nov 28		Dec 27			Jan 9		Feb 13			Feb 27	
	FCMF	ECMF	%KES	FCMF	FCMPN	FCMF	ECMF	%KES	FCMF	FCMPN	FCMF	ECMF	%KES	FCMF	FCMPN	FCMF	ECMF	%KES	FCMF	FCMPN	FCMF	ECMF	%KES	FCMF	FCMPN	FCMF	ECMF	%KES	FCMF	FCMPN	FCMF	ECMF	%KES	FCMF	FCMPN
	7																																		
03-SAM-00.7	31	19	0/0*	11	23				2	33	63	96		39	79	160	83		5	11	220	100		29	33	41	34	0	100	540	43	29	0	9	6.8
03-SAM-13.1	27	27																																	
03-SAM-15.0						30		0																											
03-SAM-22.0	4		0			4		0																											
03-SAM-26.6						8	15	0			20		0			80		0			20		0												
03-SAM-28.8	310	250	0/0*			2500	2900	23/6*			120		15/0*			8		0			54		0/17*			17	57	33							
03-FRI-00.8	7	1	0													44		0			9		0												
03-FRI-06.5																										6		0							
03-THO-00.3	150	140	0																																
03-THO-03.6	1100	1100									2700		0																						
03-WIL-00.0	71	43				120	140				7000		0													200	92	78							
03-PAR-00.0																2800		0			1400		2												
03-COL-00.0	18	24		21	22				55	33				190	130				310	240				88	79				37	49					
03-ALI-PUMP	49	43	0	120	24														3	2				9	6.8	1		0	100	170	1	1		1	11
03-ALI-GATE																9	9																		
03-NED-PUMP	300	100		44	33						31	38																							
03-SED-PUMP	320	260		49	33																								300	240	100	88	0	310	350
03-BAY-GATE				12	33											10	18				220	120												5	49
03-WED-GATE	32	6		1	2				160	24																			220	540					
03-MCE-GATE														220	170	120	220		110	49	56	37		88	79	49	43		17	23	1	1		54	130
03-EDI-01.2	14	12		5	13				130	920	360	240		25	21	10	22				63	58		9	13	29	28		32	49	9	10	0/0*	10	13
03-EDI-01.6	12	6																																	
03-OYS-00.0									4	2				50	33				12	11				2	6.8										
03-SKA-00.5						140	110									120		10			39		0												

* QA sample result

This page is purposely left blank

Appendix D. Other laboratory and field results

Site	Date	Time	Temp (deg C)	D.O. (mg/L)	Conductivity (umhos/cm)	Turbidity (NTU)	Flow (cfs)	Flow Comments	Sampling Comments
03-ALI-GATE	2/21/2006	16:00	4.99	6.46	18400				upper 6" of water column
03-ALI-GATE	2/21/2006	16:01			24000				middle of water column
03-ALI-GATE	2/21/2006	16:02			34300				lower 6" of water column
03-ALI-GATE	2/21/2006	9:55			40000				
03-ALI-GATE	3/28/2006	12:50	10	8.82	35400				upper 6" of water column
03-ALI-GATE	3/28/2006	12:51	9.36		39000				lower 6" of water column
03-ALI-GATE	4/11/2006	12:40	13.21	8.41	30000	26			upper 6" of water column
03-ALI-GATE	4/11/2006	12:41	12.7		40000				lower 6" of water column
03-ALI-GATE	4/25/2006	13:15	17.44	9.02	23400				upper 6" of water column
03-ALI-GATE	4/25/2006	13:16			25500				lower 6" of water column
03-ALI-GATE	5/9/2006	12:30	17.2	15.15	23500	31			
03-ALI-GATE	5/25/2006	12:00	16.98	13.14					
03-ALI-GATE	6/13/2006	10:25	16.49	6.3	41800	8.4			upper 6" of water column
03-ALI-GATE	6/13/2006	10:26			41800				lower 6" of water column
03-ALI-GATE	6/27/2006	13:10	23.23		39400	53			
03-ALI-GATE	7/11/2006	10:30	16.37	7.08	42400	7.1			
03-ALI-GATE	7/25/2006	13:25	23.04	7.89	42400				
03-ALI-GATE	8/9/2006	15:15	19.72	5.5	43300	7.7			
03-ALI-GATE	8/29/2006	14:40	17.05	5.17	36100				
03-ALI-PUMP	2/7/2006	15:00	8.03	6.38	8000	27			upper 6" of water column
03-ALI-PUMP	2/7/2006	15:01			37000				lower 6" of water column
03-ALI-PUMP	2/21/2006	9:30	4.31	6.1	1200				upper 6" of water column
03-ALI-PUMP	2/21/2006	9:31			3900				middle of water column
03-ALI-PUMP	2/21/2006	9:32			40000				lower 6" of water column
03-ALI-PUMP	3/14/2006	9:35	6.42		19300	50			
03-ALI-PUMP	3/28/2006	12:40	10.1	10.1	26400				
03-ALI-PUMP	4/11/2006	12:20	13.58	10.82	21000	30			
03-ALI-PUMP	4/25/2006	13:00	15.6	11.92	17000				upper 6" of water column
03-ALI-PUMP	4/25/2006	13:01			33000				middle of water column
03-ALI-PUMP	4/25/2006	13:02			42500				lower 6" of water column
03-ALI-PUMP	5/9/2006	12:15	17.59	17.1	2100	24			upper 6" of water column
03-ALI-PUMP	5/9/2006	12:16			42000				lower 6" of water column
03-ALI-PUMP	5/25/2006	12:10	18.69	16.99					upper 6" of water column
03-ALI-PUMP	5/25/2006	12:11	14.5						lower 6" of water column
03-ALI-PUMP	6/13/2006	10:15	18.42	10.1	27900	19			upper 6" of water column
03-ALI-PUMP	6/13/2006	10:16			41000				lower 6" of water column
03-ALI-PUMP	6/27/2006	12:40	24.29		39000	16			upper 6" of water column
03-ALI-PUMP	6/27/2006	12:41	19.18		41000				lower 6" of water column
03-ALI-PUMP	7/11/2006	10:05	18.59	11.5	41400	9.5			upper 6" of water column
03-ALI-PUMP	7/11/2006	10:06	16.03		45300				lower 6" of water column
03-ALI-PUMP	7/25/2006	13:15	23.87	19.51	43300				upper 6" of water column
03-ALI-PUMP	7/25/2006	13:16	22.48		44000				lower 6" of water column
03-ALI-PUMP	8/9/2006	14:50	21.24	5.3	43500	4.7			upper 6" of water column
03-ALI-PUMP	8/9/2006	14:51	19.58		44600				lower 6" of water column
03-ALI-PUMP	8/29/2006	14:50	18.67	14.65	36100				
03-ALI-PUMP	9/12/2006	13:20	17.75	10.41	40000	7			
03-ALI-PUMP	10/17/2006	15:10	14.31	10.6	41000	12			upper 6" of water column

Site	Date	Time	Temp (deg C)	D.O. (mg/L)	Conductivity (umhos/cm)	Turbidity (NTU)	Flow (cfs)	Flow Comments	Sampling Comments
03-ALI-PUMP	10/17/2006	15:11	11.95		42600				lower 6" of water column
03-ALI-PUMP	10/31/2006	11:00	5.59	12.9	37400				upper 6" of water column
03-ALI-PUMP	10/31/2006	11:01	9		41600				lower 6" of water column
03-ALI-PUMP	11/6/2006	11:10			18000				upper 6" of water column
03-ALI-PUMP	11/6/2006	11:11			35000				lower 6" of water column
03-ALI-PUMP	11/7/2006	10:55			14200				upper 6" of water column
03-ALI-PUMP	11/7/2006	10:56			26000				lower 6" of water column
03-ALI-PUMP	11/28/2006	13:25	1.94	6.68	10500	27			upper 6" of water column
03-ALI-PUMP	11/28/2006	13:26	1.96		11500				lower 6" of water column
03-ALI-PUMP	12/12/2006	16:35	7.48	6.7	13300				upper 6" of water column
03-ALI-PUMP	12/12/2006	16:36	8.18		32100				lower 6" of water column
03-ALI-PUMP	12/27/2006	10:50	5.15	8.38	7200				upper 6" of water column
03-ALI-PUMP	12/27/2006	10:51	8.31		30000				lower 6" of water column
03-ALI-PUMP	1/9/2007	14:50	6.88	10.2	2500	290			upper 6" of water column
03-ALI-PUMP	1/9/2007	14:51	6.9		3500				lower 6" of water column
03-ALI-PUMP	1/23/2007	13:30		5.05					
03-ALI-PUMP	2/13/2007	13:35	7.89	7	12200	28			upper 6" of water column
03-ALI-PUMP	2/13/2007	13:36	7.86		15000				middle of water column
03-ALI-PUMP	2/13/2007	13:37	7.78		29500				lower 6" of water column
03-ALI-PUMP	2/27/2007	14:00	5.5	8.03	8000				upper 6" of water column
03-ALI-PUMP	2/27/2007	14:01	5		13000				middle of water column
03-ALI-PUMP	2/27/2007	14:02	6.31		34500				lower 6" of water column
03-BAY-GATE	2/7/2006	14:38	8.84	4.56	8600	28			upper 6" of water column
03-BAY-GATE	2/7/2006	14:39			16000				middle of water column
03-BAY-GATE	2/7/2006	14:40			36400				lower 6" of water column
03-BAY-GATE	2/21/2006	14:20	4.74	5.31	14600				
03-BAY-GATE	3/14/2006	14:30	9.09		14500	14			upper 6" of water column
03-BAY-GATE	3/14/2006	14:31			25000				lower 6" of water column
03-BAY-GATE	3/28/2006	12:25	9.17	9.9	14800				upper 6" of water column
03-BAY-GATE	3/28/2006	12:26	10.26		38500				lower 6" of water column
03-BAY-GATE	4/11/2006	11:30	10.56	6.25	20000	7.5			upper 6" of water column
03-BAY-GATE	4/11/2006	11:31	11.45		39300				lower 6" of water column
03-BAY-GATE	4/25/2006	12:40	15.37	10	1900				upper 6" of water column
03-BAY-GATE	4/25/2006	12:41			14000				lower 6" of water column
03-BAY-GATE	5/9/2006	11:30	16.59	9.47	20900	19			
03-BAY-GATE	5/25/2006	11:20	16.41	9.91					
03-BAY-GATE	6/13/2006	10:55	18.75	4.27	26800	9.95			
03-BAY-GATE	6/27/2006	12:15	23.05		27100				
03-BAY-GATE	7/11/2006	10:50	19.48	5.85	34400	7.2			turbidity is an estimate
03-BAY-GATE	7/25/2006	12:50	25.36	9.11	36200				
03-BAY-GATE	8/9/2006	14:25	21.71	8.89	40300	5.6			
03-BAY-GATE	8/29/2006	14:10	18.33	4.26	35100				
03-BAY-GATE	9/12/2006	13:40	21.2	12.65	36900	4.75			
03-BAY-GATE	10/17/2006	14:55	16	5.09	24000	31			
03-BAY-GATE	10/31/2006	10:45	8.1		27600				
03-BAY-GATE	11/6/2006	11:00			19000				
03-BAY-GATE	11/7/2006	10:45			11500				upper 6" of water column
03-BAY-GATE	11/7/2006	10:46			16500				lower 6" of water column
03-BAY-GATE	11/28/2006	13:00	2.76	6.97	7680	22			
03-BAY-GATE	12/12/2006	16:50	7.18	7.95	15300				
03-BAY-GATE	12/27/2006	10:35	5.04	8.15	8000				

