Quality Assurance Project Plan

Samish Bay Fecal Coliform Bacteria Total Maximum Daily Load Study

by
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2004 303(d) Listings Addressed in this Study: See Table 1

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Abstract

Samish River, Samish Bay, Friday Creek, Thomas Creek, Edison Slough, and an unnamed slough to Samish Bay have been listed by the state of Washington under Section 303(d) of the Clean Water Act for non-attainment of Washington State fecal coliform bacteria criteria. The listings are based on sampling done since 1993 by the Washington State Department of Ecology (Ecology), Washington State Department of Health, and Skagit Stream Team.

EPA requires states to set priorities for cleaning up 303(d) listed waters and to establish a Total Maximum Daily Load (TMDL) for each. A TMDL entails an analysis of how much of a pollutant load a waterbody can assimilate without violating water quality standards. This Quality Assurance Project Plan describes the technical study that will monitor levels of fecal coliform bacteria in the Samish Bay watershed, and will form the basis for a proposal to allocate contaminant loads to sources. The study will be conducted by Ecology's Environmental Assessment Program.

Introduction

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. 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, 2005a). 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 Quality Assurance (QA) Project Plan describes the technical study that will develop FC bacteria TMDLs in Samish Bay and its tributaries. These TMDLs will set water quality targets to meet FC bacteria standards, identify key reaches for source reduction, and allocate pollutant loads to point and nonpoint sources. The study will be conducted by Ecology's Environmental Assessment (EA) Program in cooperation with the Ecology Water Quality Program at the Northwest Regional Office, Washington State Department of Health, Skagit County, Samish Tribe, and other local governments.

Background

Study Area

Samish Bay

Samish Bay is located in northwestern Skagit and southern Whatcom counties north of Padilla Bay and south of Bellingham Bay within Water Resource Inventory Area (WRIA) 03 (Figure 1). 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.

Towns and communities are generally low density and 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 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 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 and Skagit County Departments of Health 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 2003. New community on–site septic systems in Blanchard and Edison lowered fecal coliform concentrations enough for parts of the shellfish beds to be upgraded in 2001. Recent fecal coliform results have shown high levels of FC throughout much of the watershed.

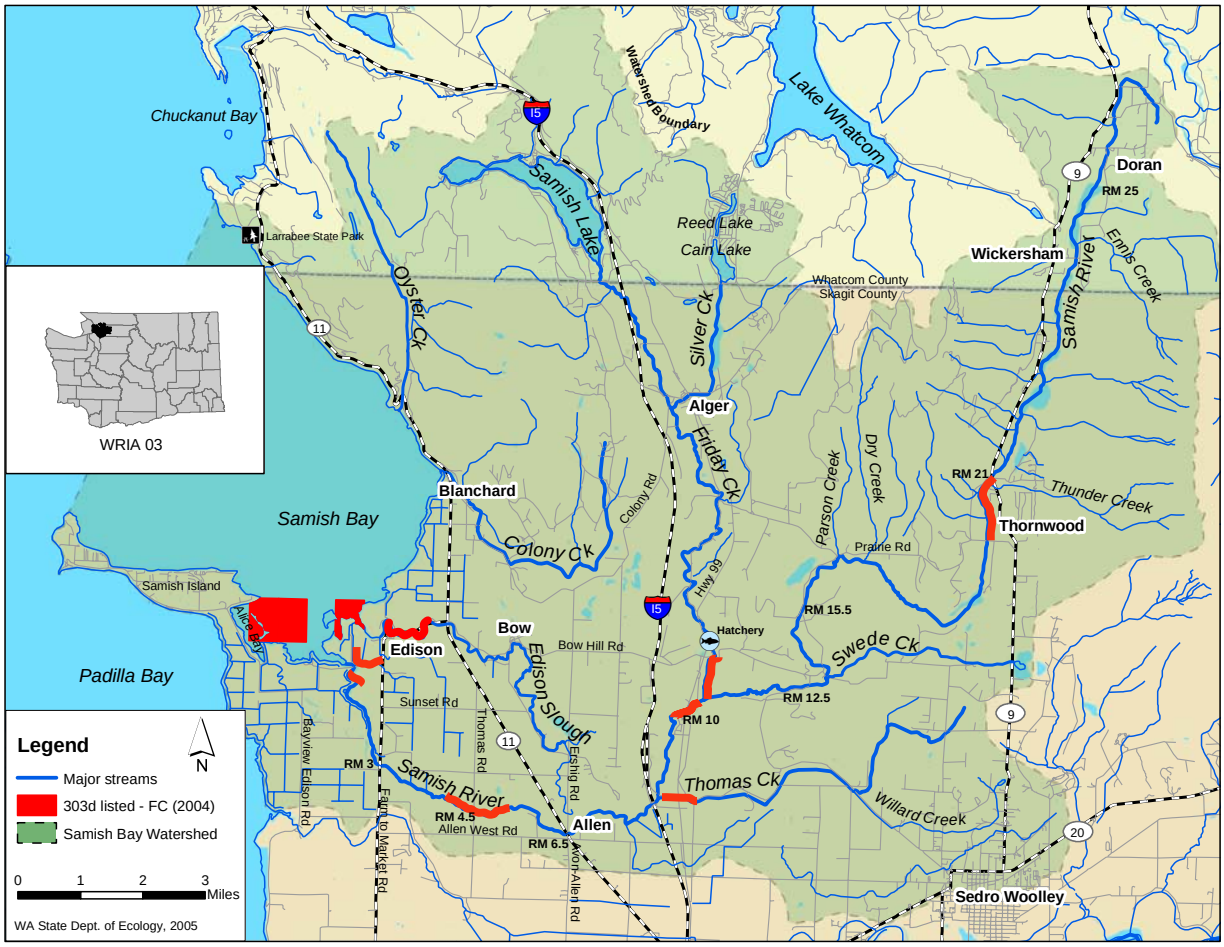

Figure 1. Map of the Samish Bay watershed showing 303(d) listed areas.

The water quality characteristics of the streams, drainage ditches, and sloughs are influenced by the various uses of the water along with wastewater additions and runoff from adjacent land. Runoff loads can add excessive fecal coliform during rain events. Most 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 have been included on Washington State's 303(d) list (Table 1 and Figure 1).

Table 1. 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 fecal coliform standards and will be addressed in the Samish Bay Fecal Coliform TMDL Study.

Waterbody	Waterbody ID	New 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	

Samish River

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: 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 ten percent is used for commercial agriculture. There are also many small hobby and subsistence farms. The Samish River mainstem 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 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 percent of the Thomas Creek subbasin, and forests cover about 40 percent. 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 percent 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 tideflats 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 and 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 and employed the equivalent of 36 full time workers, paying them over $1.13 million in wages. Retail stores, restaurants, festivals, and other public events also depend on shellfish resources. The bay also supports natural populations of crab and other shellfish important to the area.

The Washington Department of Health (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. The 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.

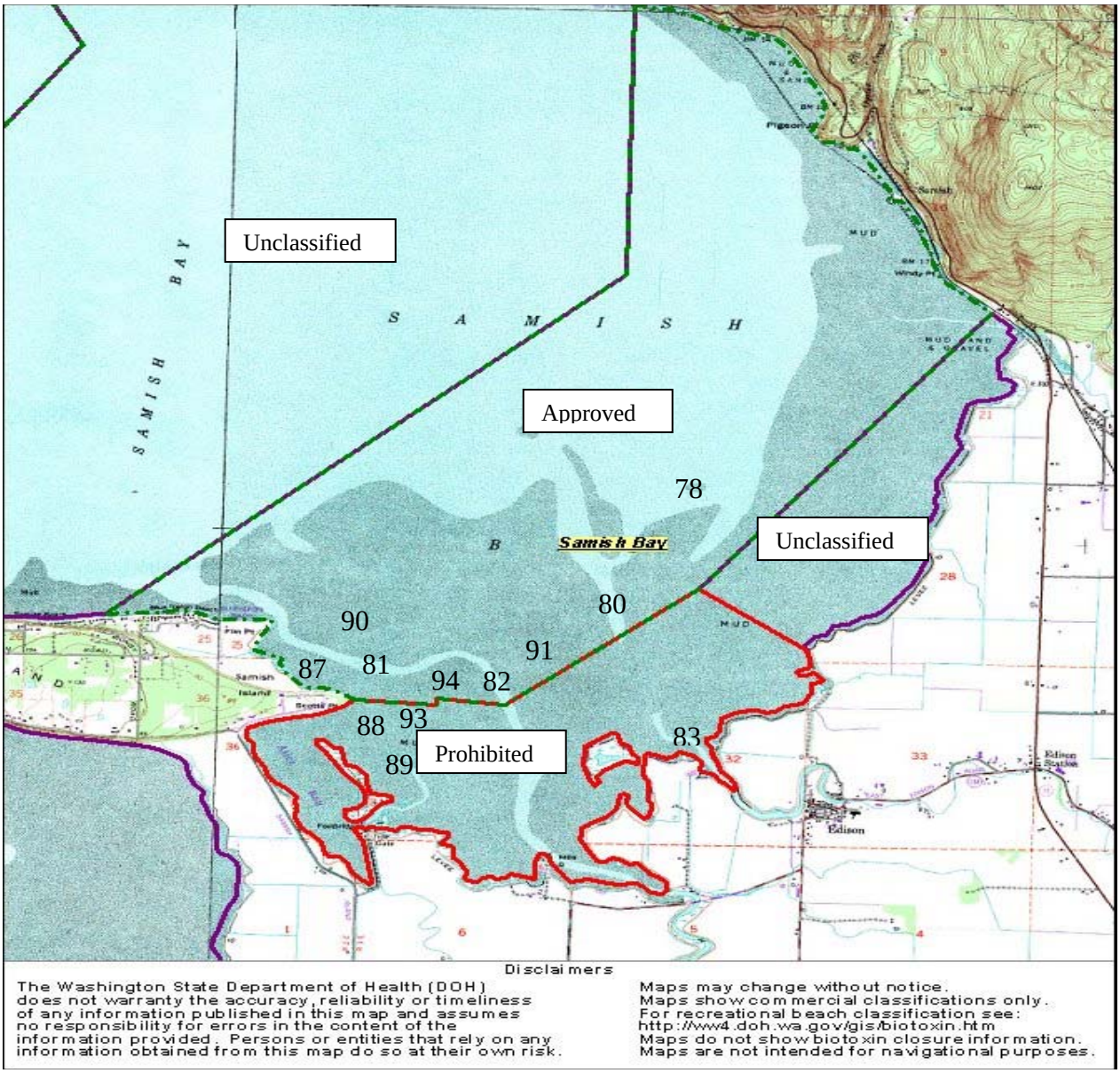

Figure 2. Washington State Department of Health classifications for harvesting shellfish in Samish Bay (DOH, 2005). Selected DOH FC sampling sites also shown.

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.

A revised water quality standards rule (Chapter 173-201A WAC) was adopted on July 1, 2003. The freshwater bacteria criteria portion of this version has recently been approved by EPA, but the marine bacteria portion has not. Samish Bay is still classified as Class A (excellent)

according to the 1997 rule and freshwater in the Samish Bay watershed is now considered *Primary Contact Recreation* water according to the 2003 rule.

Characteristic uses for Class A marine waterbodies include fish, shellfish, and crustacean rearing/spawning/harvesting; wildlife habitat; recreation (primary contact recreation, sport fishing, boating, and aesthetic enjoyment); and commerce and navigation (WAC 173-201A).

Under the 2003 rule, freshwater waterbodies are required to meet water quality standards based on the beneficial uses of the waterbody. For fecal coliform bacteria, former Class A waters become *Primary Contact Recreation.* Examples of *Primary Contact* uses are swimming, snorkeling, and activities where the water and skin or body openings (e.g., eyes, ears, mouth, nose, and urogenital) come into direct and extended contact.

Numeric criteria for specific water quality parameters are intended to protect designated uses. Under the revised water quality standards, while the waterbody classification system has changed, the FC bacteria numeric target for each of the waterbodies included in this study has not.

WAC 173-201A-060 describes the application of freshwater or marine water quality standards on the basis of salinity. Where 95% of the vertically averaged daily maximum salinity levels are less than one part per thousand (ppt), the freshwater standards apply. For fecal coliform, the marine water quality standard (14 cfu/100 mL) applies where salinity is 10 ppt or greater. If data shows a 95th percentile conductivity of 17,700 micromhos, equivalent to a salinity greater than 10 ppt, then marine fecal coliform standards will apply. To determine the upstream extent of the marine waterbody designation on the Samish River and other drainages to the bay, Ecology will collect conductivity and/or salinity data during high tide conditions. Freshwater and marine standards are listed below for bacteria.

Fecal Coliform Bacteria

- For Class A Freshwater (1997 rule) and freshwater Primary Contact Recreation (2003 rule): *"…fecal coliform organism levels shall both not exceed a geometric mean[1] value of 100 colonies/100 mL, and not have more than 10 percent of all samples obtained for calculating the geometric mean value exceeding 200 colonies/100 mL."*

- For Class A Marine Water (1997 rule): *"…fecal coliform organism levels shall both not exceed a geometric mean[1] value of 14 colonies/100 mL, and not have more than 10 percent of all samples obtained for calculating the geometric mean value exceeding 43 colonies/100 mL."*

The FC criteria have two statistical components: a geometric mean and an upper limit value that 10 percent of the samples cannot exceed. Fecal coliform samples collected randomly follow a lognormal distribution. In Washington State FC TMDL studies, the upper limit statistic (i.e., not

[1] The geometric mean is calculated as the nth root of the product of n numbers.

more than 10% of the samples shall exceed) has been interpreted as a 90th percentile value of the lognormalized 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 commercial crab and salmon fisherman have more regular contact with the waters of Samish Bay.

Potential Sources of Bacteria

Permit Holders

Fecal coliform bacteria can be present in a wide variety of municipal and industrial wastewater and stormwater sources. No method is 100 percent 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 National Pollution Discharge Elimination System (NPDES) and general permits from Ecology.

Virtually all homes in the unincorporated community of Edison, including the Edison elementary school, discharge to a new (1996) wastewater collection system. 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. A state waste permit for the ground discharge is anticipated in the near future. Skagit County will be the permit holder (Ziebart, 2006).

The 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, and they are inspected periodically by Washington State Department of Agriculture (WSDA). New Concentrated Animal Feeding Operations (CAFO) regulations are under development and will be administered by WSDA. 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).

Sedro Woolley and its surrounding urban growth area is a NPDES Phase II municipal separate storm sewer system (MS4) permit candidate and is located near headwaters of Willard Creek, a small tributary to Thomas Creek. Willard Creek likely drains some of the Phase II area; but, map resolution showing phase II boundaries is poor, so this area will be investigated on a finer scale while in the field.

Washington State Department of Transportation (WSDOT) highways and facilities are also required to be covered under a MS4 permit. The WSDOT controls state highways 9, 11, and 537 (also called Farm to Market Road), and Interstate 5.

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.