Site	Date	Time	Temp (deg C)	D.O. (mg/L)	Conductivity (umhos/cm)	Turbidity (NTU)	Flow (cfs)	Flow Comments	Sampling Comments
03-BAY-GATE	1/9/2007	14:35	6.71	9.42	2580	130			
03-BAY-GATE	1/23/2007	13:45		7.85					
03-BAY-GATE	2/13/2007	13:20	8.14	6.95	10100	19			
03-BAY-GATE	2/27/2007	15:45	5.92	6.19	9400				upper 6" of water column
03-BAY-GATE	2/27/2007	15:46	5.74		32000				lower 6" of water column
03-BUT-00.0	9/13/2006	16:35	12.2		65.7		0.62		
03-BUT-00.0	9/26/2006	17:10					0.62		
03-BUT-00.0	9/27/2006	17:10	12.9		56.3				
03-BUT-00.0	10/18/2006	15:35	10.03		63.5		1.2		
03-BUT-00.0	11/1/2006	11:10					0.9		
03-BUT-00.0	11/6/2006	14:40					56		
03-BUT-00.0	12/13/2006	13:50	7.17		39.7		26	estimate	
03-BUT-00.0	12/27/2006	15:25	5.78		40.6		16		
03-BUT-00.0	1/24/2007	14:05					17	estimate	
03-BUT-00.0	2/14/2007	14:15	6.48		42.9		1.6		
03-BUT-00.0	2/28/2007	12:25	4.74		35.8		13		
03-COL-00.0	2/7/2006	10:20	5.42	9.82	500	6.2	27		upper 6" of water column
03-COL-00.0	2/7/2006	10:21			30000				lower 6" of water column
03-COL-00.0	2/21/2006	11:35	2.41	10.28	6500		5.7		upper 6" of water column
03-COL-00.0	2/21/2006	11:36			6600				lower 6" of water column
03-COL-00.0	3/14/2006	10:30	5.62		1230	20			
03-COL-00.0	3/28/2006	9:35	8.13	8.26	3440		11		
03-COL-00.0	4/11/2006	10:15	8.21	8.2	968	12	21		
03-COL-00.0	4/25/2006	11:00	12.29	7.94	5260		16		
03-COL-00.0	5/9/2006	9:15	9.51	7.9	855	7.4	6.4		
03-COL-00.0	5/25/2006	13:20	14.14	6.5	2100		3.2		
03-COL-00.0	6/13/2006	12:35	14.9	5.67	2940	12	4.4		
03-COL-00.0	6/27/2006	14:00	22.56		9120				
03-COL-00.0	6/27/2006	14:10					1.4		
03-COL-00.0	7/11/2006	13:00	18.92	11.67	19400	5	1		
03-COL-00.0	7/25/2006	10:45	25.89	8.11	34900		1.6		
03-COL-00.0	8/9/2006	12:00	20.9	9.71	32100	5.75	1.2		
03-COL-00.0	8/29/2006	10:35	17.47	4.68	23600		1	estimate	
03-COL-00.0	9/12/2006	10:10	15.5	6.79	25000	3	0.8	estimate	
03-COL-00.0	9/26/2006	11:00					0.4	estimate	
03-COL-00.0	10/17/2006	11:25	11.66	7.82	16500	7	0.37		
03-COL-00.0	10/31/2006	9:45	3.98	5.81	25600		0.3	estimate	
03-COL-00.0	11/6/2006	9:25			4300		91	estimate	
03-COL-00.0	11/7/2006	9:10			1200		55	estimate	
03-COL-00.0	11/28/2006	10:30	2.26	12.11	198		14	estimate	
03-COL-00.0	12/12/2006	10:50	7.04	11.27	444		15		upper 6" of water column
03-COL-00.0	12/12/2006	10:51	6.94		6700				middle of water column
03-COL-00.0	12/12/2006	10:52	7.05		42200				lower 6" of water column
03-COL-00.0	12/27/2006	9:10	5.66	10.92	177		28		upper 6" of water column
03-COL-00.0	12/27/2006	9:11	5.86		5000				middle of water column
03-COL-00.0	12/27/2006	9:12	5.83		40000				lower 6" of water column
03-COL-00.0	1/9/2007	10:55	7.27	11.07	127	4.2	49		upper 6" of water column
03-COL-00.0	1/9/2007	10:56	7.41		1000				middle of water column
03-COL-00.0	1/9/2007	10:57	7.8		34500				lower 6" of water column
03-COL-00.0	1/23/2007	11:30					40		
03-COL-00.0	2/13/2007	10:05	6.6	10.7	405	2.9	5		upper 6" of water column

Site	Date	Time	Temp (deg C)	D.O. (mg/L)	Conductivity (umhos/cm)	Turbidity (NTU)	Flow (cfs)	Flow Comments	Sampling Comments
03-COL-00.0	2/13/2007	10:06	7.62		3600				middle of water column
03-COL-00.0	2/13/2007	10:07	7.72		37300				lower 6" of water column
03-COL-00.0	2/27/2007	10:55	4.07		296		20		upper 6" of water column
03-COL-00.0	2/27/2007	10:56	4.07		277				middle of water column
03-COL-00.0	2/27/2007	10:57	4.05		291				lower 6" of water column
03-DRY-00.0	3/15/2006	11:25	5.01		43				
03-EDI-01.2	2/7/2006	12:45	5.75	8.08	142	20			
03-EDI-01.2	2/21/2006	13:30	2.85	8.4	206				
03-EDI-01.2	3/14/2006	12:30	7		220	15			
03-EDI-01.2	3/28/2006	10:50	8.91	6.97	585				
03-EDI-01.2	4/11/2006	13:40	14.18	10.61	238	15			
03-EDI-01.2	4/25/2006	14:40	18.41	8.83	6800				
03-EDI-01.2	5/9/2006	10:25	13.96	7.8	807	9.4			
03-EDI-01.2	5/25/2006	12:30	19.34	7.5	1490				
03-EDI-01.2	6/13/2006	11:30	18.85	4.11	1940	20			
03-EDI-01.2	6/27/2006	10:40	22.79		25700				
03-EDI-01.2	7/11/2006	11:40	22.32	8.2	34800	18			
03-EDI-01.2	7/25/2006	11:35	25.47	4.53	42700				
03-EDI-01.2	8/9/2006	12:35	20.65	4.86	44800	11			
03-EDI-01.2	8/29/2006	11:00	18.72	2.04	26000				
03-EDI-01.2	9/12/2006	14:40	22.4	11.1	28000	9.7			
03-EDI-01.2	10/17/2006	10:40	10.41	4.39	38700	8.8			
03-EDI-01.2	10/31/2006	10:05	1.7	7.41	35200				
03-EDI-01.2	11/6/2006	10:05			9000				upper 6" of water column
03-EDI-01.2	11/6/2006	10:06			28000				lower 6" of water column
03-EDI-01.2	11/7/2006	9:50			5500				upper 6" of water column
03-EDI-01.2	11/7/2006	9:51			23000				lower 6" of water column
03-EDI-01.2	11/28/2006	11:40	0.91	8.72	522				
03-EDI-01.2	12/12/2006	12:30	6.71	6.65	2100				upper 6" of water column
03-EDI-01.2	12/12/2006	12:31	6.67		8500				lower 6" of water column
03-EDI-01.2	12/27/2006	9:45	4.71	8.66	327				
03-EDI-01.2	1/9/2007	13:00	6.24	9.96	126	22			
03-EDI-01.2	1/23/2007	14:40		9.07					
03-EDI-01.2	2/13/2007	11:40	6.84	6.52	629	21			upper 6" of water column
03-EDI-01.2	2/13/2007	11:41	7.32		28000				lower 6" of water column
03-EDI-01.2	2/27/2007	12:45	5.84	9.01	203				upper 6" of water column
03-EDI-01.2	2/27/2007	12:46	4.56		358				middle of water column
03-EDI-01.2	2/27/2007	12:47	4.75		12000				lower 6" of water column
03-EDI-01.6	2/7/2006	12:15	5.92	8.27	125	17			
03-EDI-01.6	2/21/2006	13:00	2.81		206				
03-EDI-01.6	3/14/2006	12:20	6.95		165	7.3			
03-EDI-01.6	3/28/2006	11:10	9.25	7.4	354				
03-EDI-01.6	4/11/2006	14:00	13.65	11.65	141				
03-EDI-01.6	4/25/2006	14:25	20.6	12.24	488				upper 6" of water column
03-EDI-01.6	4/25/2006	14:26			530				lower 6" of water column
03-EDI-01.6	5/9/2006	10:05	12.68	5.7	441	7.6			
03-EDI-01.6	5/25/2006	12:50	19.13	11.51	3500				
03-EDI-01.6	6/13/2006	11:40	18.07	6.57	540	8.5			
03-EDI-01.6	6/27/2006	11:00	23.11		1700				
03-EDI-01.6	7/11/2006	12:05	22.56	9.1	24400	6.7			
03-EDI-01.6	7/25/2006	12:05	24.48	11.49	40000				