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

Birding is common in the Samish Valley; migratory and other birds are often seen in fields and in the bay itself. Birds, elk, deer, beaver, muskrat, and other wildlife in headwater and rural valley areas are potential sources of FC bacteria. Open fields are attractive 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 state criteria. Sometimes animals are locally concentrated and can cause elevated counts. Marshy areas above river mile (RM) 25 on the Samish River, for example, will be monitored for concentrated animal population effects. Concentrated bird presence in the watershed will be noted during sampling surveys.

Nonpoint Sources

Agriculture

Nonpoint sources and practices are dispersed and not readily 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 on non-commercial farms is another source.

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. 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 antiquated onsite sewage systems can seep fecal coliform 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.

Recreation

Recreational opportunities in the Samish watershed are extensive. Unfortunately there are few toilet facilities for recreators. 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 locate more portable toilets at critical recreational access points (Dewey, 2005).

Other nonpoint sources

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

Historical Data Review

Washington State Department of Ecology

Ecology has collected ambient monitoring data, including fecal coliform and streamflow, from the Samish River at Highway 99 (RM 10) since 1976 (Ecology, 2005b). Ambient monitoring records from this site contain several FC bacteria counts that indicate non-compliance with water quality standards. FC counts and loads at Hwy 99 show a seasonal cycle. Concentrations are higher in the months of June through November while loading is highest in fall, winter, and spring when flows are high (Figures 3 and 4). Annual mean fecal coliform concentrations and loads at Hwy 99 have not changed significantly since 1976.

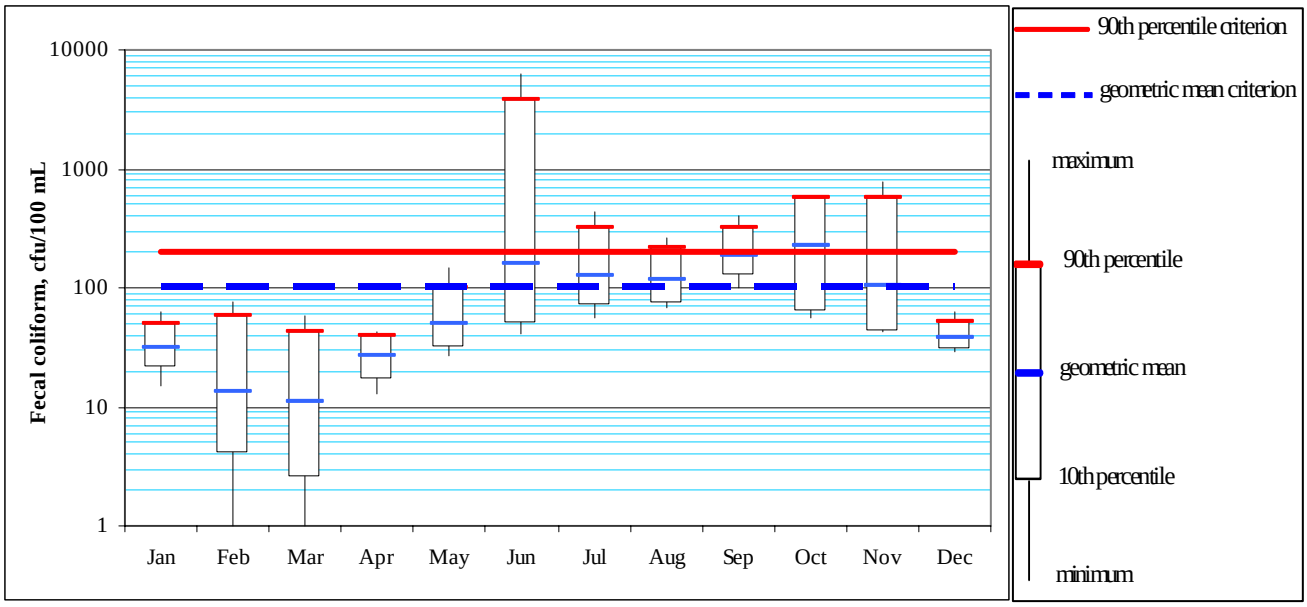

Figure 3. Samish River at RM 10 (Hwy 99) fecal coliform concentrations from Ecology's monthly Ambient Monitoring Program, 2000 to 2005 (4 or more samples/month).

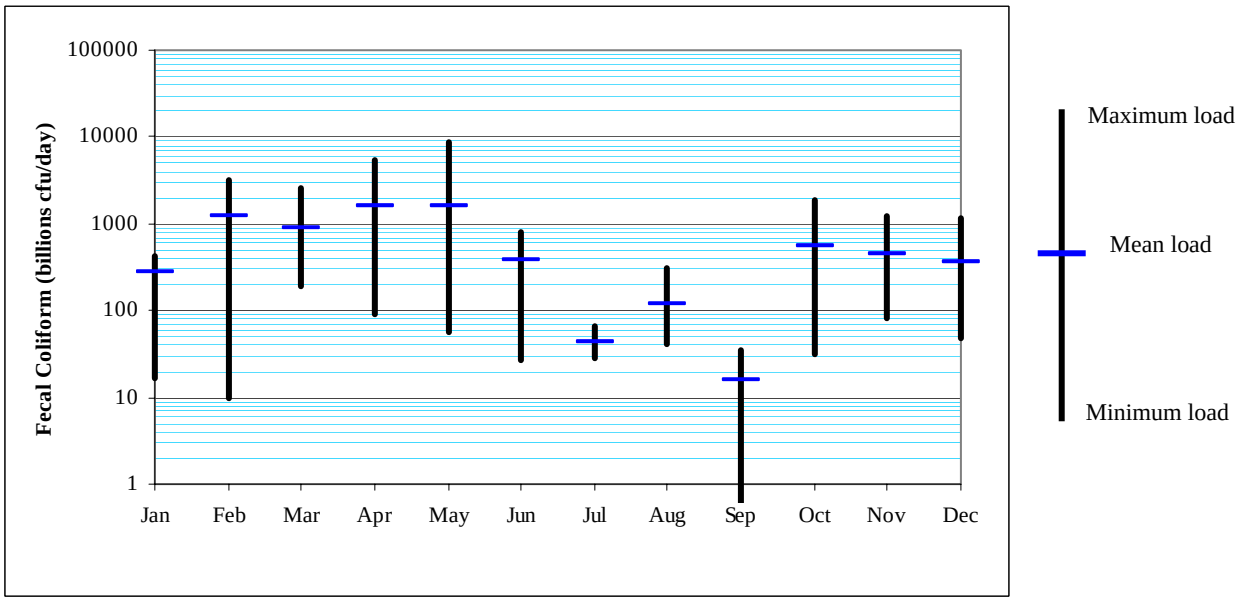

Figure 4. Samish River at RM 10 (Hwy 99) fecal coliform loads from Ecology's monthly Ambient Monitoring Program, 2000 to 2005 (4 or more samples/month).

Ecology also collected FC and E. coli data in east Samish Lake at five sites in June, July, August and September of 2004 (Bell-McKinnon, 2004). All samples showed little fecal contamination. FC results ranged from 1 to 96 colony forming units/100 mL (cfu/100 mL) with a geometric mean of 7.4 cfu/100 mL. E. coli results ranged from 1 to 91 cfu/100 mL with a geometric mean of 5.4 cfu/100 mL.

Skagit County Public Works

Skagit County Public Works recently published the Samish Bay watershed Water Quality Monitoring Project Final Report, prepared by Rick Haley (2004). Sampling for the project began in April 2000 and continued into June 2003. Twenty-four sites covering the Samish Bay watershed were routinely sampled for fecal coliform, using the most probable number (MPN) method. Although the report contains sufficient data for a basin-wide FC concentration analysis, streamflow data at several key sites are lacking, making loading calculations to the bay difficult. However, the six sites on the Samish River and Friday Creek consistently measured for streamflow provide valuable loading data that were considered during the development of Ecology's sampling plan.

Of the project's 24 sites--including sites on the Samish River; Edison Slough; Friday, Thomas, and Colony creeks; and several unnamed sloughs, ditches, and pump stations--only one site, the Samish River at RM 15.5 (Prairie Road), met state standards for class A waters (Haley, 2004). Five sites' cumulative geometric means were over 100 cfu/100 mL and 23 of the 24 sites exceeded the 10% over 200 cfu/100 mL criterion. Skagit County data show how geographically widespread FC problems were in the Samish Bay watershed from 2000 to 2003.

Figure 5 shows mean longitudinal loading at five sites on the Samish River where Skagit County Public Works measured flow and sampled FC at the same time. Linear regression equations were used to calculate any missing flows so more data could be included in the analysis (Appendix A). All loads calculated for all sites in Figure 5 used data from the same days so sites could be compared without introducing bias. R-squared values from the regression analysis ranged from 0.8209 when comparing flows at RM 15.5 and RM 21, to 0.9666 when comparing RM 6.5 and RM 4.5 (Appendix A).

Dry season (July-September) and wet season (October-June) mean loading increased from RM 21 (Hwy 9) to RM 10 (Hwy 99). During both seasons, the largest percent increase occurred from RM 21 to RM 15.5 (Prairie Road) (Figure 5). Loading during both seasons decreased slightly from RM 10 to RM 4.5 at Thomas Road. Although county data showed much higher FC concentrations at RM 25 (below Ennis Creek), it is not known if this represents higher loading since streamflow was not measured (Figure 7).

The slight decrease in net FC loading below RM 10 may have been from the slow decay of upstream FC as it traveled downstream with little additional loading (Thomas Creek and an unnamed ephemeral creek are the only known sources of FC below RM 10). Or FC die-off could be masking additional sources to the river. Dilution likely did not occur since net flow does not increase from RM 10 to the mouth during wet or dry seasons (Appendix B). Identification of FC sources in the upper watershed will likely lead to reductions in upstream FC, which may then reveal lower mainstem bacteria sources, if any. Ecology is concentrating its FC sampling efforts above RM 10, although three sites will be monitored below RM 10.

Figure 5 shows lower mean FC loading in the dry season (July-September) than in the wet season (October-June), but geometric mean concentrations are not significantly different (Figure 6). The same data were used for concentration and loading charts for comparison purposes.

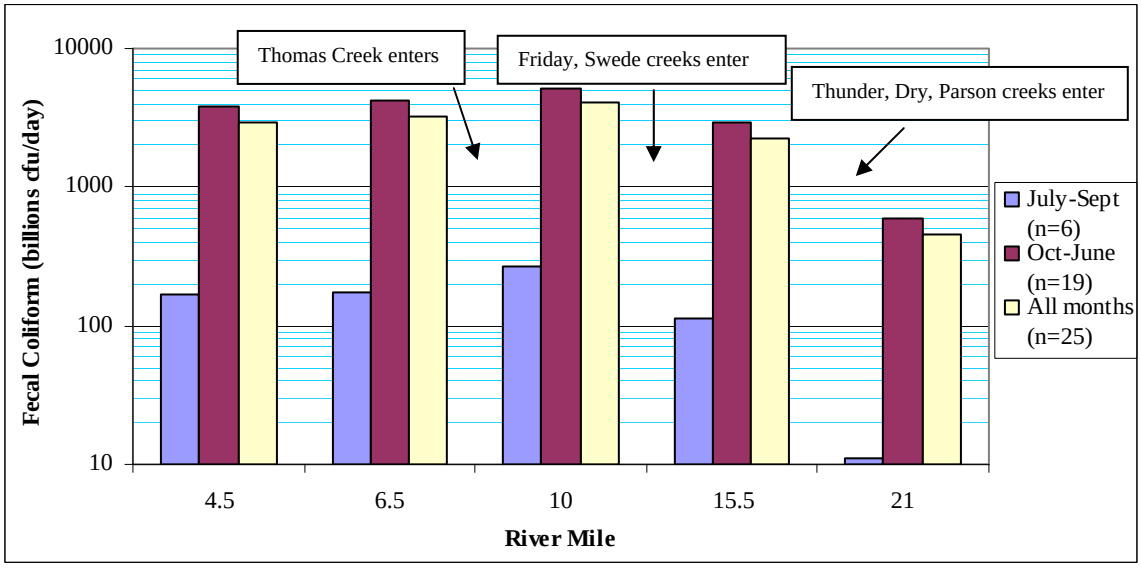

Figure 5. Longitudinal mean fecal coliform loads in the Samish River from RM 21 (Hwy 9) to RM 4.5 (Thomas Road) during Skagit County's 2000-2003 FC surveys.

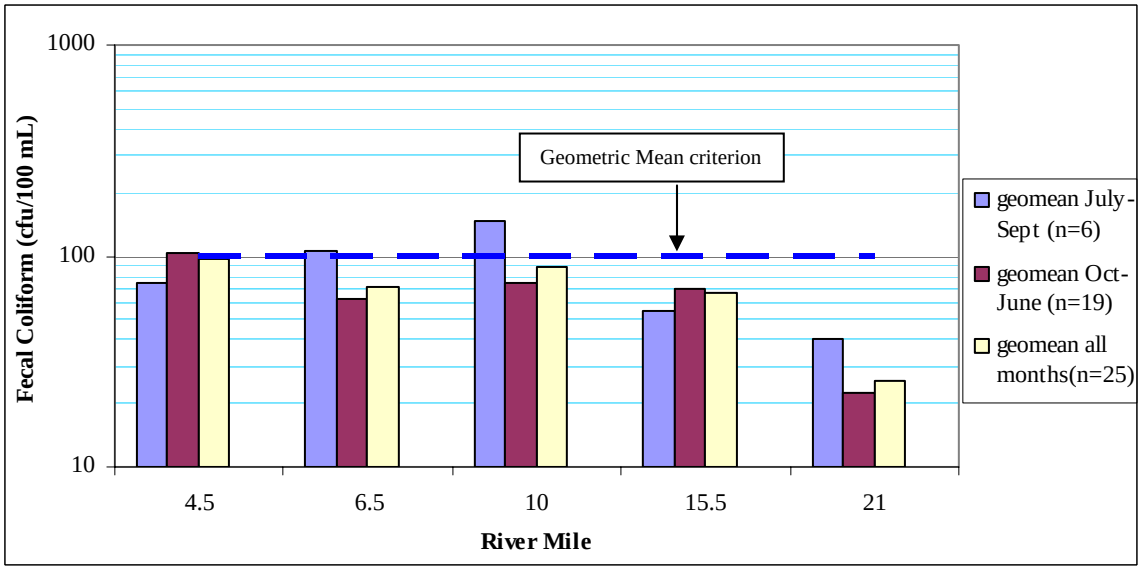

Figure 6. Longitudinal geometric mean fecal coliform concentrations in the Samish River at the same sites and same times as Figure 5.

The Samish River at RM 25 did not meet either the 90th percentile or geometric mean criteria (Figure 7). All other sites on the river met the geometric mean criterion (Haley, 2004). Although geometric mean data suggest RM 21 is the most unpolluted site, it did not meet the 90th percentile criterion. The only site on the Samish River that met both parts of the FC criterion was RM 15.5 (Haley, 2004). If nonpoint FC sources were controlled and water quality maintained from RM 15.5 downstream, conditions in Samish Bay would likely improve.