Site	Date	Time	Temp (deg C)	D.O. (mg/L)	Conductivity (umhos/cm)	Turbidity (NTU)	Flow (cfs)	Flow Comments	Sampling Comments
03-EDI-01.6	8/9/2006	12:30	20.59	4.6	44900	13			
03-EDI-01.6	8/29/2006	10:50	18.1	2.4	35000				
03-EDI-01.6	9/12/2006	14:50	26.62	19.49	41000	3.2			
03-EDI-01.6	10/17/2006	10:55	11.91		37900	16			
03-EDI-01.6	10/31/2006	10:00	7.65	13.9	33900				
03-EDI-01.6	11/6/2006	10:00			20000				
03-EDI-01.6	11/7/2006	9:40			12100				
03-EDI-01.6	11/28/2006	11:25	0.88	8.59	336				
03-EDI-01.6	12/12/2006	12:55	6.92	5.85	620				
03-EDI-01.6	12/27/2006	9:20	4.89	8.17	248				
03-EDI-01.6	1/9/2007	12:50	6.22	9.5	103	17.5			
03-EDI-01.6	2/13/2007	11:25	7.36	5.54	290	6			upper 6" of water column
03-EDI-01.6	2/13/2007	11:26	7.4		536				lower 6" of water column
03-EDI-01.6	2/27/2007	12:35	5.27	8.31	152				upper 6" of water column
03-EDI-01.6	2/27/2007	12:36	4.98		4000				lower 6" of water column
03-ENN-00.0	2/8/2006	14:35	6.17		33.6		21		
03-ENN-00.0	2/22/2006	14:25	4.22		41		4.3		
03-ENN-00.0	3/15/2006	13:05	5.38		39.5		5.9		
03-ENN-00.0	3/29/2006	14:05	7.09		36.4		8		
03-ENN-00.0	4/12/2006	15:25	7.13		36.4		9.9		
03-ENN-00.0	4/26/2006	13:00	6.93		37.7		8.1		
03-ENN-00.0	5/10/2006	13:30	8.57		43.3		3.9		
03-ENN-00.0	5/24/2006	14:15	11.1		54		2.1		
03-ENN-00.0	6/14/2006	12:35	11.32		43.4		3.4		
03-ENN-00.0	6/28/2006	15:00	14.2		50.8		0.54		
03-ENN-00.0	7/12/2006	15:40	13.11		56.5		0.26		
03-ENN-00.0	7/26/2006	16:15	18.34		69.8		0.1		
03-ENN-00.0	8/10/2006	14:20	16.13		72.1		0.07		
03-ENN-00.0	8/30/2006	14:10	14.89		153		0		
03-ENN-00.0	10/18/2006	14:30	10.57		95.5		0.07		
03-ENN-00.0	11/1/2006	10:25	4.59		79.2		0.15		
03-ENN-00.0	11/6/2006	13:55					78		
03-ENN-00.0	12/13/2006	13:10	6.91		21.4		41		
03-ENN-00.0	12/27/2006	14:35	5.05		32.2		20		
03-ENN-00.0	1/10/2007	14:20	3.55		32.1		29		
03-ENN-00.0	1/24/2007	13:30					21		
03-ENN-00.0	2/14/2007	13:25	5.76		35.9		5.2		
03-ENN-00.0	2/28/2007	11:10	4.21		31.3		14		
03-FRI-00.8	2/8/2006	16:35	7.18		55.1		230		
03-FRI-00.8	2/22/2006	10:50	4.41		59		72		
03-FRI-00.8	3/15/2006	10:10	5.79		58.9		77		
03-FRI-00.8	3/29/2006	11:40	8.19		63.5		45		
03-FRI-00.8	4/12/2006	13:55	9.68		61.3		56		
03-FRI-00.8	4/26/2006	15:35	10.2		63.2		60		
03-FRI-00.8	5/10/2006	11:40					38		
03-FRI-00.8	5/24/2006	11:20	13.52		83.5		17		
03-FRI-00.8	6/14/2006	10:05	14.49		69.5		26		
03-FRI-00.8	6/28/2006	12:10	16.88		92.8		4.1		
03-FRI-00.8	7/12/2006	12:50	14.59		99.5		4.7		
03-FRI-00.8	7/26/2006	12:30	19.8		100		7.7		
03-FRI-00.8	8/10/2006	12:30	15.13		103		23		

Site	Date	Time	Temp (deg C)	D.O. (mg/L)	Conductivity (umhos/cm)	Turbidity (NTU)	Flow (cfs)	Flow Comments	Sampling Comments
03-FRI-00.8	8/30/2006	11:45	14.09		130		10		
03-FRI-00.8	9/13/2006	11:10	12.98		110		33		
03-FRI-00.8	9/27/2006	14:40	14.43		76.9		15	estimate	
03-FRI-00.8	10/18/2006	11:45	11.4		77.4		26		
03-FRI-00.8	10/31/2006	12:40	4.94		90.6		12		
03-FRI-00.8	11/6/2006	12:45					430		
03-FRI-00.8	11/7/2006	12:25					360		
03-FRI-00.8	12/13/2006	11:30	6.77		53.3		270		
03-FRI-00.8	12/27/2006	12:30	5.49		52.9		220		
03-FRI-00.8	1/10/2007	12:50	3.86		51.3		360		
03-FRI-00.8	1/24/2007	12:30					190		
03-FRI-00.8	2/14/2007	11:15	5.86		59.7		44		
03-FRI-00.8	2/28/2007	9:50	4.69		51.4		140		
03-FRI-03.8	2/8/2006	15:55	7.36		54.5		140		
03-FRI-03.8	2/22/2006	15:05	5		58.7		56		
03-FRI-03.8	3/15/2006	14:20	6.02		57.6		63		
03-FRI-03.8	3/29/2006	15:45	8.6		59.6		33		
03-FRI-03.8	4/12/2006	16:35	9.68		60.5		46		
03-FRI-03.8	4/26/2006	14:40	10.01		60.5		49		
03-FRI-03.8	5/10/2006	14:15	12.71		63.1		33		
03-FRI-03.8	5/24/2006	15:20	14.86		79.8		18		
03-FRI-03.8	6/14/2006	14:10	14.98		66		19		
03-FRI-03.8	6/28/2006	17:50					5		
03-FRI-03.8	7/12/2006	17:05	14.86		78.8		5.1		
03-FRI-03.8	7/26/2006	17:15	20.35		89.3		2.3		
03-FRI-03.8	8/10/2006	15:00	16.56		95.3		4.2		
03-FRI-03.8	8/30/2006	15:10	15.4		97.8		1.4		
03-FRI-03.8	9/13/2006	15:45	14.03		88.2		3.4		
03-FRI-03.8	9/27/2006	16:50	15.4		66.3		8.5		
03-FRI-03.8	10/18/2006	15:30	12.37		70.8		13		
03-FRI-03.8	11/1/2006	11:05	3.12		77.7				
03-FRI-03.8	11/1/2006	11:10					4.2		
03-FRI-03.8	11/6/2006	14:25					220		
03-FRI-03.8	12/13/2006	13:40	6.92		51.6		160		
03-FRI-03.8	12/27/2006	15:15	5.53		52.8		130		
03-FRI-03.8	1/10/2007	15:35	3.66		50.4		190		
03-FRI-03.8	1/24/2007	13:55					130		
03-FRI-03.8	2/14/2007	14:05	5.94		56.2		46		
03-FRI-03.8	2/28/2007	12:05	4.77		50		100		
03-FRI-04.3	9/13/2006	16:50	14.17		91.6		3.1		
03-FRI-04.3	9/27/2006	17:20	15.95		67.9		8.2		
03-FRI-04.3	10/18/2006	15:45	12.65		71.5		13		
03-FRI-04.3	11/1/2006	11:15					3.3		
03-FRI-04.3	11/6/2006	14:30					160		
03-FRI-04.3	12/13/2006	13:55	6.92		53.8		130		
03-FRI-04.3	12/27/2006	15:30	5.5		54.3		120		
03-FRI-04.3	1/24/2007	14:00					180		
03-FRI-04.3	2/14/2007	14:30	5.74		58.2		44		
03-FRI-04.3	2/28/2007	12:30	4.8		51.8		87		
03-FRI-06.5	2/8/2006	16:15	7.34		57.5		120		
03-FRI-06.5	2/22/2006	15:45	5.24		57.9		42		

Site	Date	Time	Temp (deg C)	D.O. (mg/L)	Conductivity (umhos/cm)	Turbidity (NTU)	Flow (cfs)	Flow Comments	Sampling Comments
03-FRI-06.5	3/15/2006	14:45	6.02		56.5		45		
03-FRI-06.5	3/29/2006	16:30	8.97		58.5		17		
03-FRI-06.5	4/12/2006	17:05	9.84		59.3		24		
03-FRI-06.5	4/26/2006	15:05	10.13		59.1		35		
03-FRI-06.5	5/10/2006	14:30	14.09		60.3		17		
03-FRI-06.5	5/24/2006	15:45	15.49		70		11		
03-FRI-06.5	6/14/2006	14:35	15.99		62.6		8.9		
03-FRI-06.5	6/28/2006	18:25					1.8		
03-FRI-06.5	7/12/2006	17:40	16.36		71.5		1.6		
03-FRI-06.5	7/26/2006	17:40	22.2		73.2		0.3	estimate	
03-FRI-06.5	8/10/2006	15:15	17.92		76.7		1.3	estimate	
03-FRI-06.5	8/30/2006	15:35	17.07		83.1		0.1	estimate	
03-FRI-06.5	9/13/2006	17:25	16.15		71.2		0.9	estimate	
03-FRI-06.5	9/27/2006	17:45	17.9		61.9		3.5	estimate	
03-FRI-06.5	10/18/2006	16:10	13.63		63.1		5.8	estimate	
03-FRI-06.5	11/1/2006	11:30	4.81		63		1.3	estimate	
03-FRI-06.5	11/6/2006	15:00					190		
03-FRI-06.5	12/13/2006	14:10	7.1		55.3		130		
03-FRI-06.5	12/27/2006	15:45	5.76		55.5		110		
03-FRI-06.5	1/10/2007	15:50					170		
03-FRI-06.5	1/24/2007	14:15					110		
03-FRI-06.5	2/14/2007	14:50	5.56		55.7		30		
03-FRI-06.5	2/28/2007	12:45	4.94		53		80		
03-MCE-GATE	2/7/2006	9:59	5.8	6.39	4000	31			upper 6" of water column
03-MCE-GATE	2/7/2006	10:00			30000				lower 6" of water column
03-MCE-GATE	2/21/2006	12:40	4.96	2.54	15500				upper 6" of water column
03-MCE-GATE	2/21/2006	12:41			18000				middle of water column
03-MCE-GATE	2/21/2006	12:42			36000				lower 6" of water column
03-MCE-GATE	3/14/2006	11:25	6.94		15700	23			upper 6" of water column
03-MCE-GATE	3/14/2006	11:26			22400				middle of water column
03-MCE-GATE	3/14/2006	11:27			28200				lower 6" of water column
03-MCE-GATE	3/28/2006	10:05	9.04	1.38	20000				upper 6" of water column
03-MCE-GATE	3/28/2006	10:06			35000				lower 6" of water column
03-MCE-GATE	4/11/2006	10:40	9.95	1.41	18800	19			
03-MCE-GATE	4/25/2006	10:45	12.08	2.25	15600				
03-MCE-GATE	5/9/2006	9:45	10.7	0.3	14300	50			
03-MCE-GATE	5/25/2006	13:05	16.09	3.21					
03-MCE-GATE	6/13/2006	12:10	15.62	1.8	17300	50			
03-MCE-GATE	6/27/2006	13:45	24.01		25600				
03-MCE-GATE	7/11/2006	12:40	17.18	5.06	24200	35			
03-MCE-GATE	7/25/2006	11:05	18.11	1.98	22800				
03-MCE-GATE	8/9/2006	11:30	16.17	2.3	21800	35			
03-MCE-GATE	8/29/2006	10:15	14.09	0	40000				
03-MCE-GATE	9/12/2006	10:35	12.7	0	24800	72			
03-MCE-GATE	10/17/2006	11:50	11.41	0.07	20400	85			
03-MCE-GATE	10/31/2006	9:20	3.41	1.29	23400				
03-MCE-GATE	11/6/2006	9:40			2200				upper 6" of water column
03-MCE-GATE	11/6/2006	9:41			23600				lower 6" of water column
03-MCE-GATE	11/7/2006	9:25			5100				upper 6" of water column
03-MCE-GATE	11/7/2006	9:26			19000				lower 6" of water column
03-MCE-GATE	11/28/2006	10:50	2.41	4.53	5120	29			upper 6" of water column