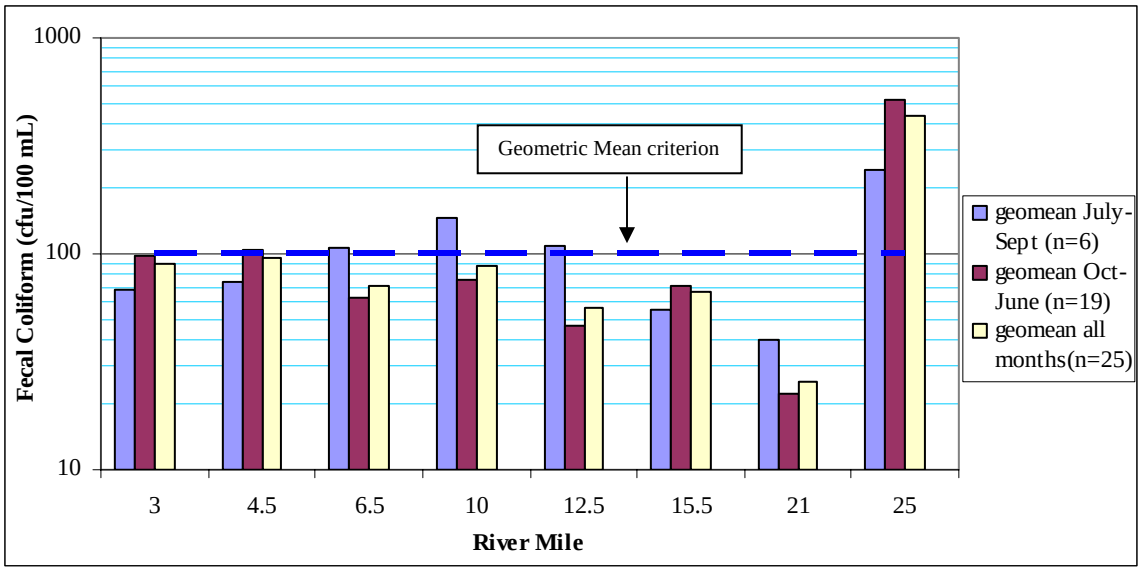

Figure 7. Longitudinal geometric mean fecal coliform concentrations* on the Samish River at all sites from RM 25 (near Ennis Creek Road) to RM 3 (Farm to Market Road) during Skagit County's 2000-2003 FC surveys.

*Note: FC results greater than 2400 cfu/100 mL were estimated as 2500 cfu/100 mL for the sake of data analysis and graphing. RM 25 frequently had counts over 2400, so the geometric mean for both seasons may actually be much higher than the graph shows.

Figure 8 shows monthly loading at RM 4.5 (Thomas Road), the site that best estimates loading to the bay. The highest mean FC loads of the year occur in late spring and fall when certain land use practices, such as manure spreading and riparian cattle grazing, coincide with rain events and are more likely to affect water quality.

Mean monthly FC concentrations at Thomas Road were highest from May through November and lowest during winter and early spring months, likely because rain had flushed much of the problem FC into the bay (Figure 9). The aforementioned land use practices were not as abundant during this time, though sources of FC still exist. March and April were the only months when FC concentrations met both parts of the FC criterion at Thomas Road.

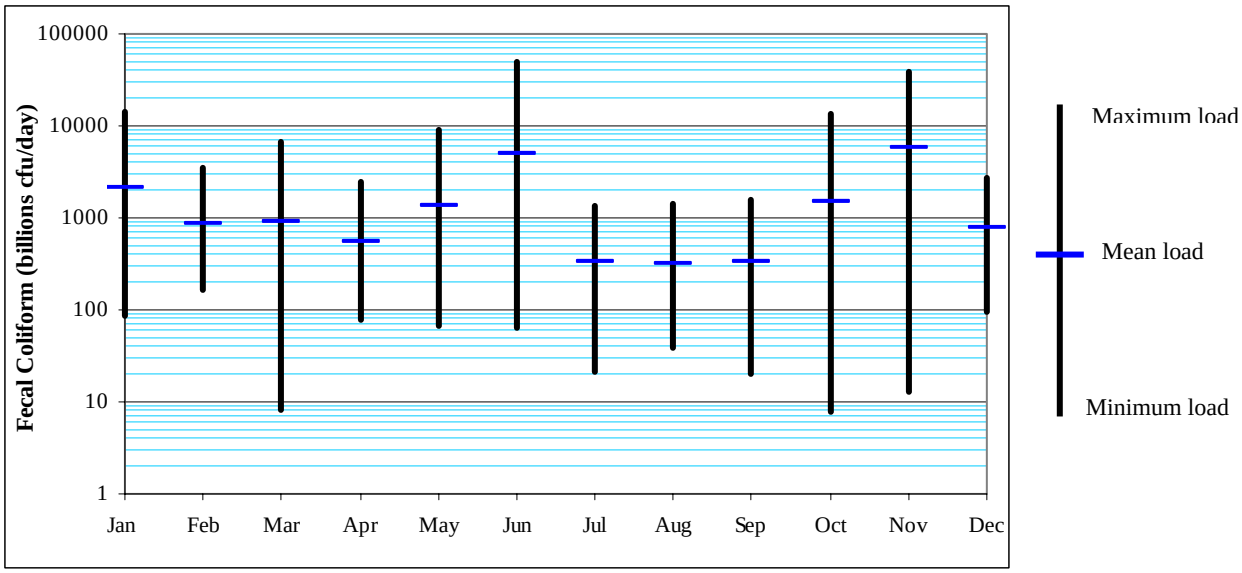

Figure 8. Monthly FC loads in the Samish River at RM 4.5 (Thomas Road) during Skagit County's 2000-2003 FC surveys (8 or more samples/month).

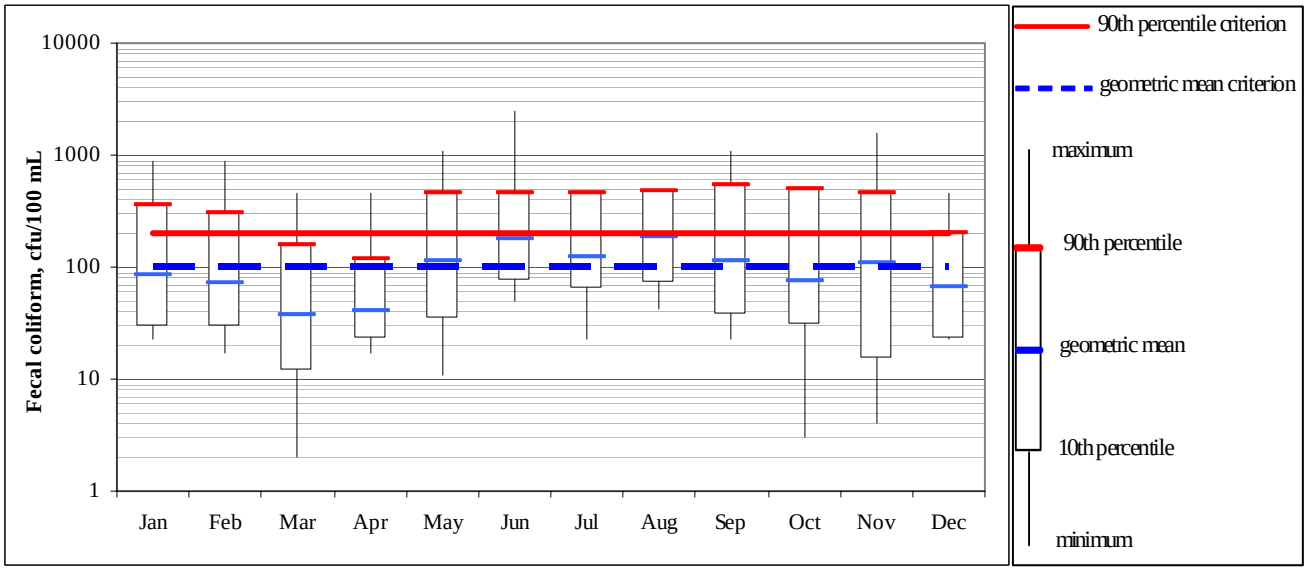

Figure 9. Monthly FC concentrations in the Samish River at RM 4.5 (Thomas Road) during Skagit County's 2000-2003 FC surveys (8 or more samples/month); same data as in Figure 8.

Monthly fecal coliform loading and concentration patterns at Hwy 9 are representative of Samish River sites between RM 4.5 and RM 25 (Figures 10 and 11). The highest loading occurred in late spring and fall, although loading increases were not as pronounced in the fall. FC concentrations mirrored this pattern with one important exception--summer FC concentrations tended to stay high, even though loading decreased significantly. Most of the Samish River exceeded the 90th percentile criterion during late spring and summer. Mean monthly FC concentrations for all eight Samish River sites are represented by simple bar charts in Appendix C. All charts represent data from the same dates for an unbiased site-to-site seasonal comparison.

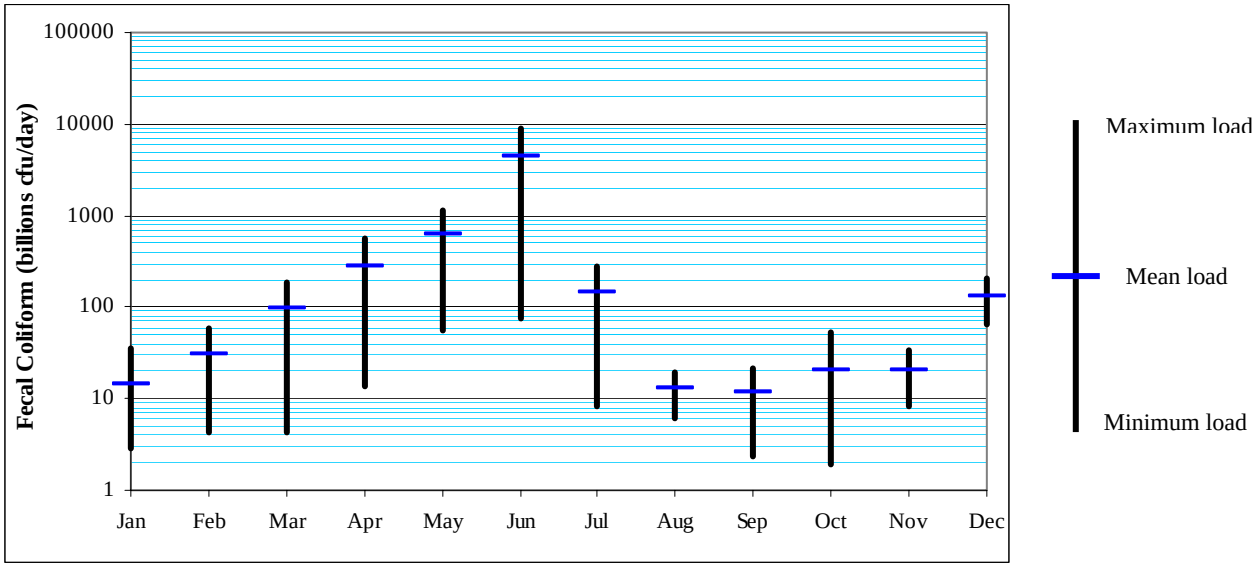

Figure 10. Samish River at RM 21 (Hwy 9) monthly FC loads from Skagit County's 2000-2003 FC surveys (2-3 samples/month).

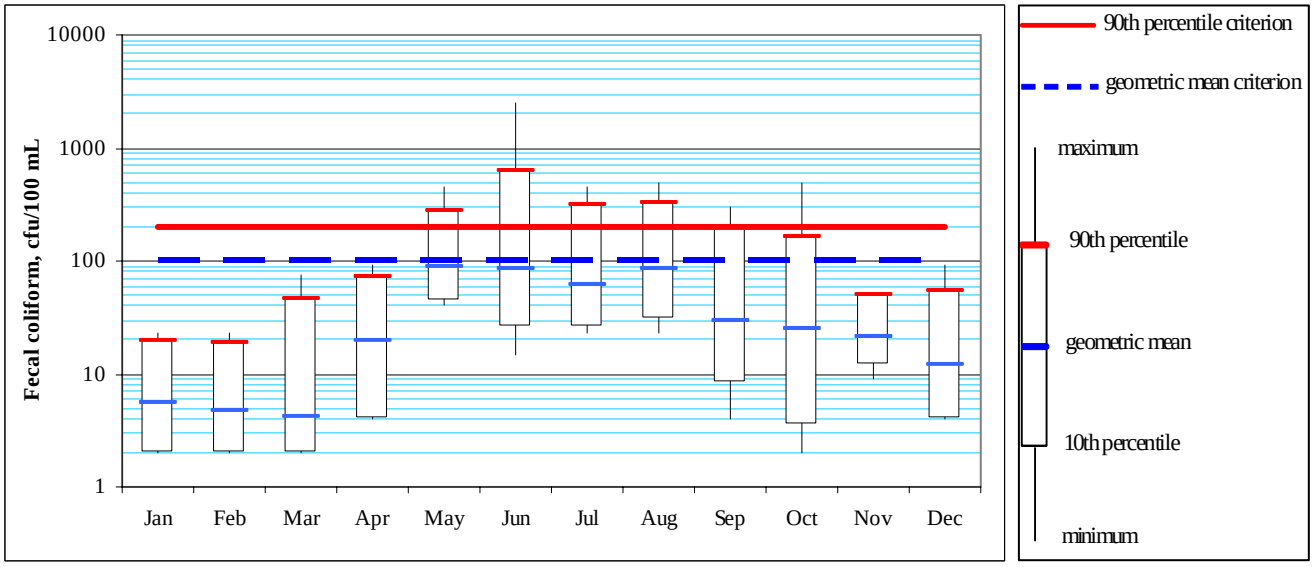

Figure 11. Samish River at RM 21 (Hwy 9) monthly FC concentrations from Skagit County's 2000-2003 FC surveys (5 or more samples/month).

Flows at RM 25 (below Ennis Creek) were not measured during Skagit County's Samish Bay watershed Project. However, concentration data suggest potentially high loading (Figure 12). FC counts do not meet the geometric mean nor 90th percentile criteria at any time of the year. The highest concentrations occur in late spring and fall/winter. Ecology will sample and investigate possible sources of FC above RM 25, as well as measure flow so loading can be assessed in the upper watershed.

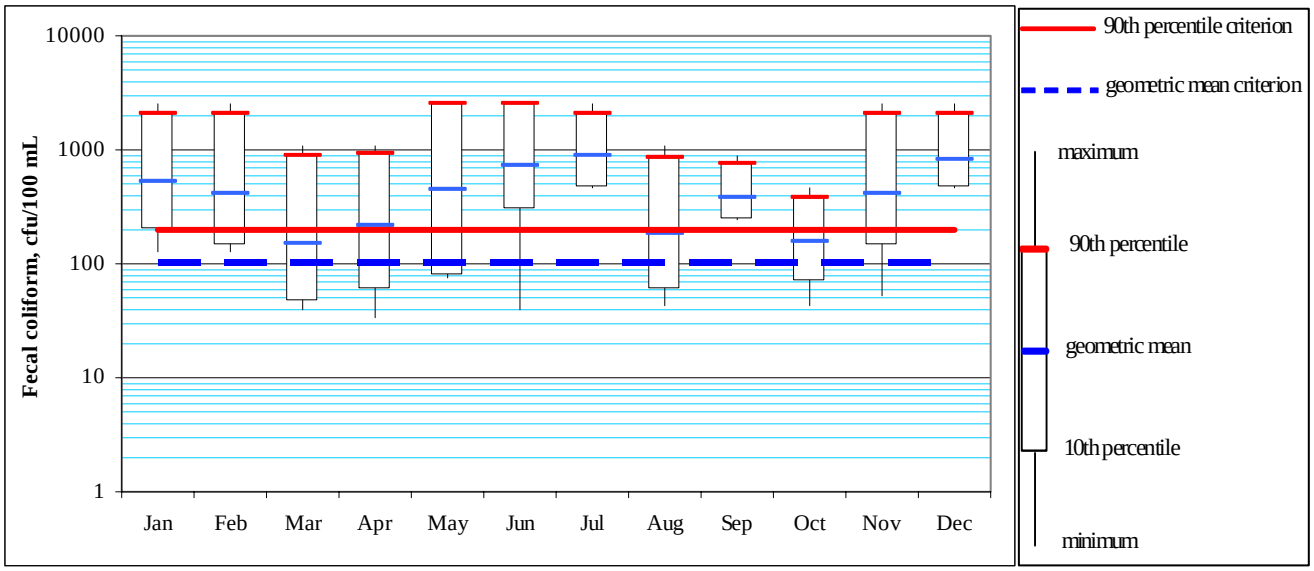

Figure 12. Samish River at RM 25 (below Ennis Creek) monthly FC concentrations from Skagit County's 2000-2003 FC surveys (3-5 samples/month).

Bacteria concentrations drop substantially from RM 25 to RM 21 (Figure 7), possibly due to wetland attenuation, dilution from known and unknown sources, and/or die-off. Because of improving water quality conditions between RM 25 and RM 21 and lack of river access, Ecology will not sample this reach of the Samish River.

No known creeks or drainages enter the Samish River between RM 15.5 and RM 10 except Friday and Swede creeks. Swede Creek has a very small influence on overall FC loading at RM 10 (Figure 13). Friday Creek, however, contributes over one-third of the loading at RM 10. Friday Creek does not meet state standards below Prairie Road and is listed on the 303(d) list. Improving water quality on Friday Creek is a priority for Ecology. Unknown sources to this reach will also be investigated.

Other reaches of the river could not be analyzed for relative contributions due to missing streamflows and/or FC concentrations.

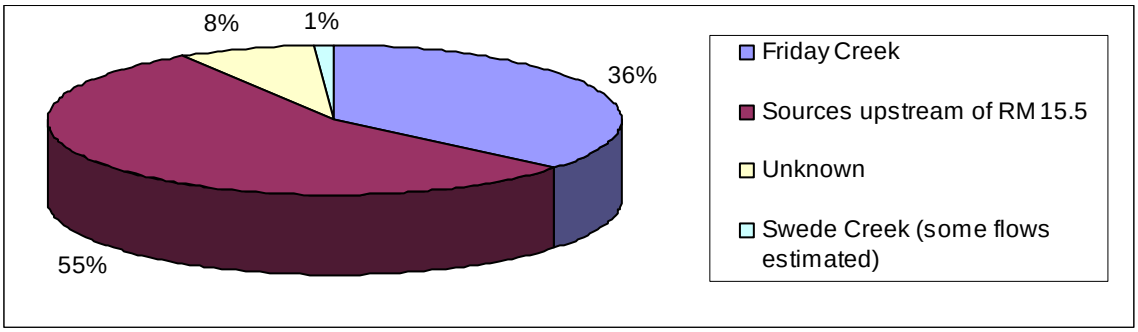

Figure 13. Relative contributions of annual FC to the Samish River at RM 10 (Hwy 99).

Several key sites are still monitored by Skagit County Public Works under the Skagit County Monitoring Program (www.skagitcounty.net/scmp) including sites on the Samish River; Thomas, Swede, Friday, and Colony creeks; Alice Bay pump station; and Edison Slough and associated drainages. Coordinated sampling between Ecology and Skagit County Public Works on overlapping sites will occur, if feasible. Frequent communication and information sharing will contribute greatly to the success of the TMDL study.

Samish Tribe

The Samish Tribe sampled FC at 27 sites in the Samish Bay watershed from August 1998 to June 2000 (Woodward, 2005). Summary FC concentrations are shown in Table 2. Streamflow measurements were not taken. Samish Tribe and Skagit County data show similar FC concentration patterns. For example, concentrations in upper Thomas Creek were high, then decreased downstream at Hwy 99, but never met state standards. Both sets of data also showed that the Samish River at Ennis Creek Road had the highest FC concentrations in the Samish River mainstem, while concentrations dropped off markedly at the next downstream site, Highway 9. Both data sets showed that lower Samish River, Colony Creek, and Edison Slough did not meet state standards. However, the tribe's data suggest Friday Creek met standards at Prairie Road, while the county's data showed it exceeded the 90th percentile criterion. Loads could not be calculated due to lack of streamflow data.

Table 2. Locations sampled by the Samish Tribe in the Samish Bay watershed. Geometric Mean and 90th percentile shown. Excursions of state FC criteria are bolded.

Waterbody	Site Location	Geometric Mean	90th Percentile	n
Samish R	Ennis Creek Rd	86	**796**	34
	Hwy 9	23	99	34
	First Prairie Rd crossing from Hwy 99	17	41	35
	Grip Rd	44	162	20
	Thomas Rd	36	72	9
	Avon-Allen Rd	59	**310**	32
	Bayview-Edison Rd	43	**280**	31
Ennis Ck	where Ennis Ck turns into a roadside ditch along Ennis Creek Rd	3	28	32
Parson Ck	Prairie Rd	97	**944**	33
Swede Ck	Grip Rd	45	140	19
Thomas Ck	across F&S Grade Rd where the creek turns into a roadside ditch	**136**	**632**	34
	Hwy 99	73	**232**	34
Friday Ck	Nulle Rd (below Samish Lake)	9	39	33
	Prairie Rd	39	127	34
Bear Ck	West Lake Samish Rd	7	42	33
Reed Lk	outflow to Cain Lk	9	49	34
Silver Ck	Cain Lake outflow	45	140	41
	Cain Lake Rd	73	**232**	42
Colony Ck	E fork at Woods Rd	17*	NA	2
	W fork at Woods Rd	2*	NA	3
	upper Colony Ck (specific location not known)	22	**200**	31
	bridge at 15489 Colony Rd (driveway)	28	**322**	33
	downstream of S. Blanchard Rd	71	**438**	32
	upstream of culverts at Blanchard Rd	56	185	34
Harrison	Colony Mt Rd	17	**291**	30
	bridge at 15489 Colony Rd (driveway)	67	**600**	31
Edison Slough	at Edison school bridge, near wastewater treatment facility	51	**300**	31

* Not enough samples were taken for a meaningful geometric mean so average is shown.

Washington State Department of Health

The DOH samples fecal coliform in Samish Bay once monthly. Sampling sites near the border of the approved and prohibited shellfish zones and near Alice Bay and Edison Slough are listed in Table 3 and can be seen in Figure 2. Sites near the channel of the Samish River as it enters the approved shellfish zone (82, 94, 91, and 81) had the highest geometric means and percentages of samples over 43 cfu/100 mL in the approved section of the bay. The 90th percentile is now used by the DOH instead of the 10% exceedance standard and decisions to reclassify areas are based on the most recent 30 samples (Lennartson, 2005). The DOH will continue to sample FC at selected sites in Samish Bay once a month throughout Ecology's TMDL.

Table 3. Washington State Department of Health January 1995 to July 2005 fecal coliform (MPN method) summary data for selected sites in Samish Bay.

Site	Classification	Number of Samples	Geometric Mean (cfu[1]/100 mL)	% Samples >43 cfu[1]/100 mL	Range[2] (cfu[1]/100 mL)
93	prohibited	54	4.8	9.3	1.7 - 170
88	prohibited	105	7.7	12.4	1.7 - 920
89	prohibited	104	7.3	9.6	1.7 - 540
83	prohibited	100	6.7	20	1.7 - 540
78	approved	91	2.5	3.3	1.7 - 540
80	approved	104	3.9	7.7	1.7 - 240
91	approved	99	3.9	10.1	1.7 - 350
82	approved	106	5.3	11.3	1.7 - 540
94	approved	72	5	11.1	1.7 - 920
81	approved	94	4.7	8.5	1.7 - 240
90	approved	92	4.3	7.6	1.7 - 170
87	approved	106	3.9	4.7	1.7 - 350

[1]colony forming unit.
[2] 1.7 = <1.8 cfu/100 mL.

Geometric mean fecal coliform concentrations at site 94 showed seasonal increases in late spring and early winter when loads from the Samish River were also high (Figure 14). Geometric mean FC concentrations were highest in November and December.

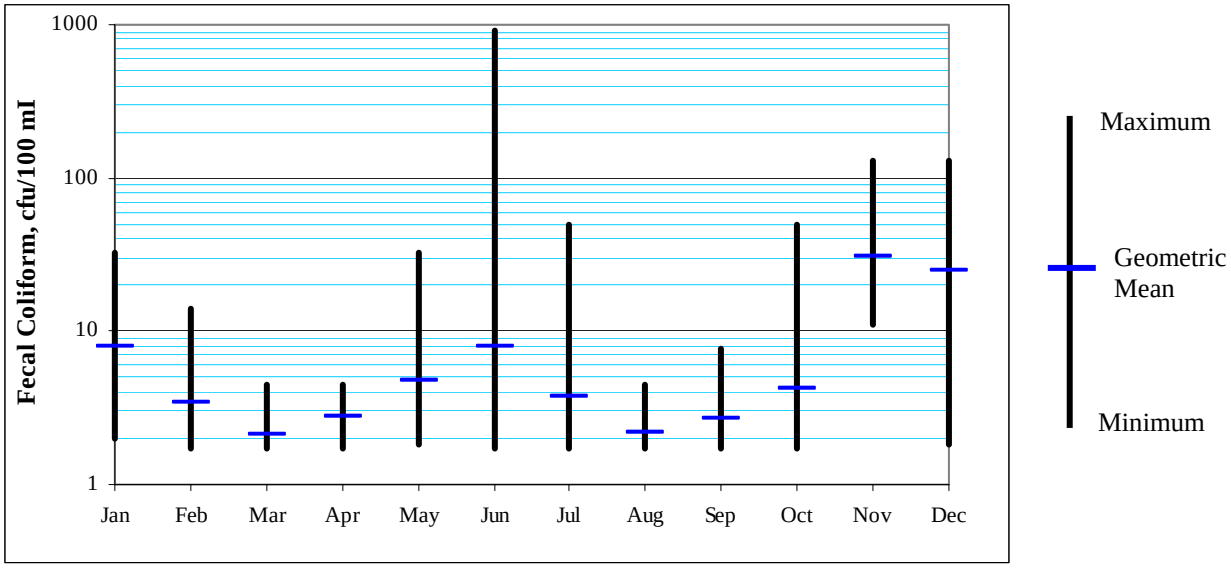

Figure 14. Samish River at DOH site 94 fecal coliform concentrations, 1998 to 2005 (4 or more samples/month).

USGS

The US Geological Survey (USGS) sampled total coliform 121 times from 1959 to 1974. This QA Project Plan is only evaluating recent fecal coliform data, so USGS bacteria data was not analyzed. However, the USGS flow station at Highway 99 is still in operation and has been recording streamflow since 1943 (Figure 15). Regression analysis using USGS streamflow data will be valuable during times of high flow or time constraints, such as during storm event sampling.

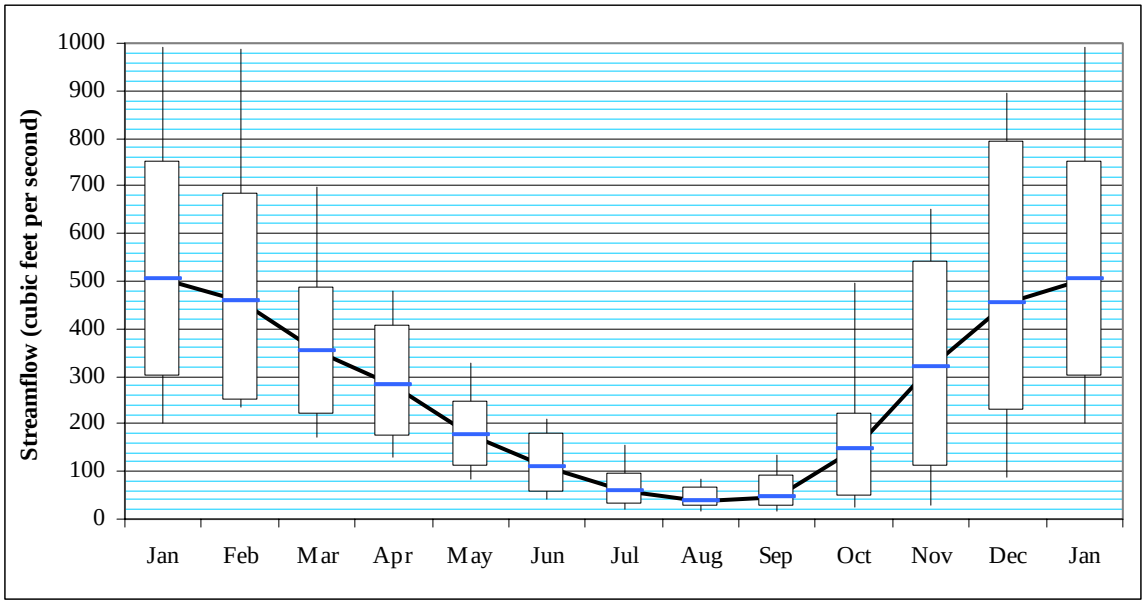

Figure 15. Mean monthly streamflow on the Samish River at RM 10 (Hwy 99) recorded by USGS from 1943 to 2004. Boxes represent 10th and 90th percentiles.

Skagit County and Ecology Storm Monitoring

The Skagit County Health, Conservation District, Planning and Permit Center, and Ecology sampled 10 sites in the Samish watershed from December 1994 through February 1996, mostly to characterize runoff during rain events in known problem areas (Palmer, et al., 1996). Sites included the Samish River, Friday and Thomas creeks, and three pumps to Edison Slough and Samish Bay. Flows were measured at the stream sites but not at the pump stations. They concluded that FC levels at all sites violated the state water quality standards. A non-parametric test (Kruskal Wallis one-way analysis by ranks) showed that sampling sites were uniformly high; no stream segment, tributary, or pump station was significantly higher than any other. FC loads at Thomas Creek were significantly lower than loads at other stream sites. FC concentrations from the three pump stations appear to be comparable to Samish River sites when sampled under similar conditions, but loads from pump stations were unknown because of lack of flow data.