Site	Date	Time	Temp (deg C)	D.O. (mg/L)	Conductivity (umhos/cm)	Turbidity (NTU)	Flow (cfs)	Flow Comments	Sampling Comments
03-MCE-GATE	11/28/2006	10:51	2.39		5250				lower 6" of water column
03-MCE-GATE	12/12/2006	12:05	7.85	4.09	11000				upper 6" of water column
03-MCE-GATE	12/12/2006	12:06	8.71		13500				middle of water column
03-MCE-GATE	12/12/2006	12:07	8.06		19500				lower 6" of water column
03-MCE-GATE	12/27/2006	8:55	5.51	4.72	5700				upper 6" of water column
03-MCE-GATE	12/27/2006	8:56	5.53		9100				lower 6" of water column
03-MCE-GATE	1/9/2007	10:40	7.27	5.5	3200	32			upper 6" of water column
03-MCE-GATE	1/9/2007	10:41	7.52		12000				lower 6" of water column
03-MCE-GATE	1/23/2007	12:30		7.12					
03-MCE-GATE	2/13/2007	11:10	8.06	9.35	44800	1.8			
03-MCE-GATE	2/27/2007	10:40	4.81	2.58	12800				upper 6" of water column
03-MCE-GATE	2/27/2007	10:41	9.09		40000				lower 6" of water column
03-NED-PUMP	2/7/2006	13:10	7.55	3.9	10600	45			sampled at end of pipe
03-NED-PUMP	2/21/2006	10:35	4.59	3.95	9900				sampled at end of pipe
03-NED-PUMP	3/14/2006	9:00	6.57		5000	30			upper 6" of water column
03-NED-PUMP	3/14/2006	9:01			10000				middle of water column
03-NED-PUMP	3/14/2006	9:02			33000				lower 6" of water column
03-NED-PUMP	3/28/2006	11:30	9.52	8	8270				upper 6" of water column
03-NED-PUMP	3/28/2006	11:31	9.49		8240				middle of water column
03-NED-PUMP	3/28/2006	11:32	9.53		13300				lower 6" of water column
03-NED-PUMP	4/11/2006	14:15	12.96	6.25	61.6	22			upper 6" of water column
03-NED-PUMP	4/11/2006	14:16	11.26		15500				lower 6" of water column
03-NED-PUMP	4/25/2006	11:35	15.3	9.4	4320				upper 6" of water column
03-NED-PUMP	4/25/2006	11:36			10500				middle of water column
03-NED-PUMP	4/25/2006	11:37			43900				lower 6" of water column
03-NED-PUMP	5/9/2006	14:10	12.6	5.56	13400	13			upper 6" of water column
03-NED-PUMP	5/9/2006	14:11			34000				middle of water column
03-NED-PUMP	5/9/2006	14:12	18.55		44000				lower 6" of water column
03-NED-PUMP	5/25/2006	15:30	20.32	11.73					upper 6" of water column
03-NED-PUMP	5/25/2006	15:31	16.5						lower 6" of water column
03-NED-PUMP	6/13/2006	9:35	17.64	1.97	21000	13			upper 6" of water column
03-NED-PUMP	6/13/2006	9:36			36500				lower 6" of water column
03-NED-PUMP	6/27/2006	10:25	21.7		33000				upper 6" of water column
03-NED-PUMP	6/27/2006	10:26			38500				lower 6" of water column
03-NED-PUMP	7/25/2006	11:50	23.85	12.28	40000				upper 6" of water column
03-NED-PUMP	7/25/2006	11:51	21.64		43500				lower 6" of water column
03-NED-PUMP	8/9/2006	13:25	20.67	8.56	44500	10			upper 6" of water column
03-NED-PUMP	8/9/2006	13:26	20.05		44600				lower 6" of water column
03-NED-PUMP	8/29/2006	11:15	18.31	2.28	27000				
03-NED-PUMP	9/12/2006	15:05	20.25	10.31	41500	2.8			
03-NED-PUMP	10/17/2006	13:55	14.14	6.5	38300	11			upper 6" of water column
03-NED-PUMP	10/17/2006	13:56	12.4		45000				lower 6" of water column
03-NED-PUMP	10/31/2006	10:20	4.94	5.23	37300				upper 6" of water column
03-NED-PUMP	10/31/2006	10:21	6.65		43200				lower 6" of water column
03-NED-PUMP	11/6/2006	10:15			17800				upper 6" of water column
03-NED-PUMP	11/6/2006	10:16			26000				lower 6" of water column
03-NED-PUMP	11/7/2006	10:00			7100				upper 6" of water column
03-NED-PUMP	11/7/2006	10:01			18500				lower 6" of water column
03-NED-PUMP	11/28/2006	12:00	1.3	7.85	4150	50			upper 6" of water column
03-NED-PUMP	11/28/2006	12:01	8.33		4500				lower 6" of water column
03-NED-PUMP	12/12/2006	12:40	7.28	8.9	9100				upper 6" of water column

Site	Date	Time	Temp (deg C)	D.O. (mg/L)	Conductivity (umhos/cm)	Turbidity (NTU)	Flow (cfs)	Flow Comments	Sampling Comments
03-NED-PUMP	12/12/2006	12:41	7.71		21800				lower 6" of water column
03-NED-PUMP	12/27/2006	9:30	4.57	8.1	2950				upper 6" of water column
03-NED-PUMP	12/27/2006	9:31	8.99		45000				lower 6" of water column
03-NED-PUMP	1/9/2007	13:40	7.07	8.6	1490	100			upper 6" of water column
03-NED-PUMP	1/9/2007	13:41	7.12		1520				lower 6" of water column
03-NED-PUMP	1/23/2007	15:25		7.45					
03-NED-PUMP	2/13/2007	11:55	7.84	5.43	28800	20			upper 6" of water column
03-NED-PUMP	2/13/2007	11:56	7.96		29100				middle of water column
03-NED-PUMP	2/13/2007	11:57	8.04		29500				lower 6" of water column
03-NED-PUMP	2/27/2007	13:10	6.47	4.36	8400				upper 6" of water column
03-NED-PUMP	2/27/2007	13:11	6.35		12000				middle of water column
03-NED-PUMP	2/27/2007	13:12	6.35		12000				lower 6" of water column
03-OYS-00.0	2/7/2006	9:22					23		
03-OYS-00.0	2/21/2006	11:05	3.4	13.9	75.7		4.8		
03-OYS-00.0	3/14/2006	10:00	4.66		70.6	0.5	9.4		
03-OYS-00.0	3/28/2006	9:25	6.67		76.6		5.2		
03-OYS-00.0	4/11/2006	9:40	6.75	11.89	69	0.9	10		
03-OYS-00.0	4/25/2006	9:25	8.62	11.4	72		9.6		
03-OYS-00.0	5/9/2006	14:35	9.5	11.4	79	0.5	3.8		
03-OYS-00.0	5/25/2006	14:45	11.46	10.6	89.9		4.5		
03-OYS-00.0	6/13/2006	13:05	12.29	10.37	79.5	0.7	3.6		
03-OYS-00.0	6/27/2006	14:40	14.62		108		1		
03-OYS-00.0	7/11/2006	13:20	13.05	10.22	125	<0.5	0.42		
03-OYS-00.0	7/25/2006	10:15	15.06	9.4	151		0.23		
03-OYS-00.0	8/9/2006	11:05	13.52	9.83	158	<0.5	0.23		
03-OYS-00.0	8/29/2006	9:50	13.15	9.6	173		0.07		
03-OYS-00.0	9/12/2006	11:10	12.06	10.65	210	<0.5	0.07		
03-OYS-00.0	9/26/2006	10:35					0.2	estimate	
03-OYS-00.0	10/17/2006	12:15	9.52	11.18	165	<0.5	0.2		
03-OYS-00.0	10/31/2006	9:05	4.35	10.9	134		0.2	estimate	
03-OYS-00.0	11/6/2006	9:15					85	estimate	
03-OYS-00.0	11/7/2006	9:00					51		
03-OYS-00.0	11/28/2006	10:10	1.11	14.01	65.8	0.6	11		
03-OYS-00.0	12/12/2006	10:30	6.4	12.15	59.9		16		
03-OYS-00.0	12/27/2006	8:30					25		
03-OYS-00.0	1/9/2007	10:15	6.76	12.03	58.9	2.5	46		
03-OYS-00.0	1/23/2007	11:05		12.69			38	estimate	
03-OYS-00.0	2/13/2007	9:20	6.22	12.3	76.7	0.5	4.1		
03-OYS-00.0	2/27/2007	10:10	3.65	12.94	61.2		18		
03-PAR-00.0	2/8/2006	11:35	7.27		41				
03-PAR-00.0	2/8/2006	12:35					3.6		
03-PAR-00.0	2/22/2006	12:10	6.2		64.5		0.77		
03-PAR-00.0	3/15/2006	11:20	6.18		51.7		1.6		
03-PAR-00.0	3/29/2006	12:45	9.12		62		0.88		
03-PAR-00.0	4/12/2006	14:30	8.4		50.5		1	estimate	
03-PAR-00.0	4/26/2006	11:25	8.64		63.5		0.82		
03-PAR-00.0	5/10/2006	13:00	10.8		78.5		0.7		
03-PAR-00.0	5/24/2006	12:45	11.57		86.5		0.36		
03-PAR-00.0	6/14/2006	10:40	11.55		45.1		1.5		
03-PAR-00.0	6/28/2006	13:30	13.42		85		0.24		
03-PAR-00.0	7/12/2006	13:50	12.07		88.5		0.25		

Site	Date	Time	Temp (deg C)	D.O. (mg/L)	Conductivity (umhos/cm)	Turbidity (NTU)	Flow (cfs)	Flow Comments	Sampling Comments
03-PAR-00.0	7/26/2006	14:20	15.31		98.1		0.11		
03-PAR-00.0	8/10/2006	13:25	13.14		73		0.19		
03-PAR-00.0	8/30/2006	12:45	13.27		102		0.07		
03-PAR-00.0	9/13/2006	13:10	12.43		111		0.07	estimate	
03-PAR-00.0	9/27/2006	15:35	14.64		92.6		0.05		
03-PAR-00.0	10/18/2006	12:50	10.58		107		0.1		
03-PAR-00.0	10/31/2006	13:25	5.97		105		0.1		
03-PAR-00.0	11/6/2006	13:20					12		
03-PAR-00.0	12/13/2006	12:20	6.69		33.3		6.3		
03-PAR-00.0	12/27/2006	13:10	5.59		38		3.2		
03-PAR-00.0	1/10/2007	13:30	4.19		36.3		4.7		
03-PAR-00.0	1/24/2007	13:00					3.2		
03-PAR-00.0	2/14/2007	12:10	7.24		69.6		0.3		
03-PAR-00.0	2/28/2007	10:25	4.79		36.3		3.2		
03-SAM-00.7	2/7/2006	14:20	6.02		83	19	610	estimate	
03-SAM-00.7	2/21/2006	14:50	4.37	11.98	190		190	estimate	
03-SAM-00.7	3/14/2006	14:05	7.31		171	6.2	190	estimate	
03-SAM-00.7	3/28/2006	12:15	8.89	10.41	245		150	estimate	
03-SAM-00.7	4/11/2006	14:30	11.31	11.18	434	13	160	estimate	
03-SAM-00.7	4/25/2006	13:35	13.71	10.2	361		170	estimate	
03-SAM-00.7	5/9/2006	13:53				6.4	130	estimate	
03-SAM-00.7	5/9/2006	13:55	13.75		541				
03-SAM-00.7	5/25/2006	10:50	13.41	10.04	730		120	estimate	
03-SAM-00.7	6/13/2006	11:10	14.93	9.31	514	9.3	110	estimate	
03-SAM-00.7	6/27/2006	11:50	20.04		736		62	estimate	
03-SAM-00.7	7/11/2006	11:10	17.29	9.395	1200	6.4	47	estimate	
03-SAM-00.7	7/25/2006	12:30	22.25	9.61	1270		36	estimate	
03-SAM-00.7	8/9/2006	14:10	18.44	8.84	1870	5	25	estimate	
03-SAM-00.7	8/29/2006	15:05	18.41	7.69	6900		21	estimate	
03-SAM-00.7	9/12/2006	14:00	17.05	6.31	21600	5.3	25	estimate	
03-SAM-00.7	9/26/2006	13:10					28	estimate	
03-SAM-00.7	10/17/2006	14:05	12.77	9.01	35600	9.1	29	estimate	
03-SAM-00.7	10/31/2006	10:30	4.21	9.63	33300		25	estimate	
03-SAM-00.7	11/6/2006	10:50			7000		1600	estimate	
03-SAM-00.7	11/7/2006	10:40			8000		1300	estimate	
03-SAM-00.7	11/28/2006	12:45	1.83	12.49	4200	13	380	estimate	
03-SAM-00.7	12/12/2006	17:00	6.71	11.39	98.9		480	estimate	
03-SAM-00.7	12/13/2006	8:55	6.54		1400		750	estimate	
03-SAM-00.7	12/27/2006	10:20	5.37	11.67	430		510	estimate	
03-SAM-00.7	1/9/2007	14:20	6.39	11.65	55.9	65	990	estimate	
03-SAM-00.7	1/23/2007	13:55		11.7			540	estimate	
03-SAM-00.7	2/13/2007	12:55	7.53	10.9	4780	7.6	140	estimate	
03-SAM-00.7	2/27/2007	15:35	4.65	11.98	81.6		440	estimate	
03-SAM-04.6	2/7/2006	15:26	6.33		80		610		
03-SAM-04.6	2/8/2006	9:12	6.67		80		550		
03-SAM-04.6	2/21/2006	16:30	4.65		89.3		190		
03-SAM-04.6	2/22/2006	9:10	4.98		88				
03-SAM-04.6	2/22/2006	10:50					190		
03-SAM-04.6	3/14/2006	15:05	7.26		85		190		
03-SAM-04.6	3/15/2006	8:50	6.32		85.7		180		
03-SAM-04.6	3/28/2006	13:35	8.58		91		150		

Site	Date	Time	Temp (deg C)	D.O. (mg/L)	Conductivity (umhos/cm)	Turbidity (NTU)	Flow (cfs)	Flow Comments	Sampling Comments
03-SAM-04.6	3/29/2006	9:25	7.57		87.5		150		
03-SAM-04.6	4/11/2006	14:50	9.93		81.5		160		
03-SAM-04.6	4/12/2006	12:25	9.78		85.2		160		
03-SAM-04.6	4/25/2006	15:00	12.38		81		170		
03-SAM-04.6	4/26/2006	8:23					160		
03-SAM-04.6	4/26/2006	8:25	10.53		88.4				
03-SAM-04.6	5/9/2006	13:35	10.83		89.4		130		
03-SAM-04.6	5/10/2006	9:55	9.99		91.9		120		
03-SAM-04.6	5/24/2006	9:45	12.23		104		110		
03-SAM-04.6	5/25/2006	15:50	13.85		103		120		
03-SAM-04.6	6/13/2006	14:00	13.99		96		110		
03-SAM-04.6	6/14/2006	9:45	13.29		94.8		110		
03-SAM-04.6	6/27/2006	15:05	19.2		118		62		
03-SAM-04.6	6/28/2006	10:25	15.4		120		60		
03-SAM-04.6	7/11/2006	14:25	14.88		122		47		
03-SAM-04.6	7/12/2006	10:40	13.72		121		49		
03-SAM-04.6	7/25/2006	14:10	19.52		133		36		
03-SAM-04.6	7/26/2006	10:35	16.37		128		33		
03-SAM-04.6	8/9/2006	15:45	16		124		25		
03-SAM-04.6	8/10/2006	11:40	14.47		127		27		
03-SAM-04.6	8/29/2006	12:50	14.74		132		21		
03-SAM-04.6	8/30/2006	10:35	14.04		133		21		
03-SAM-04.6	9/12/2006	12:40	13.93		153		25		
03-SAM-04.6	9/13/2006	10:00	12.98		142		23		
03-SAM-04.6	9/26/2006	14:00					28		
03-SAM-04.6	9/27/2006	11:35	12.71		107		27		
03-SAM-04.6	10/17/2006	13:25	10.93		110		29		
03-SAM-04.6	10/18/2006	10:40	10.58		111		29		
03-SAM-04.6	10/31/2006	11:15	4.4		116		25		
03-SAM-04.6	11/1/2006	11:50	4.05		120		22		
03-SAM-04.6	11/6/2006	11:30					1600	estimate	
03-SAM-04.6	11/7/2006	11:20					1300	estimate	
03-SAM-04.6	11/28/2006	13:50	1.89		64.8		380		
03-SAM-04.6	12/12/2006	16:20	6.79		54.5		480		
03-SAM-04.6	12/13/2006	9:05	6.57		54.7		750		
03-SAM-04.6	12/27/2006	11:00	5.51		62.1		510		
03-SAM-04.6	1/9/2007	15:05	6.48		50.7		990		
03-SAM-04.6	1/10/2007	10:15	4.5		53.3		790		
03-SAM-04.6	1/23/2007	12:55					540		
03-SAM-04.6	1/24/2007	11:20					510		
03-SAM-04.6	2/13/2007	14:00	7.16		86.6		140		
03-SAM-04.6	2/14/2007	9:45	6.85		89.2		160		
03-SAM-04.6	2/27/2007	14:50	4.59		62.9		440		
03-SAM-04.6	2/28/2007	8:50	4.95		66.8		370		
03-SAM-06.5	2/8/2006	9:21	6.73		64.5		560		
03-SAM-06.5	2/22/2006	9:00	4.92		86.9		200		
03-SAM-06.5	3/15/2006	9:00	6.26		84.8		190		
03-SAM-06.5	3/29/2006	9:35	7.5		85.5		160		
03-SAM-06.5	4/12/2006	16:35					160		
03-SAM-06.5	4/12/2006	12:40	9.65		83				
03-SAM-06.5	4/26/2006	8:45	10.25		82.5		170		

Site	Date	Time	Temp (deg C)	D.O. (mg/L)	Conductivity (umhos/cm)	Turbidity (NTU)	Flow (cfs)	Flow Comments	Sampling Comments
03-SAM-06.5	5/10/2006	9:40	9.57		89.4		120		
03-SAM-06.5	5/24/2006	10:00	12.08		102		110		
03-SAM-06.5	6/13/2006	14:10	13.81		92.9		110		
03-SAM-06.5	6/28/2006	10:55	14.89		117		54		
03-SAM-06.5	7/11/2006	14:40	14.42		121		50		
03-SAM-06.5	7/26/2006	11:00	18.18		126		32		
03-SAM-06.5	8/10/2006	11:45	14.11		124		31		
03-SAM-06.5	8/29/2006	12:00	14.14		129		23		
03-SAM-06.5	9/12/2006	12:15	12.99		151		26		
03-SAM-06.5	9/27/2006	10:55	12.15		105		33		
03-SAM-06.5	10/17/2006	12:40	10.57		107		37		
03-SAM-06.5	10/31/2006	11:30	4.37		113		29		
03-SAM-06.5	11/6/2006	11:40					1600	estimate	
03-SAM-06.5	11/7/2006	11:30					1300	estimate	
03-SAM-06.5	11/28/2006	14:00	1.89		62.6		380		
03-SAM-06.5	12/13/2006	9:20	6.6		53.2		790		
03-SAM-06.5	12/27/2006	11:25	5.54		60.7		540		
03-SAM-06.5	1/10/2007	10:20	4.42		53.7		800		
03-SAM-06.5	1/24/2007	11:35					520		
03-SAM-06.5	2/14/2007	9:55	6.7		87.1		180		
03-SAM-06.5	2/28/2007	9:00	4.93		65.9		380		
03-SAM-10.3	2/8/2006	10:50	6.79		57		530		
03-SAM-10.3	2/22/2006	10:45	4.87		73		189		
03-SAM-10.3	3/15/2006	10:00	6.23		71.5		180		
03-SAM-10.3	3/29/2006	11:35	7.96		74		148		
03-SAM-10.3	4/12/2006	13:50	9.46		72.3		157		
03-SAM-10.3	4/26/2006	10:25	9.76		71.5		160		
03-SAM-10.3	5/10/2006	11:35	9.93		78.1		118		
03-SAM-10.3	5/24/2006	11:10	12.08		88.5		106		
03-SAM-10.3	6/13/2006	15:10	13.55		82		105		
03-SAM-10.3	6/28/2006	12:05					62		
03-SAM-10.3	7/12/2006	12:45	12.9		103		52		
03-SAM-10.3	7/26/2006	12:10	15.33		109		37		
03-SAM-10.3	8/10/2006	12:25	13.7		109		31		
03-SAM-10.3	8/30/2006	11:35	13.13		115		25		
03-SAM-10.3	9/13/2006	11:00	12.24		124		27		
03-SAM-10.3	9/27/2006	13:35	12.5		94.2		31		
03-SAM-10.3	10/18/2006	11:40	10.63		99.8		33		
03-SAM-10.3	10/31/2006	12:35	4.18		105		29		
03-SAM-10.3	11/6/2006	12:40					1500	estimate	
03-SAM-10.3	11/7/2006	12:20					1200	estimate	
03-SAM-10.3	12/13/2006	11:25	6.73		48.7		721		
03-SAM-10.3	12/27/2006	12:25	5.63		56.1		491		
03-SAM-10.3	1/10/2007	12:40	4.24		51		756		
03-SAM-10.3	1/24/2007	12:20					486		
03-SAM-10.3	2/14/2007	11:00					155		
03-SAM-10.3	2/14/2007	11:10	6.55		72.3				
03-SAM-10.3	2/28/2007	9:45	4.88		57.3		354		
03-SAM-13.1	2/8/2006	11:00	6.74		56.8		320		
03-SAM-13.1	2/22/2006	11:00	5.37		78		100		
03-SAM-13.1	3/15/2006	10:15	6.69		78.5		100		