Skagit County Stream Team

As a volunteer organization, the Stream Team's goal is to educate the public and create baseline data for three watersheds: Padilla and Samish bays and the Nookachamps Creek subbasin. FC data collection started in 1999 and is ongoing. Stream Team volunteers analyze FC samples using membrane filters. Consistency is important when evaluating and comparing data. Different methods and QA/QC procedures were followed in the collection and analysis of the Stream Team's data. Nevertheless, results aligned with Skagit County Public Work and Samish Tribe data, showing FC contamination in similar areas in the watershed. Selected Skagit Stream Team Water Quality Reports and contact information can be found on the internet at: www.skagitcd.org/ and www.padillabay.gov/involvestreamteam.asp

Project Description

Project Goals and Objectives

Objectives of the proposed study are as follows:

- Identify and characterize fecal coliform bacteria concentrations and loads from all tributaries, point sources, and drainages into Samish Bay under various seasonal or hydrological conditions, including stormwater contributions.

- Establish fecal coliform load allocations (for nonpoint sources) and wasteload allocations (for point sources) to protect beneficial uses, including primary and secondary contact and shellfish harvesting.

- Identify location of sources of fecal coliform to the Samish River upstream of RM 10 (Hwy 99) where, according to historical data, most FC loading occurs.

- Identify relative contributions of FC loading to the bay so clean-up activities can focus on the largest sources.

Study Design

The project objectives will be met through characterizing annual and seasonal FC bacteria loads in the Samish River and its tributaries, Colony Creek, Oyster Creek, Edison Slough, and all drainages flowing into Samish Bay. Figures 1 and 16 show a small creek flowing into northwest Samish Bay, south of Larrabee State Park. This creek will not be sampled because of its location relative to shellfish beds, small size, and the low probability of FC contamination. Fecal coliform concentrations will be monitored at the mouths of all tributaries, point sources, significant drainage/discharges, and key locations within the bay over a 14 month period. When possible, flow will be measured at all sites at the time of sampling.

The freshwater component of the Samish Bay TMDL Study will use a fixed network of sites sampled twice monthly and a set of four synoptic storm event surveys (Table 4). Samish Bay will be sampled once monthly by the DOH at strategic locations. Ecology will coordinate with the DOH and sample in the lower watershed on the same day as bay sampling occurs. The upper Samish River and its tributaries will be sampled the following day with an overlapping site on the Samish River to track any changing water quality conditions over the course of the two sampling days.

Instantaneous FC loads will be estimated at each site using the best available streamflow data. If possible, seasonal and annual FC loads will be estimated from regression analyses of the results (Cohn et al., 1992; Christensen et al., 2001). Loads estimated at individual sites and within reaches will be compared to adjacent loads to characterize potential areas of excessive FC loading or areas of FC losses.
Continuous streamflow data will be obtained from three stream gaging stations:

– Samish River at RM 10 – Hwy 99 (USGS).
– Friday Creek near Hatchery (Ecology, Stream Hydrology Unit).
– Silver Creek near Alger (Ecology, Stream Hydrology Unit).

Another continuous station will be added in the upper Samish River by the Stream Hydrology Unit shortly after sampling is underway. Ecology will also install staff gages at other sites to develop discharge rating curves based on stage.

Fecal coliform bacteria are sensitive to saltwater and die-off rates change when entering estuarine waters. Monitoring of stations under tidal influence will occur during ebb tide so fecal coliform samples reflect the fresh water input. Salinity will be checked to ensure stream water is sampled. This data will also be useful when determining if tidegates are working properly.

Special Studies

FC samples taken by Skagit County and the DOH are analyzed using the most probable number (MPN) method. Saltwater samples are typically analyzed using the MPN method because of regulatory reasons. Some researchers also believe the MPN method is better at enumerating injured or stressed organisms, and organisms in turbid or saline waters. Ecology typically uses the membrane filtration (MF) method in streams because of its practicality and precision. Joe Joy compared MF and MPN methods during the Nooksack TMDL Study (Joy, 2000). MPN results showed a wider confidence interval than MF, and a built-in positive statistical bias. The overall relationship between MPN and MF pairs was significant after lognormal transformation, but not highly correlated (R^2=0.533). Splitting samples on the first one or two surveys, especially those taken at the mouths of tributaries to the bay, and analyzing them using both methods will be necessary to assess method and result comparability in the Samish watershed.

Escherichia coli (E. coli) and percent KES (Klebsiella, Enterobacter, and Serratia) will be collected from selected sites once a month. E. coli and percent KES will help to characterize wastes from various sources. For example, samples with a large number of E. coli would more likely come from an animal source than those with a high percentage of KES. A higher percentage KES would indicate bacteria from decaying vegetation. Future decisions about the types of Best Management Practices (BMPs) and specific source identification procedures could be influenced by this information.

Time-of-travel studies may be conducted on the lower Samish River using rhodamine dye during high and low flows. The dye is nontoxic and biodegradable and only visible near the point of injection. Estimates of travel time will be calculated using the arrival time of the peak concentration of dye at the downstream station, instream flow measurements, length of stream reach, and the dye concentration profile over time. The time of travel study will allow determination of the reach-average velocity between upstream monitoring stations and Samish Bay. Time of travel data and FC bacteria die-off rates will be used to estimate the distance fecal coliform bacteria travel in the river before they die and how far upstream FC bacteria sources affect the bay.

Small Drainage Areas to Bay

The Samish Bay watershed has many small direct-drainage areas that discharge water and pollutants to the bay. These include unnamed sloughs, small creeks, pump stations and ditches--all with tidegates--that drain a significant portion of the Samish Valley, especially when heavy rains occur. Fecal coliform loading from these sources may be significant, but historical streamflow data are lacking due to the difficulty of measuring flows in tidal areas, especially from tidegates and pumps where drainage water may or may not be flowing. Also, many pump stations are not individually metered, which makes it hard to discern energy usage at each pump and thus flow rates. Ecology plans on measuring flow in these places, but methods for measuring flow at tidally influenced sites are still under development.

Fixed-Network Sampling

Data from the fixed-network will provide FC data sets to meet the following needs:

- Provide an estimate of the annual and seasonal geometric mean and 90th percentile statistics FC counts. The schedule should provide at least 24 samples per site to develop the annual statistics, including 6 samples per site during the dry season (July-September) and 18 samples per site during the wet season (October-June).

- Provide reach-specific FC load and concentration comparisons in the Samish River and Friday and Thomas creeks to define areas of increased FC loading (e.g., malfunctioning on-site systems, livestock, wildlife, or manure spreading) or FC decreases (e.g., settling with sediment, die-off, dilution, or diversion). With accurate streamflow monitoring, tributary and source loads also can be estimated.

- Identify if certain land uses affect instream changes in FC loads.

The fixed-network sites will be sampled twice monthly from February 2006 through March 2007 (Table 4). The locations of the fixed-network water quality stations are listed in Table 5 and can be seen in Figure 16. Stations were selected based on historical site locations and FC results. Major tributaries of the Samish River will be sampled as close to their confluence with the mainstem as possible. There are 33 sites in the freshwater portion of the watershed: 11 sites on the Samish River mainstem; 10 sites total on Samish River tributaries; 5 sites on Edison Slough and associated drainage ditches; and 7 sites on various drainages flowing into Samish Bay, including Colony Creek, pump stations, and ditches.

Table 4. Proposed temporal distribution of fixed-network, synoptic storm event, and DOH bay sampling surveys.

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Fixed Network	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Samish Bay sampling (DOH)	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Synoptic Storm event				1	1				1	1	1*	1*	1*	1*

*Four storm events sampled in the months of May, June, October, and November if possible; other sites may be added or removed from the sampling plan depending upon access and new information provided during the QA Project Plan review, field observations, and preliminary data analysis.

Table 5. Fixed-network sites in the Samish Bay watershed.

Watershed or Sub-Watershed	Road Crossing or Access	Reason for Site
Samish River	Bay View Edison Rd.	At mouth
Samish River	Thomas Rd.	1st site upstream of tidal influence
Samish River	Chuckanut Dr.	Next access down from Hwy 99
Samish River	Hwy 99 / Burlington-Alger Rd.	Below Friday Ck./ above Thomas Ck.
Samish River	F & S Grade Rd.	1st access upstream from Hwy 99
Samish River	2nd Prairie Rd crossing	Increasing FC in area
Samish River	Off Prairie Rd.	Above Parson Creek / good access to river
Samish River	3rd Prairie Rd. crossing	At Thornwood, below Thunder Ck.
Samish River	Highway 9	Above Thornwood and Ennis Ck.
Samish River	Wickersham Rd.	At Wickersham, just above Ennis Ck.
Samish River	Ennis Ck. Rd.	Uppermost Samish R. site (1st access with flow)
Ennis Creek	Wickersham Rd.	At mouth
Parson Creek	Prairie Rd.	At mouth
Friday Creek	Prairie Rd.	Near mouth, below hatchery
Friday Creek	Friday Creek Rd.	1st crossing down from Parson Ck. Rd./ good access
Friday Creek	Colony Rd.	Just above Silver Creek
Silver Creek	Off Lake Samish Rd., in Alger	Near mouth
Thomas Creek	Hwy 99 / Burlington-Alger Rd.	Near mouth
Thomas Creek	F & S Grade Rd.	Just up from confluence with Willard Ck.
Willard Creek	F & S Grade Rd.	Willard Ck just abv. confluence w/Thomas
Swede Creek	Grip Rd.	Near mouth
Oyster Creek	Down from Highway 11	Near mouth
Colony Creek	Blanchard Rd.	Above tidegates
Drainage to McElroy Slough	Near Blanchard	Source of FC to Samish Bay (tidegates)
Drainage to Samish Bay	Off Smith Ave. at Key Ave.	Source of FC to Samish Bay (tidegate/pump)
Drainage to Edison Slough	Smith Rd.	Source of FC to Edison Slough (tidegates)
Drainage to Edison Slough	In south Edison	Source of FC to Edison Slough (tidegates/pump)
Drainage to Edison Slough	Near Edison Slough mouth	Source of FC to Edison Slough (tidegates)
Edison Slough	Above School and "WWTP"	Above Edison "WWTP"
Edison Slough	Farm to Market Rd. in Edison	Abv. tidegates and below Edison "WWTP"
Drainage to Samish Bay	West of Samish R. mouth	Source of FC to Samish Bay (tidegates)
Drainage to Alice Bay	Off Samish Island Rd.	Source of FC to Alice Bay (pump station)
Drainage near Alice Bay	Off Samish Island Rd.	Source of FC to Alice and Samish bays (tidegates)
33 fixed-network sites		

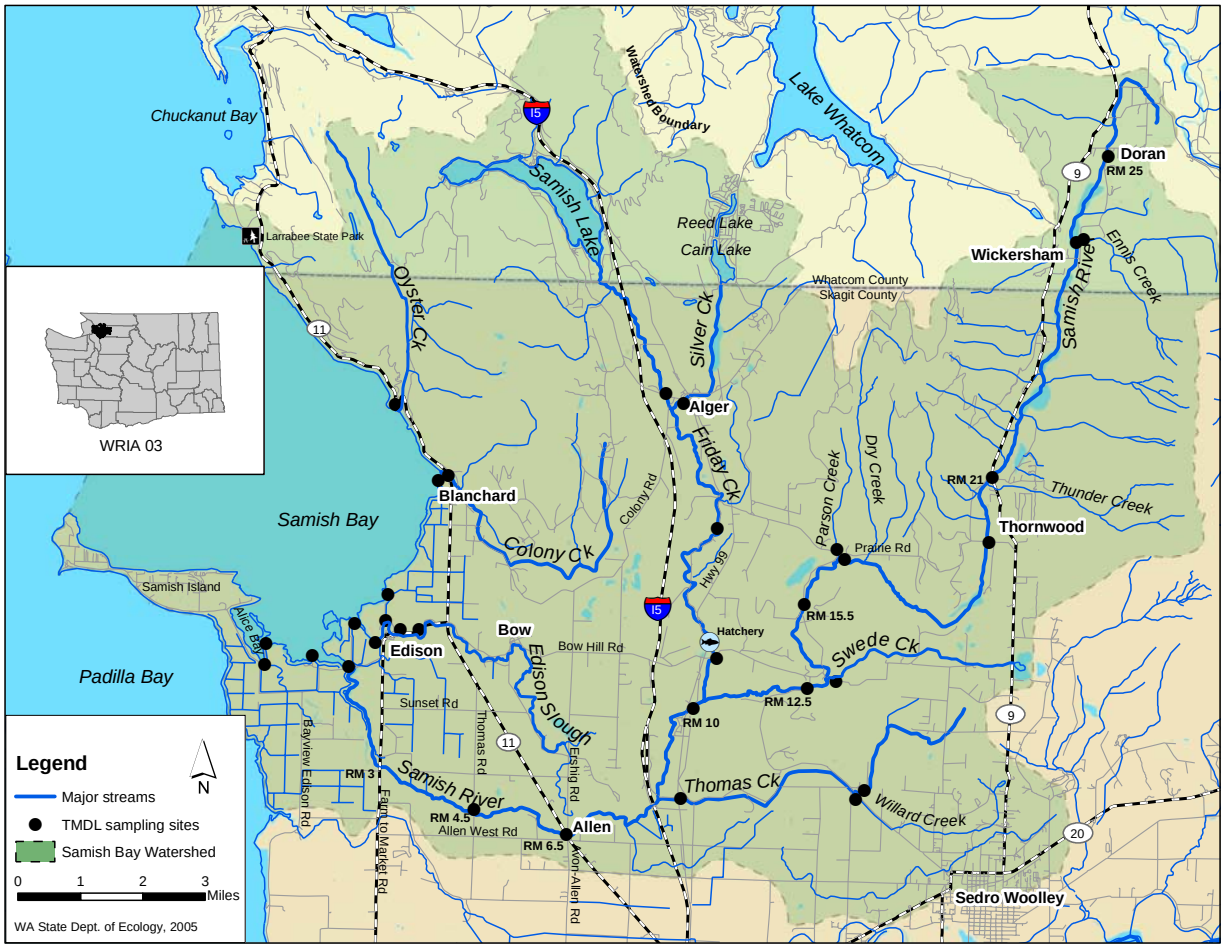

Figure 16. Map of the Samish Bay watershed showing proposed TMDL sampling sites.

Storm Monitoring

The purpose of storm monitoring is to better characterize potential sources of FC loading to the study area streams and the bay. Historical data show higher FC loading during rain events in late spring and fall. Weather permitting, storm sampling will occur in the months of May, June, October, and/or November. If sufficient rain and runoff do not occur during these months, the schedule will be adjusted.