Site	Date	Time	Temp (deg C)	D.O. (mg/L)	Conductivity (umhos/cm)	Turbidity (NTU)	Flow (cfs)	Flow Comments	Sampling Comments
03-SAM-13.1	3/29/2006	11:50	8.21		77		92		
03-SAM-13.1	4/12/2006	14:00	9.27		75.1		98		
03-SAM-13.1	4/26/2006	10:40	9.34		74.7		95		
03-SAM-13.1	5/10/2006	11:55	9.94		82.2		72		
03-SAM-13.1	5/24/2006	11:30	11.55		88.5		68		
03-SAM-13.1	6/13/2006	15:20	12.85		83.2		73		
03-SAM-13.1	6/28/2006	12:30	13.54		101		40		
03-SAM-13.1	7/12/2006	13:00	12.8		101		32		
03-SAM-13.1	7/26/2006	12:40	14.46		108		27		
03-SAM-13.1	8/10/2006	12:40	12.69		106		25		
03-SAM-13.1	8/30/2006	11:50	12.59		112		24		
03-SAM-13.1	9/13/2006	11:40	11.51		123		17		
03-SAM-13.1	9/27/2006	15:00	12.66		99.1		19		
03-SAM-13.1	10/18/2006	11:55	10.17		112		20		
03-SAM-13.1	10/31/2006	12:50	5.15		109		23		
03-SAM-13.1	11/6/2006	12:50					1100		
03-SAM-13.1	11/7/2006	12:30					690		
03-SAM-13.1	12/13/2006	11:35	6.66		43.2		590		
03-SAM-13.1	12/27/2006	12:40	5.72		57.5		300		
03-SAM-13.1	1/10/2007	12:55	4.52		49.9		430		
03-SAM-13.1	1/24/2007	12:35					300		
03-SAM-13.1	2/14/2007	11:25	7.06		78.1		93		
03-SAM-13.1	2/28/2007	9:55	5.04		59.6		230		
03-SAM-15.0	2/8/2006	11:25	6.76		57.8		300		
03-SAM-15.0	2/22/2006	11:40	5.56		82.1		97		
03-SAM-15.0	3/15/2006	10:40	6.81		80.6		93		
03-SAM-15.0	3/29/2006	12:10	8.55		78.4		87		
03-SAM-15.0	4/12/2006	14:20	9.21		75.7		92		
03-SAM-15.0	4/26/2006	11:00	9.38		75		90		
03-SAM-15.0	5/10/2006	12:50	10.85		82.7		68		
03-SAM-15.0	5/24/2006	12:20	11.79		90		65		
03-SAM-15.0	6/14/2006	10:35	12.04		84.6		68		
03-SAM-15.0	6/28/2006	13:00	14.17		103		38		
03-SAM-15.0	7/12/2006	13:40	11.69		104		30		
03-SAM-15.0	7/26/2006	13:30	14.95		111		25		
03-SAM-15.0	8/10/2006	13:15	12.45		109		24		
03-SAM-15.0	8/30/2006	12:15	12.35		114		20		
03-SAM-15.0	9/13/2006	12:25	11.38		124		19		
03-SAM-15.0	9/27/2006	15:25	13.05		101		19		
03-SAM-15.0	10/18/2006	12:25	10.09		116		19		
03-SAM-15.0	10/31/2006	13:10	6		113		19		
03-SAM-15.0	11/6/2006	13:15					960		
03-SAM-15.0	12/13/2006	12:15	6.6		42.1		520		
03-SAM-15.0	12/27/2006	13:05	5.65		58.6		670		
03-SAM-15.0	1/10/2007	13:20	4.5		49.6		400		
03-SAM-15.0	1/24/2007	12:55					270		
03-SAM-15.0	2/14/2007	11:55	7.14		78.4		84		
03-SAM-15.0	2/28/2007	10:15	5.1		60.7		210		
03-SAM-16.5	2/8/2006	11:40	6.71		57.5		290		
03-SAM-16.5	2/22/2006	11:50	5.52		82		91		
03-SAM-16.5	3/15/2006	11:20	6.86		80		87		

Site	Date	Time	Temp (deg C)	D.O. (mg/L)	Conductivity (umhos/cm)	Turbidity (NTU)	Flow (cfs)	Flow Comments	Sampling Comments
03-SAM-16.5	3/29/2006	12:40	8.56		78		88		
03-SAM-16.5	4/12/2006	14:30	9.14		76.2		92		
03-SAM-16.5	4/26/2006	14:15	9.44		67				
03-SAM-16.5	4/26/2006	11:30					97		
03-SAM-16.5	5/10/2006	13:05	10.9		83		68		
03-SAM-16.5	5/24/2006	12:40	11.69		92		64		
03-SAM-16.5	6/14/2006	11:00	12.05		85.6		67		
03-SAM-16.5	6/28/2006	13:20	14.36		105		36		
03-SAM-16.5	7/12/2006	14:00	11.61		106		30		
03-SAM-16.5	7/26/2006	14:05	15.06		113		23		
03-SAM-16.5	8/10/2006	13:30	12.44		112		23		
03-SAM-16.5	8/30/2006	12:35	12.13		116		17		
03-SAM-16.5	9/13/2006	13:15	11.13		127		16		
03-SAM-16.5	9/27/2006	15:40	12.32		105		17		
03-SAM-16.5	10/18/2006	13:00	9.92		120		17		
03-SAM-16.5	10/31/2006	13:20	5.93		116		17		
03-SAM-16.5	11/6/2006	13:25					940		
03-SAM-16.5	12/13/2006	12:25	6.53		41		510		
03-SAM-16.5	12/27/2006	13:15	5.6		58.8		260		
03-SAM-16.5	1/10/2007	13:25	4.48		49.5		390		
03-SAM-16.5	1/24/2007	13:05					260		
03-SAM-16.5	2/14/2007	12:15	7.11		77.9		84		
03-SAM-16.5	2/28/2007	10:20	5.11		61		200		
03-SAM-20.7	2/8/2006	12:11	6.8		51.9		230		
03-SAM-20.7	2/22/2006	12:45	4.94		72.2		72		
03-SAM-20.7	3/15/2006	12:20	6.89		72.1		70		
03-SAM-20.7	3/29/2006	13:20	8.54		71.1		70		
03-SAM-20.7	4/12/2006	14:50	8.89		65.9		74		
03-SAM-20.7	4/26/2006	11:55	9.46		66.5		81		
03-SAM-20.7	5/10/2006	13:10	10.69		73		58		
03-SAM-20.7	5/24/2006	13:00	11.48		78.6		60		
03-SAM-20.7	6/14/2006	11:30	12.15		78.9		49		
03-SAM-20.7	6/28/2006	14:10	13.92		97.1		26		
03-SAM-20.7	7/12/2006	15:00	10.94		99.8		23		
03-SAM-20.7	7/26/2006	14:40	13.87		108		15		
03-SAM-20.7	8/10/2006	13:40	11.48		105		16		
03-SAM-20.7	8/30/2006	13:30	11.03		110		11		
03-SAM-20.7	9/13/2006	13:40	10.4		122		9.8		
03-SAM-20.7	9/27/2006	15:55	11.78		100		9.7		
03-SAM-20.7	10/18/2006	13:30	9.7		114		9.6		
03-SAM-20.7	11/1/2006	9:50	7.37		110		9.8		
03-SAM-20.7	11/6/2006	13:30					750		
03-SAM-20.7	12/13/2006	12:35	6.35		36.1		410		
03-SAM-20.7	12/27/2006	13:30	5.42		53.5	23	210		
03-SAM-20.7	1/10/2007	13:50	4.29		44.9		310		
03-SAM-20.7	1/24/2007	13:10					210		
03-SAM-20.7	2/14/2007	12:25	7.06		68.5		64		
03-SAM-20.7	2/28/2007	10:40	4.96		54.5		160		
03-SAM-22.0	2/8/2006	13:20	6.9		47.3		180		
03-SAM-22.0	2/22/2006	13:25	4		62.8		53		
03-SAM-22.0	3/15/2006	12:35	6.58		62		49		

Site	Date	Time	Temp (deg C)	D.O. (mg/L)	Conductivity (umhos/cm)	Turbidity (NTU)	Flow (cfs)	Flow Comments	Sampling Comments
03-SAM-22.0	3/29/2006	13:45	8.95		62		44		
03-SAM-22.0	4/12/2006	15:15	9.41		60.7		47		
03-SAM-22.0	4/26/2006	12:25	10.14		59.5		51		
03-SAM-22.0	5/10/2006	13:20	11.04		63.9		32		
03-SAM-22.0	5/24/2006	13:30	12.27		71		30		
03-SAM-22.0	6/14/2006	12:00	13.1		72.5		28		
03-SAM-22.0	6/28/2006	14:30	14.83		89.5		13		
03-SAM-22.0	7/12/2006	15:10	11.73		92		9.2		
03-SAM-22.0	7/26/2006	15:40	14.2		97		6.4		
03-SAM-22.0	8/10/2006	14:05	11.93		96.2		5		
03-SAM-22.0	8/30/2006	13:55	11.22		96.7		3.2		
03-SAM-22.0	9/13/2006	14:05	10.84		103		3		
03-SAM-22.0	9/27/2006	16:05	11.51		84.4		3	estimate	
03-SAM-22.0	10/18/2006	13:55	9.58		95.4		2.4		
03-SAM-22.0	11/1/2006	10:05	4.86		92.1		3	estimate	
03-SAM-22.0	11/6/2006	13:40					600		
03-SAM-22.0	12/13/2006	12:50	6.37		33.9		320		
03-SAM-22.0	12/27/2006	13:40	5.16		46.3	2.1	160		
03-SAM-22.0	1/10/2007	14:00	4.2		39.5		240		
03-SAM-22.0	1/24/2007	13:15					160		
03-SAM-22.0	2/14/2007	12:40	6.87		58.6		36		
03-SAM-22.0	2/28/2007	10:50	4.66		46.5		120		
03-SAM-26.6	2/8/2006	14:15	6.55		43.7		61		
03-SAM-26.6	2/22/2006	14:35	1.15		54.3		19		
03-SAM-26.6	3/15/2006	13:10	5.33		51.7		18		
03-SAM-26.6	3/29/2006	14:30	8.67		56		18		
03-SAM-26.6	4/12/2006	15:40	8.75		54.5		16		
03-SAM-26.6	4/26/2006	13:15	8.37		52.5		15		
03-SAM-26.6	5/10/2006	13:35	11.08		64.8		12		
03-SAM-26.6	5/24/2006	14:10	13.76		82.3				
03-SAM-26.6	5/24/2006	14:45					10		
03-SAM-26.6	6/14/2006	12:55	14.03		78.7		10		
03-SAM-26.6	6/28/2006	15:05	16.16		85		5		
03-SAM-26.6	7/12/2006	15:45	15.28		82.1		4.6		
03-SAM-26.6	7/26/2006	15:55	18.21		101		4.4		
03-SAM-26.6	8/10/2006	14:25	16.86		83.5		3.9		
03-SAM-26.6	8/30/2006	14:15	15.73		92.6		0.5	estimate	
03-SAM-26.6	9/13/2006	14:30	14.14		103		0.1	estimate	
03-SAM-26.6	9/27/2006	16:15	17.98		88.8		0.1	estimate	upper 6" of water column
03-SAM-26.6	9/27/2006	16:16	12.21		90.6				lower 6" of water column
03-SAM-26.6	10/18/2006	14:20	9.57		107		0.1	estimate	
03-SAM-26.6	11/1/2006	10:15	4.07		98.8		0.1	estimate	
03-SAM-26.6	11/6/2006	13:50					260		
03-SAM-26.6	12/13/2006	13:05	6.05		39.8		140		
03-SAM-26.6	12/27/2006	14:40	4.71		43.3		66		
03-SAM-26.6	1/10/2007	14:25	3.52		38.5		100		
03-SAM-26.6	1/24/2007	13:25					70		
03-SAM-26.6	2/14/2007	13:20	5.9		53.5		15		
03-SAM-26.6	2/28/2007	11:10	3.87		42.2		48		
03-SAM-28.8	2/8/2006	15:00	8.05		46		11		
03-SAM-28.8	2/22/2006	14:05	4.41		80.4		2.3		