At least four events will be sampled, with a storm event defined as a minimum 0.3 inch of rainfall in a 24-hour period preceded by no more than trace rainfall in the previous 24 hours. Rainfall of 0.5 inch or more in 24 hours occurs on average 26 times per year, but these events are not always preceded by a 24-hour dry period. Recovery of the bay water after cessation of rainfall occurs in approximately seven days (Musselman, 1982).

Storm sampling will likely consist of two teams of two people sampling all sites twice over the duration of the event. This will characterize the storm's total bacteria component better than just one sampling event. Timing will vary with the timing of the storm. For example, if a strong storm occurs in the early morning hours of Day 1, sites could be sampled in the morning and

afternoon of Day 1. However, if the storm starts in the afternoon or evening hours, only one set of samples may be collected on Day 1 and another on Day 2. Several storms will likely be inadvertently sampled during regularly scheduled sampling runs, but only once over the duration of the storm. This data will also be used to characterize storm events in the Samish Bay watershed.

Streamflow will be measured or estimated using stage and rating curves or relationships with other monitoring locations when grab samples are collected. Daily rainfall data will be obtained from local sources.

The stormwater sampling sites will include all fixed network sites plus significant outfalls under NPDES Phase II permits. Stormwater NPDES permits are required to have corresponding Wasteload Allocations (WLAs) set in TMDL studies. Therefore, this study must determine WLAs for each permit holder (i.e., for each Phase II permit jurisdiction). The WSDOT and Friday Creek Hatchery hold wastewater permits.

After regular monitoring has commenced and land use characterized more thoroughly, adjustments to the storm monitoring schedule and site locations may be necessary. Any adjustments will be addressed through an addendum to the QA Project Plan and sent to the appropriate parties. The ability to quickly and safely access some sites and obtain a representative sample will be a challenge. Permission to sample runoff at some locations is still required.

Field and Laboratory Protocols and Analysis

Field sampling and measurement protocols will follow those listed in the Watershed Ecology Section (previously the Watershed Assessment Section) protocols manual (Ecology, 1993). Field measurements will include conductivity and/or salinity and temperature at all sites using a calibrated Hydrolab MiniSonde®. Turbidity samples taken from ditches and sloughs will be sent to the Manchester Environmental Laboratory for analysis. Ditch and slough dissolved oxygen (DO) will be collected and analyzed using the Winkler titration method (Ecology, 1993).

Grab samples will be collected using Watershed Ecology Section (WES) protocols (Ecology, 1993). Twenty percent of FC, E. coli, and percent KES samples will be duplicated in the field in a side-by-side manner to assess field and lab variability. Samples will be collected in the thalweg and just under the water's surface.

Streamflow data will be obtained at critical sampling locations to provide loading information. Streamflow at stations on Friday and Silver creeks and on the upper Samish River will be measured by continuous loggers maintained by Ecology Stream Hydrology Unit (SHU) staff. U.S. Geological Survey (USGS) data collected from the Samish River at Hwy 99 (RM 10) will be obtained from the USGS web site and checked for accuracy. Regression analysis may be used during times when all flow measurements are not possible. Project staff and local cooperating agencies will provide additional flows at all other sites.

Estimation of instantaneous flow measurements will follow the SHU protocols manual (Ecology, 2000). Flow volumes will be calculated from continuous stage height records and rating curves developed prior to, and during, the project. Stage height will be measured by a pressure transducer and recorded by a data logger every 15 minutes. All data loggers will be downloaded monthly. Staff gages will be installed at other selected sites. During the field surveys, streamflow will be measured at selected stations and/or staff gage readings will be recorded. A flow rating curve will be developed for sites with a staff gage.

If possible, Ecology will record the electrical and flow rating of pumps to Samish Bay to calculate flow volumes. Drogues, or other streamflow measurement devices, will be used if necessary to obtain flows at tidally influenced areas. Methods for measuring streamflow at tidally influenced sites are still under development.

Grab samples will be collected directly into pre-cleaned containers supplied by Manchester Environmental Laboratory (MEL) and described in the MEL User's Manual (2005). Sample containers, volumes, preservation requirements, and holding times are listed in Table 6. Samples for laboratory analysis will be stored on ice and delivered to MEL within 24 hours of collection via Greyhound bus and/or Ecology staff.

Table 6. Containers, preservation requirements, and holding times for samples collected during the Samish Bay TMDL Study (MEL, 2005).

Parameter	Sample Matrix	Container	Preservative	Holding Time
Fecal Coliform	Surface water, WWTP effluent, & runoff	250 or 500 mL glass/poly autoclaved	Cool to 4ºC	24 hours
Escherichia coli	Surface water, WWTP effluent, & runoff	250 or 500 mL glass/poly autoclaved	Cool to 4ºC	24 hours
% KES	Surface water, WWTP effluent, & runoff	250 or 500 mL glass/poly autoclaved	Cool to 4ºC	24 hours

Measurement Quality Objectives

Sampling, laboratory analysis, and data evaluation steps have several sources of error that should be addressed by measurement quality objectives. Precision in laboratory measurements (measurement quality objectives) can be more easily controlled than field sampling variability. Precision needs to be as high as possible in the laboratory. Precision for bacteria field replicates is expressed as the relative standard deviation (RSD) and results should not exceed 30% RSD.

Microbiological and analytical methods, expected range of sample results, and method resolution are listed in Table 7. The expected range of sample results are based on historical data from similar watersheds. The reporting limits of the methods listed in the table meet the expected range of results and the required level of sensitivity to meet project objectives. The laboratory's measurement quality objectives and quality control procedures are documented in the MEL Lab Users Manual (MEL, 2005).

Table 7. Targets for precision and reporting limits for the measurement systems.

Analysis	Method	Duplicate Samples Relative Standard Deviation (RSD)	Range	Reporting Limits and Resolution
Field Measurements				
Velocity[1]	Marsh McBirney Flow-Mate Flowmeter	0.1 ft/s	0.05 – 5.00 feet/second	0.01 ft/s
Water Temperature[1]	Hydrolab MiniSonde®	+/- 0.1° C	-5° – 30° C	0.01° C
Specific Conductivity[2]	Hydrolab MiniSonde®	+/- 0.5%	1 – 100,000 umhos/cm	0.1 umhos/cm
Dissolved Oxygen[1]	Winkler Titration	+/- 0.1 mg/L	1-30 mg/L	.01 mg/L
Turbidity[2]	EPA 180.1	+/- 3%	0-1000 NTU	.01 NTU[3]
Laboratory Analyses				
Fecal Coliform – MF	SM 9222D	30% RSD	1 cfu/100 mL – depends on dilution	1 cfu/100 mL
Fecal Coliform – MPN	SM 9221E2	40% RSD	1 cfu/100 mL – depends on dilution	1 cfu/100 mL
Escherichia coli	EPA 1103.1 (mTEC2)	30% RSD	1 cfu/100 mL – depends on dilution	1 cfu/100 mL
% KES	Manchester SOP	30% RSD	1% – 100%	1%

[1] as units of measurement, not percentages.
[2] as percentage of reading, not RSD.
[3] when turbidimeter is set on lowest range.
SM = Standard Methods for the Examination of Water and Wastewater, 20th Edition (APHA, AWWA and WEF, 1998).
EPA = EPA Method Code.

The targets for analytical precision of laboratory analyses in Table 7 are based on historical performance by MEL for environmental samples taken around the state by the WES Section (Mathieu, 2005a). Bias is also a component of data accuracy; however, bias from the true value is very difficult to determine for this set of parameters. Bias in field measurements will be

minimized by strictly following sampling and handling protocols. Calibration standards for microbiological analyses are not available.

Representativeness

The study was designed to have enough sampling sites and sufficient sampling frequency to adequately characterize fecal coliform spatial and temporal patterns in the watershed. Fecal coliform values are known to be highly variable over time and space. Sampling variability can be somewhat controlled by strictly following standard procedures and collecting quality control samples, but natural spatial and temporal variability can contribute greatly to the overall variability in the parameter value. Resources limit the number of samples that can be taken at one site spatially or over various intervals of time. Laboratory and field errors are further expanded by estimate errors in seasonal loading calculations and modeling estimates.

Comparability

The DOH and Skagit County Public Works enumerate FC bacteria using the MPN method. Ecology uses the MF method. Ecology will split eight samples during seven field surveys and analyze them using both methods to assess method and result comparability in the Samish Bay Watershed. Results will be compared using simple linear correlation to test if a significant relationship exists and how well correlated the methods' results are. Splitting samples with the DOH and Skagit County Public Works may also occur to further ensure all data is comparable. Ecology will follow standard fecal coliform sampling and analysis protocols (see Field and Laboratory Protocols and Analysis section) for all sampling done for the TMDL.

Completeness

EPA has defined completeness as a measure of the amount of valid data needed to be obtained from a measurement system (Lombard, et al., 2004). The goal for the Samish Bay TMDL is to correctly collect and analyze 100% of the 28 FC samples for each of the 33 sites, plus 100% of the storm event samples. However, problems occasionally arise during sample collection that cannot be controlled such as flooding, inadequate rain for storm sampling, site access problems, or sample container shortages, which can interfere with this goal. A lower limit of five samples per season per site will be required for comparison to state criteria, which should easily be met with the current sampling design. WAC 173-201A states:

"*When averaging bacteria sample data for comparison to the geometric mean criteria, it is preferable to average by season and include five or more data collection events within each period….and [the period of averaging] should have sample collection dates well distributed throughout the reporting period*."

Investigatory samples may be collected at sites not included in this QA Project Plan; or, if necessary, a site may be added to further characterize fecal coliform problems in an area. Such sampling that does not meet the lower limit criteria of five samples per season (wet or dry) per site will still be useful for source location identification, recommendations, or other analyses, but not used to set load or wasteload allocations.

Quality Control Procedures

Total variation for field sampling and analytical variation will be assessed by collecting replicate samples. Bacteria samples tend to have a high relative standard deviation between replicates compared to other water quality analyses. Bacteria sample precision will be assessed by collecting replicates for approximately 20% of samples in each survey. MEL routinely duplicates sample analyses in the laboratory to determine the presence of bias in analytical methods. The difference between field variability and laboratory variability is an estimate of the sample field variability.

All samples will be analyzed at MEL. The laboratory's measurement quality objectives and quality control procedures are documented in the MEL Lab Users Manual (MEL, 2005). MEL will follow standard quality control procedures (MEL, 2005). Field sampling and measurements will follow quality control protocols described in Ecology (1993). If any of these quality control procedures are not met, the associated results will be qualified and used with caution, or not used at all.

Standard Methods (APHA, AWWA, and WEF, 1998) recommends a maximum holding time of eight hours for microbiological samples (six hours transit and two hours laboratory processing) for nonpotable water tested for compliance purposes. MEL has a maximum holding time for microbiological samples of 24 hours (MEL, 2005) that is recommended by Standard Methods (APHA, AWWA, and WEF, 1998) for drinking water samples (<30 hours) and other types of water tested when compliance isn't an issue (<24 hours). MEL accepts samples Monday through Friday, which means Ecology can sample Sunday through Thursday.

To identify any problems with holding times, two comparison studies were conducted during the Yakima Area Creeks TMDL (Mathieu, 2005b). A total of twenty FC samples were collected in 500 mL bottles and each split into two 250 mL bottles. The samples were driven to MEL within 6 hours. One set of the split samples was analyzed upon delivery. The other set was stored overnight and analyzed the next day. Both sets were analyzed using the MF method. Replicates were compared to the Measurement Quality Objectives in Table 7.

The combined precision results between the different holding times yielded a mean RSD of 19%. This is comparable to the 23% mean RSD between field replicates for twelve EAP TMDL studies using the MF method, suggesting that a longer (i.e., 24 hour) holding time has little effect on FC results processed by MEL. Samples with longer holding times did not show a tendency towards higher or lower FC counts compared to the samples analyzed within 6-8 hours.

Data Verification and Validation

Laboratory-generated data reduction, review, and reporting will follow the procedures outlined in the MEL Users Manual (MEL, 2005). Lab results will be checked for missing and/or improbable data. Variability in lab duplicates will be quantified using the procedures outlined in the MEL Users Manual (MEL, 2005). Any estimated results will be qualified and their use restricted as appropriate. A standard case narrative of laboratory QA/QC results will be sent to the project manager for each set of samples.

Field notebooks will be checked for missing or improbable measurements before leaving each site. Field-generated data will be entered into EXCEL® spreadsheets (Microsoft, 2001) as soon as practical after returning from the field. The EXCEL® Workbook file will be labeled *Draft* until data verification and validity are completed. Data entry will be checked by the field assistant against the field notebook data for errors and omissions. Missing or unusual data will be brought to the attention of the project manager for consultation. Valid data will be moved to a separate file labeled *Final*.

As soon as FC data are verified by MEL, the laboratory microbiologist will notify the project manager by e-mail or by phone of FC results greater than 200 cfu/100 mL. The project manager will notify the NWRO Client Staff Contact and Water Quality Section Manager by e-mail of these elevated counts in accordance with EA Program Policy 1-03. The NWRO Client Staff Contact will notify local authorities or permit managers as appropriate.

Data received from MEL by Ecology's Laboratory Information Management System (LIMS) will be checked for omissions against the *Request for Analysis* forms by the field lead. Data can be in EXCEL® spreadsheets (Microsoft, 2001) or downloaded tables from Ecology's Environmental Information Management (EIM) system. These tables and spreadsheets will be located in a file labeled *Draft* until data validity is completed. Field replicate sample results will be compared to quality objectives in Table 7. Data requiring additional qualifiers will be reviewed by the project manager. After data validity and data entry tasks are completed, all field, laboratory, and flow data will be entered into a file labeled *Final*, and then into the EIM system. EIM data will be independently reviewed by another EA Program field assistant for errors at an initial 10% frequency. If significant entry errors are discovered, a more intensive review will be undertaken. At the end of the field collection phase of the study, the data will be compiled in a data summary. Quarterly progress reports will be available every three months throughout the 14 month data collection period of the project.

Data Analysis and Use

Data analysis will include evaluation of data distribution characteristics and, if necessary, appropriate distribution of transformed data. Streamflow data will be frequently reviewed during the field data survey season to check longitudinal water balances. Fecal coliform mass balance calculations will be performed on a reach basis. Estimation of univariate statistical parameters and graphical presentation of the data (box plots, time series, regressions) will be made using WQHYDRO (Aroner, 2003) and EXCEL® (Microsoft, 2001) software.

Data will be applied to several TMDL methods of evaluation. The statistical rollback method (Ott, 1995) will be applied to FC data distributions to determine target count reductions along key reaches of each waterbody during critical conditions. Ecology will evaluate the need for setting a lower fecal coliform target (lower than the standard) at the mouth of the Samish River to ensure that marine water quality and the shellfish resources are protected. Ideally, at least 20 data are needed from a broad range of hydrologic conditions to determine an annual FC distribution. If sources of FC vary by season and create distinct critical conditions, seasonal targets may be required. Fewer data will provide less confidence in FC reduction targets, but the rollback method is robust enough to provide general targets for planning implementation measures.

Project Organization

The roles and responsibilities of Ecology staff are as follows:

- *Trevor Swanson*, Project Manager and Field Lead, Environmental Assessment Program, Water Quality Studies Unit: Responsible for overall project management. Defines project objectives, scope, and study design. Author of the project QA Project Plan. Manages the data collection program. Coordinates field surveys with NWRO and local staff members. Responsible for data collection, entering project data into the EIM system, and data quality review. Writes TMDL technical study report.

- *Chad Brown*, Alternate Field Lead, Environmental Assessment Program, Water Quality Studies Unit: Coordinates and conducts field surveys, at times with NWRO and local staff members. Responsible for data collection in the field and may assist with data quality review.

- *Craig Homan*, Alternate Field Lead, Water Quality Program, Northwest Regional Office: Coordinates and conducts field surveys. Responsible for data collection in the field.

- *Sally Lawrence*, Overall TMDL Project Lead, Water Quality Program, Northwest Regional Office: Acts as point of contact between Ecology technical study staff and interested parties. Coordinates information exchange, technical advisory group formation, and organizes meetings. Supports, reviews, and comments on QA Project Plan and technical report. Responsible for implementation, planning, and preparation of TMDL document for submittal to EPA.

- *Dave Garland*, Unit Supervisor, Water Quality Program, Northwest Regional Office: Responsible for approval of TMDL submittal to EPA.

- *Will Kendra*, Section Manager, Environmental Assessment Program, Watershed Ecology Section: Responsible for approval of project QA Project Plan and final TMDL report.

- *Karol Erickson***,** Unit Supervisor, Environmental Assessment Program, Water Quality Studies Unit: Reviews and approves project QA Project Plan, staffing plan, final TMDL report, and the technical study budget.

- *Stuart Magoon, Will White, and Pam Covey***,** Ecology Manchester Laboratory, Environmental Assessment Program: Provide laboratory staff and resources, sample processing, analytical results, laboratory contract services, and QA/QC data. Review sections of the QA Project Plan relating to laboratory analysis.

- *Chuck Springer*, Environmental Assessment Program, Stream Hydrology Unit: Responsible for the deployment and maintenance of continuous flow loggers and staff gauges. Responsible for producing records of hourly flow data at select sites for the study period.

- *Bill Kammin***,** Ecology Quality Assurance Officer, Environmental Assessment Program: Reviews QA Project Plan and all Ecology quality assurance programs. Provides technical assistance on QA/QC issues during the implementation and assessment of project.

Project Schedule

Table 8. Project schedule for the Samish Bay Total Maximum Daily Load Study.

Environmental Information System (EIM) Data Set	
EIM Data Engineer	Trevor Swanson
EIM User Study ID	TSWA0001
EIM Study Name	Samish Bay Fecal Coliform TMDL
EIM Completion Due	July, 2007
QA Project Plan and Sampling	
Report Author Lead	Trevor Swanson
Schedule:	
Report Supervisor Draft Due	October 31, 2005
Report Client/Peer Draft Due	November 30, 2005
Client/Peer Comments Due	December 31, 2005
Report Final Due	February 28, 2006
Sampling Begins	February, 2006
Quarterly Reports	
Report Author Lead	Trevor Swanson
Schedule:	
1st Quarter Report	May, 2006
2nd Quarter Report	August, 2006
3rd Quarter Report	November, 2006
4th Quarter Report	February, 2007
Final Report	
Report Author Lead	Trevor Swanson
Schedule:	
Report Supervisor Draft Due	December, 2007
Report Client/Peer Draft Due	January, 2008
Report External Draft Due	February, 2008
Report Final Due (original)	May, 2008

Laboratory Budget

The estimated laboratory budget and lab sample load in Table 9 is based on the proposed schedule in Table 4. Since all months have more than one survey that occur on different weeks, monthly and weekly laboratory sample loads should not overload the microbiological units at MEL. The greatest uncertainty in the laboratory load and cost estimate is with the synoptic storm survey work. Efforts will be made to keep the submitted number of samples within the estimate.

Table 9. Samish Bay Fecal Coliform TMDL--the number of monthly sample submittals for each analysis, an estimate of the monthly analytical costs, and the total analytical cost estimate[2] for the project.

	Turbidity (NTU) plus reps.	**FC (MF)**	**Reps.**	**FC (MPN)**	**Reps.**	**E. coli**	**Reps.**	**% KES**	**Reps.**	**Cost**
February	13	64	13			15	3	8	2	$ 2569
March	13	64	13	8	2					$ 1906
April	13	64	13			15	3	8	2	$ 2296
May (w/storm)	13	128	26	8	2					$ 3292
June (w/storm)	13	128	26			15	3	8	2	$ 3682
July	13	64	13	8	2					$ 1906
August	13	64	13			15	3	8	2	$ 2296
September	13	64	13	8	2					$ 1906
October (w/storm)	13	128	26			15	3	8	2	$ 3682
November (w/storm)	13	128	26	8	2					$ 3292
December	13	64	13			15	3	8	2	$ 2296
January	13	64	13	8	2					$ 1906
February	13	64	13			15	3	8	2	$ 2296
March	13	64	13	8	2					$ 1906
Totals	**182**	**1152**	**234**	**56**	**14**	**105**	**21**	**56**	**14**	**$ 35231**

Reps. = replicates for 20% of the preceding column; **FC** = fecal coliform; **E. coli** = Escherichia coli; **% KES** = % Klebsiella, Enerobacter, and Serratia.

[2] Costs include 50% discount for Manchester Laboratory.

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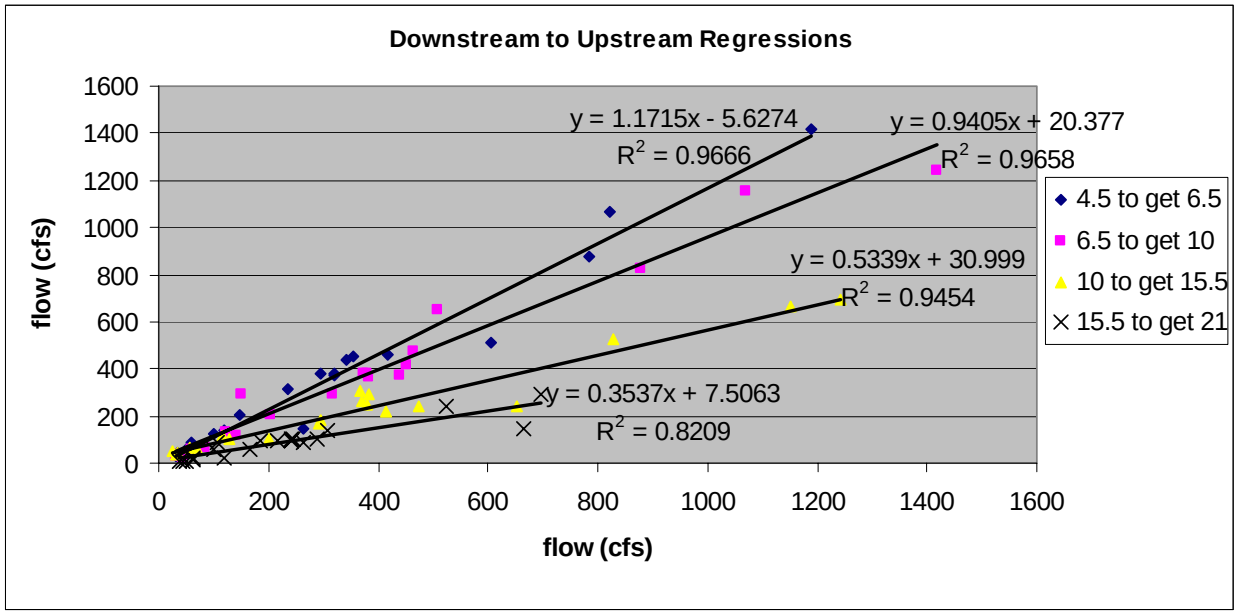
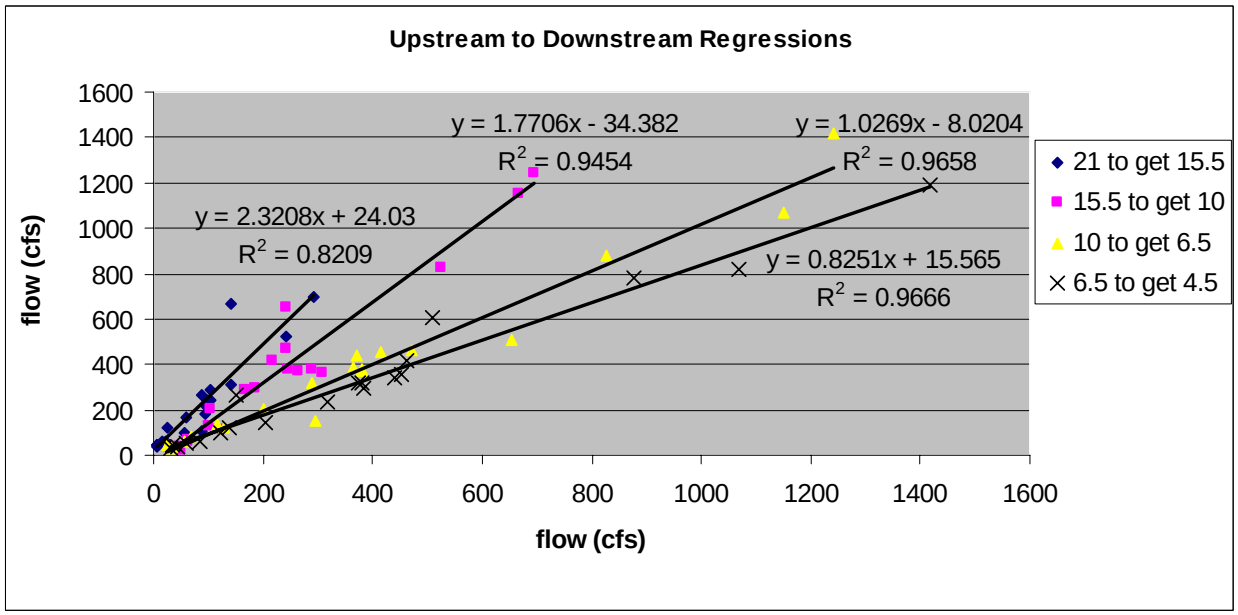
Appendix A

Samish River Flow Regressions
for Calculating Selected Missing Flows in Skagit County Data

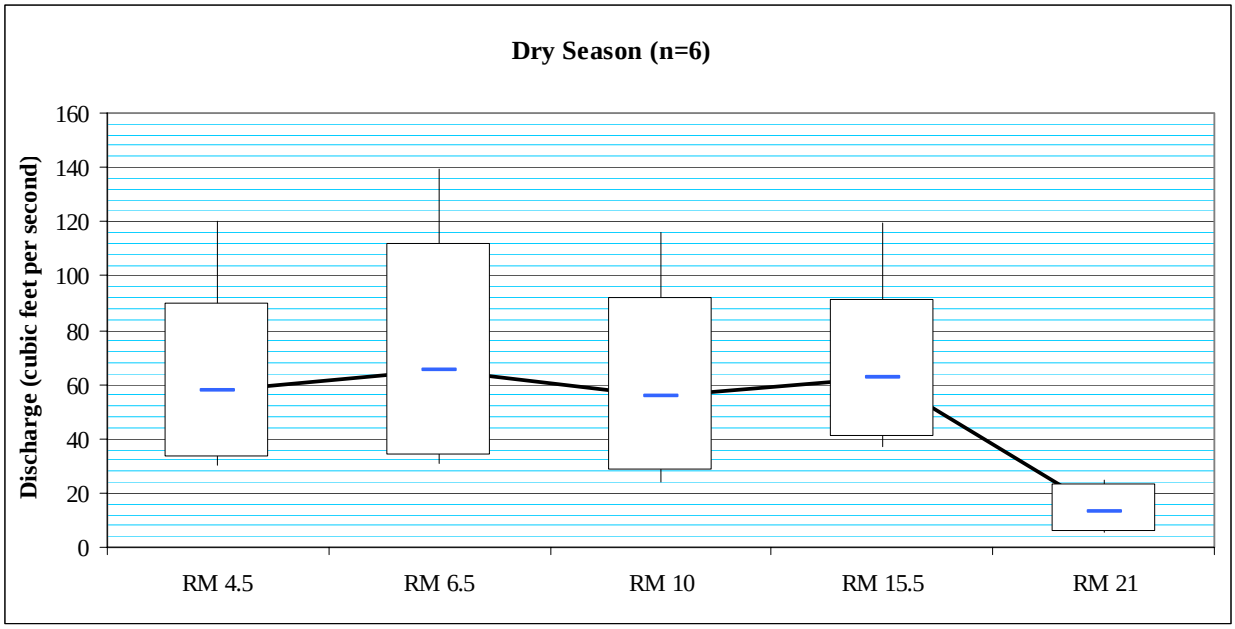
Example: If the FC concentration was known but a flow was missing at RM 21, the regression equation for *15.5 to get 21* was used to calculate the missing flow (from the *Downstream to Upstream Regression* chart). If a flow at RM 4.5 was missing, *6.5 to get 4.5* was used to calculate the missing flow (*Upstream to Downstream Regression* chart).