Site	Date	Time	Temp (deg C)	D.O. (mg/L)	Conductivity (umhos/cm)	Turbidity (NTU)	Flow (cfs)	Flow Comments	Sampling Comments
03-SAM-28.8	3/15/2006	13:30	6.46		69.2		3		
03-SAM-28.8	3/29/2006	15:00	11.82		81.3		2.6		
03-SAM-28.8	4/12/2006	16:10	9.9		92.8		2.8		
03-SAM-28.8	4/26/2006	13:45	9.22		84.4		2		
03-SAM-28.8	5/10/2006	13:40	10.65		98.8		1.5	estimate	
03-SAM-28.8	5/24/2006	14:45	13.1		122		1.4		
03-SAM-28.8	6/14/2006	13:15	13.48		90.7		2		
03-SAM-28.8	6/28/2006	15:35	16.06		118		0.48		
03-SAM-28.8	7/12/2006	16:00	15		139		0.57		
03-SAM-28.8	7/26/2006	16:35	18.94		171		0.09		
03-SAM-28.8	8/10/2006	14:30	15.64		168		0.5		
03-SAM-28.8	8/30/2006	14:25	14.15		178		0.07		
03-SAM-28.8	9/13/2006	14:45	13.94		172		0.08		
03-SAM-28.8	9/27/2006	16:30	13.16		133		0.9		
03-SAM-28.8	10/18/2006	14:40	10.28		137		2		
03-SAM-28.8	11/1/2006	10:40	3.22		131		2		
03-SAM-28.8	11/6/2006	14:00					20	estimate	
03-SAM-28.8	12/13/2006	13:20	6.85		39.1		12		
03-SAM-28.8	12/27/2006	14:50	5.51		51.4		6.5		
03-SAM-28.8	1/10/2007	15:05	3.49		35.6		7.2		
03-SAM-28.8	1/24/2007	13:40					6.7		
03-SAM-28.8	2/14/2007	13:40	6		84		2.7		
03-SAM-28.8	2/28/2007	11:45	4.42		49.7		4.6		
03-SAM-HW1	6/28/2006	15:55	17.12		118				
03-SAM-HW2	6/28/2006	16:05	17.92		118				
03-SAM-HW3	6/28/2006	16:20	19.93		120				
03-SAM-HW4	6/28/2006	16:40	14.13		71.1				
03-SAM-WF	5/10/2006	13:45	13.7		48.3				
03-SED-PUMP	2/7/2006	13:42	6.73	4.3	985	50			sampled at end of pipe
03-SED-PUMP	2/21/2006	13:50	4.63	3.97	1140				upper 6" of water column
03-SED-PUMP	2/21/2006	13:51			1500				middle of water column
03-SED-PUMP	2/21/2006	13:52			15000				lower 6" of water column
03-SED-PUMP	3/14/2006	13:20	8.37		6220	28			upper 6" of water column
03-SED-PUMP	3/14/2006	13:21			6600				lower 6" of water column
03-SED-PUMP	3/28/2006	10:35	9.83	7	4600				upper 6" of water column
03-SED-PUMP	3/28/2006	10:36			13400				lower 6" of water column
03-SED-PUMP	4/11/2006	11:15	10.39	7.58	5030	33			
03-SED-PUMP	4/25/2006	12:05	14.67	6.37	9630				
03-SED-PUMP	5/9/2006	10:40	14.73	6.8	8750	24			
03-SED-PUMP	5/25/2006	12:25	17.01	8.86					
03-SED-PUMP	6/13/2006	9:55	16.32	5.78	11900	35			
03-SED-PUMP	6/27/2006	11:15	19.26		11700				
03-SED-PUMP	7/11/2006	9:45	18.44	3.85	19500	20			
03-SED-PUMP	8/9/2006	13:50	20.44	3.78	24000	14			
03-SED-PUMP	8/29/2006	13:30	19.3	8.22	20000				
03-SED-PUMP	9/12/2006	14:30	21.8	22.39	28000	13			upper 6" of water column
03-SED-PUMP	9/12/2006	14:31	22		31500				lower 6" of water column
03-SED-PUMP	10/17/2006	13:50	13.16		32000				
03-SED-PUMP	11/6/2006	10:20			14000				
03-SED-PUMP	11/7/2006	10:15			14000				
03-SED-PUMP	11/28/2006	12:15	2.91	5.05	2160	50			upper 6" of water column

Site	Date	Time	Temp (deg C)	D.O. (mg/L)	Conductivity (umhos/cm)	Turbidity (NTU)	Flow (cfs)	Flow Comments	Sampling Comments
03-SED-PUMP	11/28/2006	12:16	2.88		3000				lower 6" of water column
03-SED-PUMP	12/12/2006	13:00	7.76	4.71	8200				
03-SED-PUMP	12/27/2006	9:55	5.36	6.48	803				upper 6" of water column
03-SED-PUMP	12/27/2006	9:56	5.38		6500				lower 6" of water column
03-SED-PUMP	1/9/2007	13:50	6.99	8.68	380	500			upper 6" of water column
03-SED-PUMP	1/9/2007	13:51	6.99		380				lower 6" of water column
03-SED-PUMP	1/23/2007	14:35		5.69					
03-SED-PUMP	2/13/2007	12:10	8.37	3.1	8260	33			upper 6" of water column
03-SED-PUMP	2/13/2007	12:11	8.35		12000				middle of water column
03-SED-PUMP	2/13/2007	12:12	8.22		20500				lower 6" of water column
03-SED-PUMP	2/27/2007	13:30	6.05	3.85	1200				upper 6" of water column
03-SED-PUMP	2/27/2007	13:31	6.01		1200				middle of water column
03-SED-PUMP	2/27/2007	13:32	5.88		3100				lower 6" of water column
03-SIL-00.4	2/8/2006	16:05	6.9		50.9		39.9		
03-SIL-00.4	2/22/2006	15:30	4.85		63.8		9.4		
03-SIL-00.4	3/15/2006	14:25	6.25		61.7		11.2		
03-SIL-00.4	3/29/2006	16:05	8.6		69.2		6.8		
03-SIL-00.4	4/12/2006	16:45	9.68		68.5		8.2		
03-SIL-00.4	4/26/2006	15:00	10.46		69.4		8.1		
03-SIL-00.4	5/10/2006	14:25	11.78		78.2		5.2		
03-SIL-00.4	5/24/2006	15:30	12.82		97		4.1		
03-SIL-00.4	6/14/2006	14:20	14.08		77.5		5.4		
03-SIL-00.4	6/28/2006	18:25					1.9		
03-SIL-00.4	7/12/2006	17:30	11.93		132		2.4		
03-SIL-00.4	7/26/2006	17:30	15.2		142		1.5		
03-SIL-00.4	8/10/2006	15:10	12.78		145		1.5		
03-SIL-00.4	8/30/2006	15:30	12.44		151		1.4		
03-SIL-00.4	9/13/2006	17:20	11.46		166		1.4		
03-SIL-00.4	9/27/2006	17:35	12.8		137		1.4		
03-SIL-00.4	10/18/2006	16:00	9.95		160		1.7		
03-SIL-00.4	11/1/2006	11:20	4.73		152		2.1		
03-SIL-00.4	11/6/2006	14:50					85.1		
03-SIL-00.4	12/13/2006	14:00	6.59		47.4		36		
03-SIL-00.4	12/27/2006	15:40	5.21		51.5		33.8		
03-SIL-00.4	1/10/2007	15:40	3.52		47		31.1		
03-SIL-00.4	1/24/2007	14:10					50.8		
03-SIL-00.4	2/14/2007	14:40	6.31		65.7		32		
03-SIL-00.4	2/28/2007	12:35	4.81		49.5		27.6		
03-SKA-00.5	3/29/2006	12:20					1.6		
03-SKA-00.5	4/12/2006	14:15	9.07		59.5		2.3		
03-SKA-00.5	4/26/2006	14:20	9.09		62.1		1.7		
03-SKA-00.5	5/10/2006	13:35					0.9		
03-SKA-00.5	5/10/2006	12:35	9.85		68				
03-SKA-00.5	5/24/2006	12:00	12.25		77.8		0.98		
03-SKA-00.5	6/14/2006	10:20	12.61		64.5		1.5		
03-SKA-00.5	6/28/2006	12:55	14.77		69.6		0.59		
03-SKA-00.5	7/12/2006	13:35	13.91		69.7		0.5		
03-SKA-00.5	7/26/2006	13:20	17.37		79.2		0.45		
03-SKA-00.5	8/10/2006	12:55	14.65		75.6		0.35		
03-SKA-00.5	8/30/2006	12:05	13.8		85.3		0.05		
03-SKA-00.5	9/13/2006	12:10	12.36		96		0.01	estimate	

Site	Date	Time	Temp (deg C)	D.O. (mg/L)	Conductivity (umhos/cm)	Turbidity (NTU)	Flow (cfs)	Flow Comments	Sampling Comments
03-SKA-00.5	9/26/2006	15:15	14.05		80		0.01	estimate	
03-SKA-00.5	10/18/2006	12:15	10.25		84.3		0.12		
03-SKA-00.5	10/31/2006	13:00	2.9		79.5		0.7		
03-SKA-00.5	11/6/2006	13:10					30		
03-SKA-00.5	12/13/2006	12:10	6.97		43.4		20		
03-SKA-00.5	12/27/2006	13:00	6		48.4		12		
03-SKA-00.5	1/10/2007	13:10	4.82		48.3		13		
03-SKA-00.5	1/24/2007	12:50					11		
03-SKA-00.5	2/14/2007	11:45	6.81		62.6		2.3		
03-SKA-00.5	2/28/2007	10:10	5.23		48		8.3		
03-SMI-GATE	2/21/2006	10:50			12000				upper 6" of water column
03-SMI-GATE	2/21/2006	10:51			32500				lower 6" of water column
03-SMI-GATE	3/14/2006	9:15			31000				
03-SMI-GATE	8/9/2006	13:10	20.31	5.91	44300	5.1			
03-SMI-GATE	10/17/2006	11:10	11.72		38600				
03-SMI-GATE	10/31/2006	10:10	3.71	7.6	34400				
03-SMI-GATE	11/6/2006	10:10			35000				
03-SMI-GATE	11/7/2006	9:55			38200				
03-SMI-GATE	1/23/2007	15:00		7.42					
03-SWE-00.0	2/8/2006	11:10	6.62		44.6		13		
03-SWE-00.0	2/22/2006	11:15	3.47		52.7		3.7		
03-SWE-00.0	3/15/2006	10:20	5.74		15.1		4.3		
03-SWE-00.0	3/29/2006	11:55	7.51		54.4		4.1		
03-SWE-00.0	4/12/2006	14:10	9.46		56.9		4.3		
03-SWE-00.0	4/26/2006	10:45	9.79		59.7		3		
03-SWE-00.0	5/10/2006	12:05	10		64		2.9		
03-SWE-00.0	5/24/2006	11:35	13.42		18.8		2.7		
03-SWE-00.0	6/13/2006	15:25	14.87		59.6		3.8		
03-SWE-00.0	6/28/2006	12:35	14.82		73.3		2		
03-SWE-00.0	7/12/2006	13:25	14.16		74.5		1		
03-SWE-00.0	7/26/2006	13:00	16.6		85		0.61		
03-SWE-00.0	8/10/2006	12:45	14.35		80.6		0.7		
03-SWE-00.0	8/30/2006	11:55	13.73		90		0.4		
03-SWE-00.0	9/13/2006	12:00	11.84		100		0.39		
03-SWE-00.0	9/27/2006	15:05	13.36		79.6		0.4		
03-SWE-00.0	10/18/2006	12:00	9.94		95.1		0.77		
03-SWE-00.0	10/31/2006	12:55	3.33		81.4		2.7		
03-SWE-00.0	11/6/2006	13:00					100	estimate	
03-SWE-00.0	12/13/2006	11:50	6.59		37.5		50		
03-SWE-00.0	12/27/2006	12:45	5.24		42		18		
03-SWE-00.0	1/10/2007	13:00	3.66		40.3		21		
03-SWE-00.0	1/24/2007	12:45					17		
03-SWE-00.0	2/14/2007	11:35	5.99		53.1		7	estimate	
03-SWE-00.0	2/28/2007	10:00	4.27		41.3		14		
03-THO-00.3	2/8/2006	10:05	7.07		104		26		
03-THO-00.3	2/22/2006	9:35	4.42		126		8.7		
03-THO-00.3	3/15/2006	9:50	6.48		127		9.7		
03-THO-00.3	3/29/2006	11:10	8.8		113		8.8		
03-THO-00.3	4/12/2006	13:10	10.6		119		7.6		
03-THO-00.3	4/26/2006	9:55	11.58		132		6.5		
03-THO-00.3	5/10/2006	10:15	11.77		139		3.8		

Site	Date	Time	Temp (deg C)	D.O. (mg/L)	Conductivity (umhos/cm)	Turbidity (NTU)	Flow (cfs)	Flow Comments	Sampling Comments
03-THO-00.3	5/24/2006	10:30	13.62		160		2.2		
03-THO-00.3	6/13/2006	15:40	15.21		145		2.7		
03-THO-00.3	6/28/2006	11:20	18.03		178		0.67		
03-THO-00.3	7/12/2006	11:20	16.45		202		0.7	estimate	
03-THO-00.3	7/26/2006	11:20	18.8		202		0.5	estimate	
03-THO-00.3	8/10/2006	12:00	15.76		222		0.6	estimate	
03-THO-00.3	8/30/2006	10:50	14.7		242		0.4	estimate	
03-THO-00.3	9/13/2006	10:20	13.13		265		0.4	estimate	
03-THO-00.3	9/27/2006	12:50	12.65		146		0.5	estimate	
03-THO-00.3	10/18/2006	11:00	9.9		183		0.6	estimate	
03-THO-00.3	10/31/2006	12:05	4.61		170		2	estimate	
03-THO-00.3	11/6/2006	12:10					90		
03-THO-00.3	11/7/2006	11:40					57		
03-THO-00.3	12/13/2006	9:40	6.43		92.8		66		
03-THO-00.3	12/27/2006	12:00	5.37		92.2		49		
03-THO-00.3	1/10/2007	10:30	4.6		90.6		40		
03-THO-00.3	1/24/2007	12:00					35		
03-THO-00.3	2/14/2007	10:20	7.05		131		26		
03-THO-00.3	2/28/2007	9:10	5.02		104		28		
03-THO-03.6	2/8/2006	9:50	6.89		74.6		11		
03-THO-03.6	2/22/2006	10:05	3.57		98		3.2		
03-THO-03.6	3/15/2006	9:20	5.8		96.3		3.8		
03-THO-03.6	3/29/2006	10:05	6.98		90.5		4		
03-THO-03.6	4/12/2006	13:30	9.26		92.6		4.8		
03-THO-03.6	4/26/2006	9:20	9.33		114		2.2		
03-THO-03.6	5/10/2006	10:45	9.14		133		1.4		
03-THO-03.6	5/24/2006	11:00	11.95		150		1.4		
03-THO-03.6	6/13/2006	14:35	13.45		112		2.8		
03-THO-03.6	6/28/2006	11:50	13.68		170		0.69		
03-THO-03.6	7/12/2006	11:50	12.93		178		0.7		
03-THO-03.6	7/26/2006	11:50	14.91		194		0.47		
03-THO-03.6	8/10/2006	12:15	13.09		191		0.56		
03-THO-03.6	8/30/2006	11:10	12.73		201		0.41		
03-THO-03.6	9/13/2006	10:40	11.67		220		0.42		
03-THO-03.6	9/27/2006	13:15	12.55		174		0.54		
03-THO-03.6	10/18/2006	11:15	9.78		189		0.56		
03-THO-03.6	10/31/2006	12:15	4.26		169		2		
03-THO-03.6	11/6/2006	12:20					40		
03-THO-03.6	11/7/2006	11:55					22		
03-THO-03.6	12/13/2006	10:15	6.43		58.8		25		
03-THO-03.6	12/27/2006	12:10	5.41		61.2		19		
03-THO-03.6	1/10/2007	10:45	4.35		66.5		15		
03-THO-03.6	1/24/2007	12:10					13		
03-THO-03.6	2/14/2007	10:50	7.12		111		10		
03-THO-03.6	2/28/2007	9:30	4.64		69.4		11		
03-VER-00.3	12/27/2006	14:00				1100			
03-WED-GATE	2/7/2006	14:00	8.14	5.89	1630	50			upper 6" of water column
03-WED-GATE	2/7/2006	14:01			40000				lower 6" of water column
03-WED-GATE	2/21/2006	15:15	4.46	4.65	6150				upper 6" of water column
03-WED-GATE	2/21/2006	15:16			11000				middle of water column
03-WED-GATE	2/21/2006	15:17			16000				lower 6" of water column

Site	Date	Time	Temp (deg C)	D.O. (mg/L)	Conductivity (umhos/cm)	Turbidity (NTU)	Flow (cfs)	Flow Comments	Sampling Comments
03-WED-GATE	2/21/2006	10:15			3000				upper 6" of water column
03-WED-GATE	2/21/2006	10:16			12000				middle of water column
03-WED-GATE	2/21/2006	10:17			40000				lower 6" of water column
03-WED-GATE	3/14/2006	13:45	8.16		36000	10			upper 6" of water column
03-WED-GATE	3/14/2006	13:46			36000				lower 6" of water column
03-WED-GATE	3/28/2006	12:00	10	10.53	20400				upper 6" of water column
03-WED-GATE	3/28/2006	12:01			41800				lower 6" of water column
03-WED-GATE	4/11/2006	12:05	12.91	4.79	38900	7.1			upper 6" of water column
03-WED-GATE	4/11/2006	12:06	12.69		41600				lower 6" of water column
03-WED-GATE	4/25/2006	13:55	17.74	9.39	19000				upper 6" of water column
03-WED-GATE	4/25/2006	13:56			31500				middle of water column
03-WED-GATE	4/25/2006	13:57			33000				lower 6" of water column
03-WED-GATE	5/9/2006	10:55	12.55	3.93	36000	13			
03-WED-GATE	5/25/2006	10:30	13.78	7.12					upper 6" of water column
03-WED-GATE	5/25/2006	10:31	12.29						lower 6" of water column
03-WED-GATE	6/27/2006	11:40	16.75		41200				
03-WED-GATE	8/29/2006	13:50	15.24	2.62	36200				
03-WED-GATE	9/12/2006	14:15	14.8	4.03	40600	16			upper 6" of water column
03-WED-GATE	9/12/2006	14:16	14.51		40800				lower 6" of water column
03-WED-GATE	11/6/2006	10:40			26000				upper 6" of water column
03-WED-GATE	11/6/2006	10:41			26200				lower 6" of water column
03-WED-GATE	11/7/2006	10:30			8900				upper 6" of water column
03-WED-GATE	11/7/2006	10:31			36100				lower 6" of water column
03-WED-GATE	11/28/2006	12:30	2.15	6.97	7300	100			
03-WED-GATE	12/12/2006	14:05	7.36	9.52	10800				upper 6" of water column
03-WED-GATE	12/12/2006	14:06	11.35		42000				lower 6" of water column
03-WED-GATE	12/27/2006	10:10	4.87	9.77	5000				upper 6" of water column
03-WED-GATE	12/27/2006	10:11	5.27		12000				lower 6" of water column
03-WED-GATE	1/9/2007	14:05	6.43	10.43	2960	390			
03-WED-GATE	1/23/2007	14:10		9.08					
03-WED-GATE	2/13/2007	12:30	7.75		10800	17			
03-WED-GATE	2/27/2007	15:15	6.21	6.08	8900				upper 6" of water column
03-WED-GATE	2/27/2007	15:16	5.49		11000				middle of water column
03-WED-GATE	2/27/2007	15:17	7.49		26000				lower 6" of water column
03-WIL-00.0	2/8/2006	10:10	7.44		101		4.6		
03-WIL-00.0	2/22/2006	10:20	5.16		114		0.57		
03-WIL-00.0	3/15/2006	9:30	6.5		105		0.69		
03-WIL-00.0	3/29/2006	10:15	8.89		102		0.71		
03-WIL-00.0	4/12/2006	13:35	10.88		109		0.87		
03-WIL-00.0	4/26/2006	9:10					0.36		
03-WIL-00.0	4/26/2006	9:15	10.61		118				
03-WIL-00.0	5/10/2006	10:40	9.14		133		0.11		
03-WIL-00.0	5/24/2006	11:05	14.61		120		0.05		
03-WIL-00.0	6/13/2006	14:50	15.89		24		0.3		
03-WIL-00.0	6/28/2006	11:40	19.85		99.5		0.05		
03-WIL-00.0	7/12/2006	12:25	14.87		101		0.05		
03-WIL-00.0	8/10/2006	12:10	13.72		191		0		
03-WIL-00.0	8/30/2006	11:25	13.28		202		0		
03-WIL-00.0	9/13/2006	10:45	12.35		222		0		
03-WIL-00.0	9/27/2006	13:05	12.58		174		0		
03-WIL-00.0	10/18/2006	11:20	9.84		184		0		

Site	Date	Time	Temp (deg C)	D.O. (mg/L)	Conductivity (umhos/cm)	Turbidity (NTU)	Flow (cfs)	Flow Comments	Sampling Comments
03-WIL-00.0	10/31/2006	12:20	3.45		155		0		
03-WIL-00.0	11/6/2006	12:25					7	estimate	
03-WIL-00.0	11/7/2006	12:00					4.3		
03-WIL-00.0	12/12/2006	10:20	6.85		84.3				
03-WIL-00.0	12/13/2006	10:20					4.6		
03-WIL-00.0	12/27/2006	12:15	5.54		74.5		4.1		
03-WIL-00.0	1/10/2007	10:50	4.31		83.5		4.1		
03-WIL-00.0	1/24/2007	12:05					3.3		
03-WIL-00.0	2/14/2007	10:35	6.6		102		1.5		
03-WIL-00.0	2/28/2007	9:20	5.46		92.7		2.7		

D.O. = dissolved oxygen.

This page is purposely left blank

Appendix E. Investigatory sites maps

This page is purposely left blank

Figure E-1. Map of upper the Samish River and investigatory sites (yellow dots with site ID). In June 2006, the Samish River headwaters flowed through station 03-SAM-HW4, not from the direction shown on the map.

Figure E-2. Map of upper Willard Creek and investigatory sites (yellow dots with site ID).

Figure E-3. Map of lower Colony Creek and investigatory sites (yellow dots with site ID). There appeared to be two channels near 03-COL-00.9 that are not shown on the map. 03-COL-00.9 was on the channel with the most streamflow.