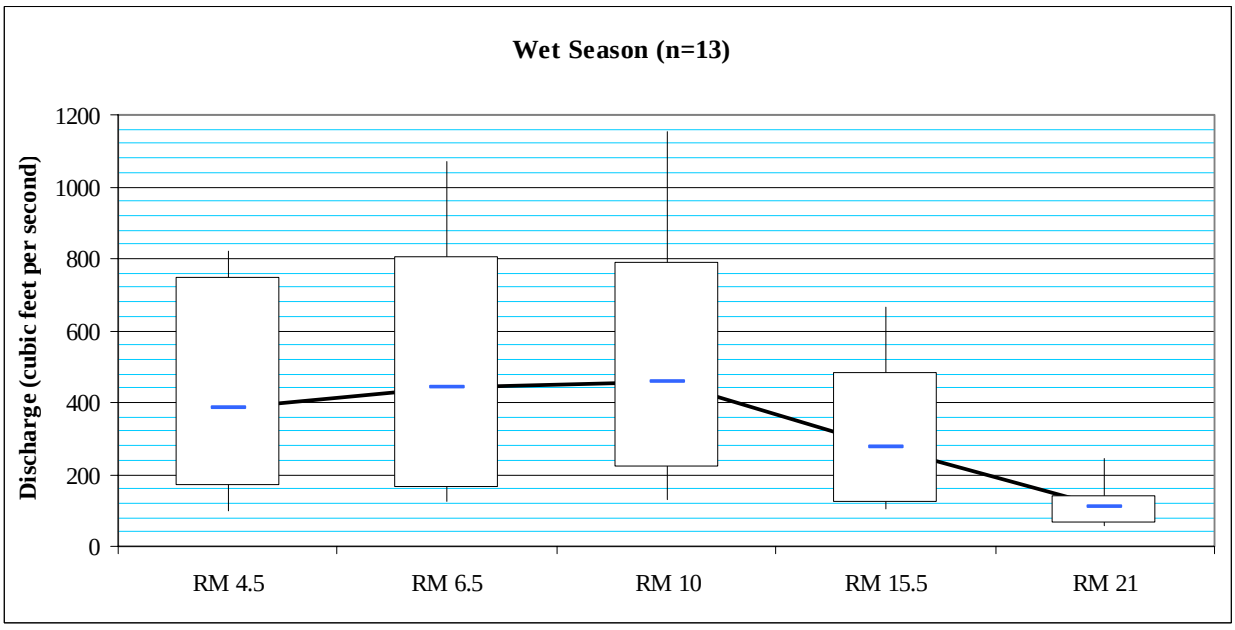




Appendix B

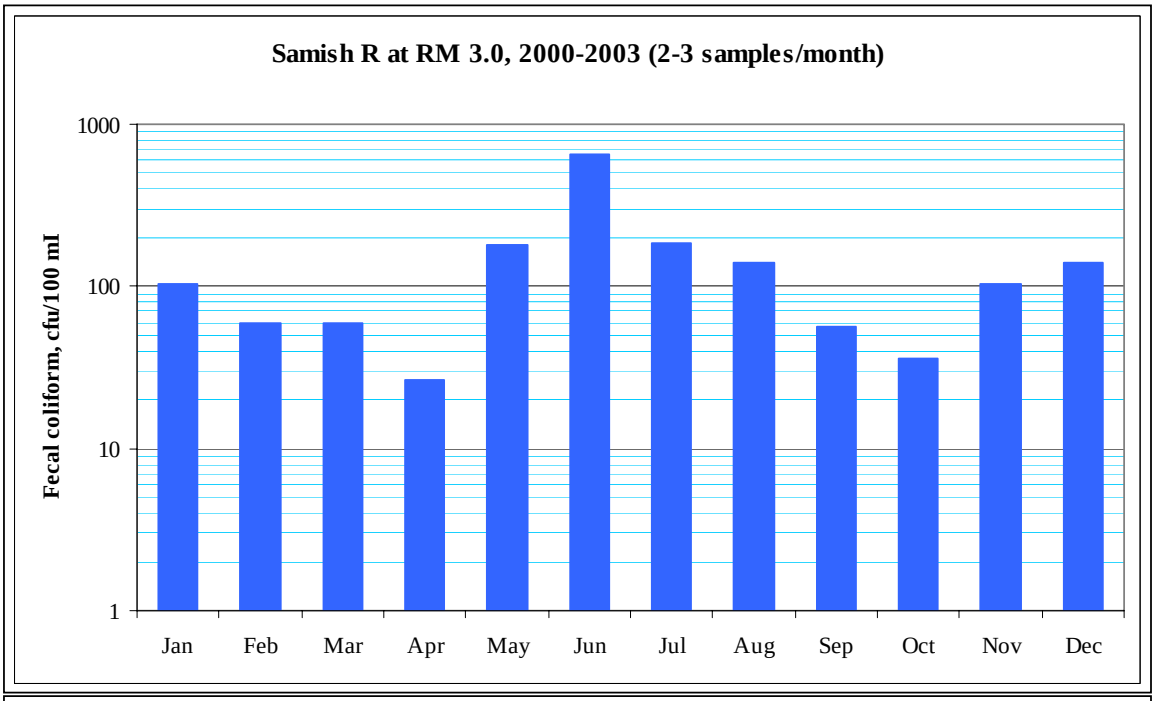
Longitudinal Mean Streamflow at Five Skagit County Sites on the Samish River. Boxes Represent 10th and 90th Percentiles

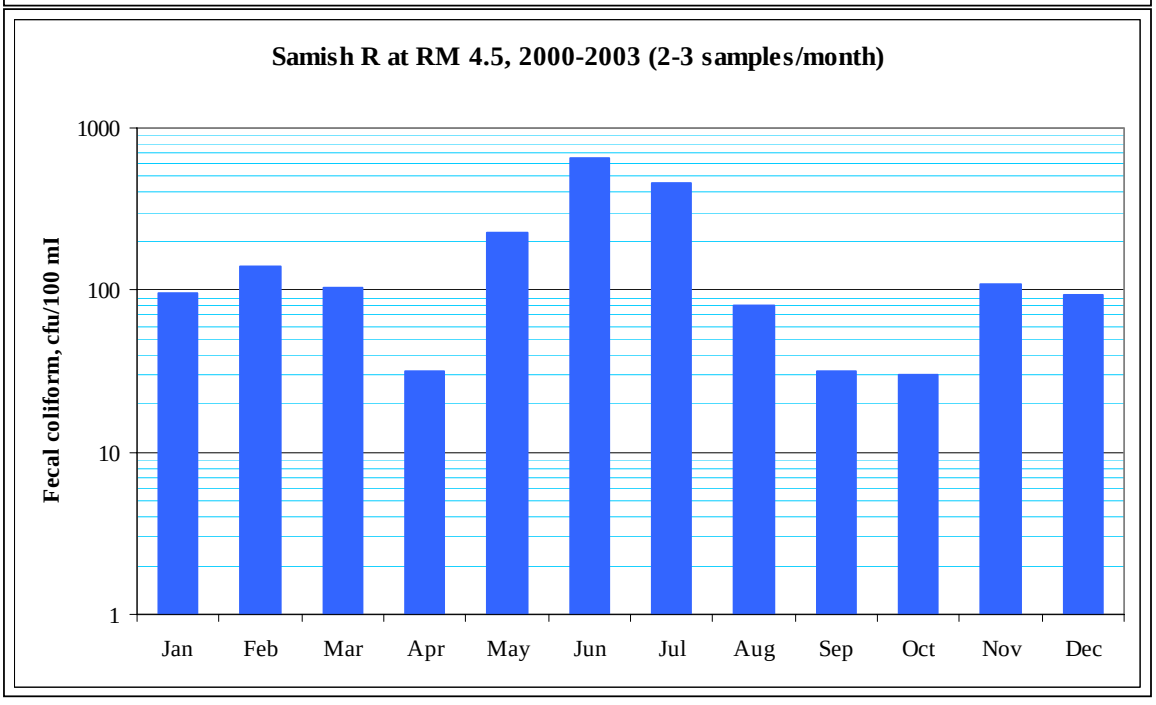


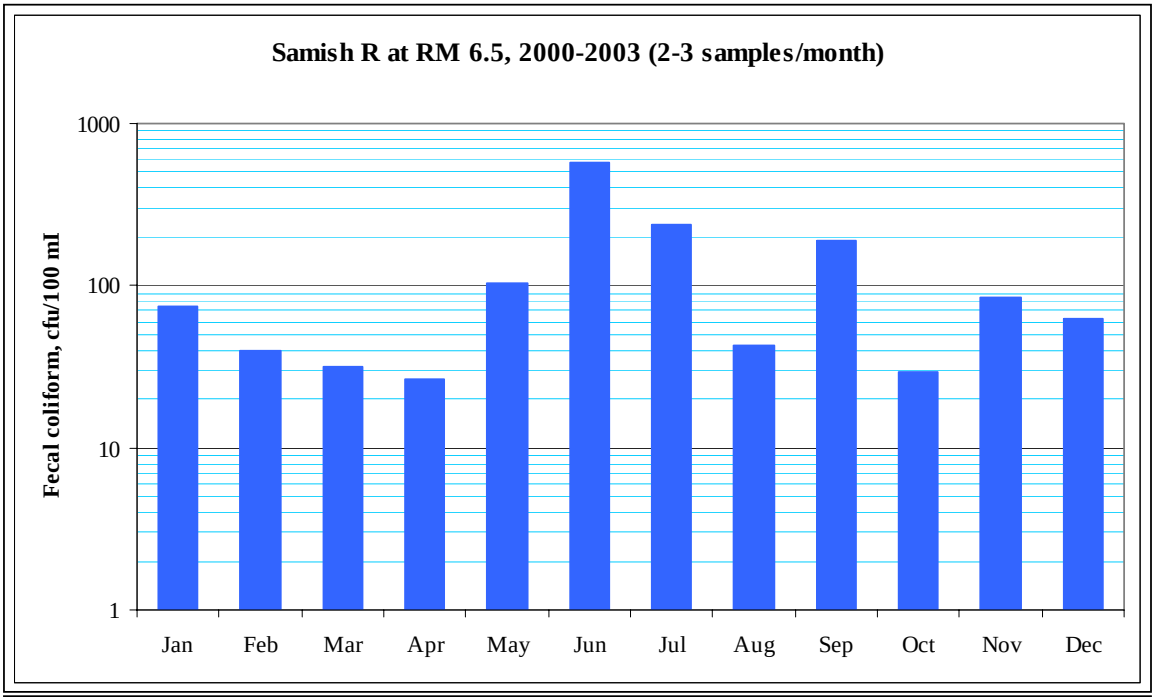


Appendix C

Mean Monthly FC Concentrations at Eight Skagit County Sites on the Samish River. All charts Represent Data From the Same Dates for an Unbiased Site to Site Seasonal Comparison.






Samish R at RM 6.5, 2000-2003 (2-3 samples/month)
Fecal coliform, cfu/100 ml
1000
100
10
1
Jan
Feb
Mar
Apr
May
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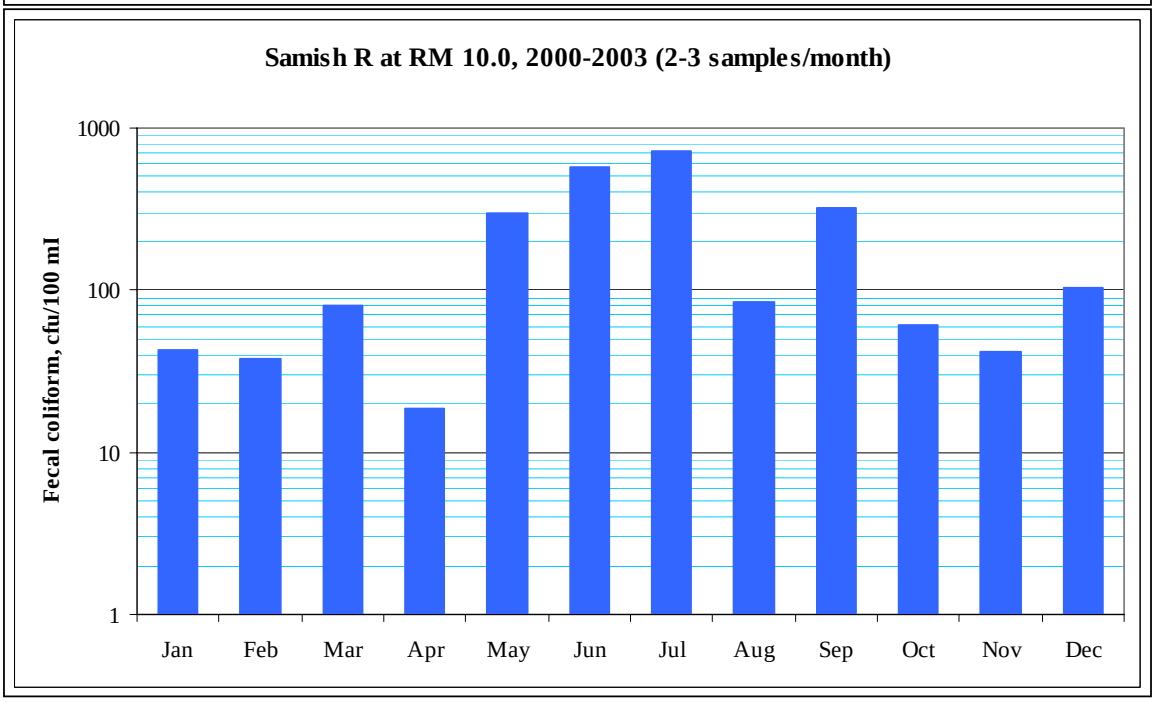
Aug
Sep
Oct
Nov
Dec


Samish R at RM 10.0, 2000-2003 (2-3 samples/month)
Fecal coliform, cfu/100 ml
1000
100
10
1
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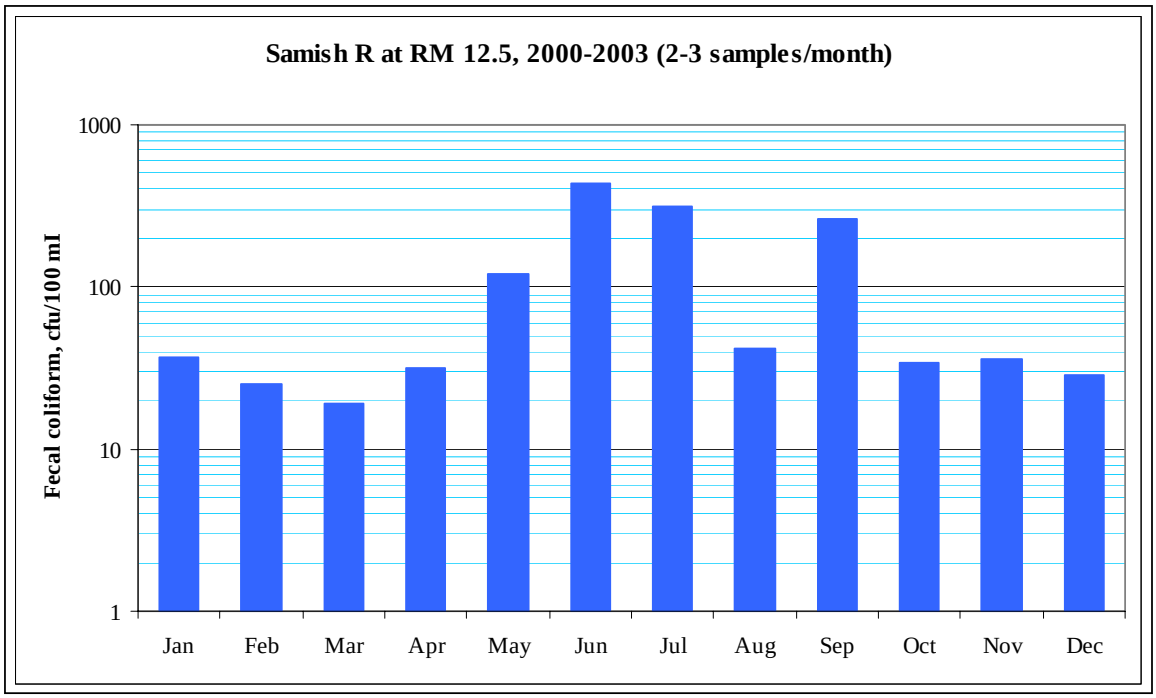
Sep
Oct
Nov
Dec


Samish R at RM 12.5, 2000-2003 (2-3 samples/month)
Fecal coliform, cfu/100 ml
1000
100
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1
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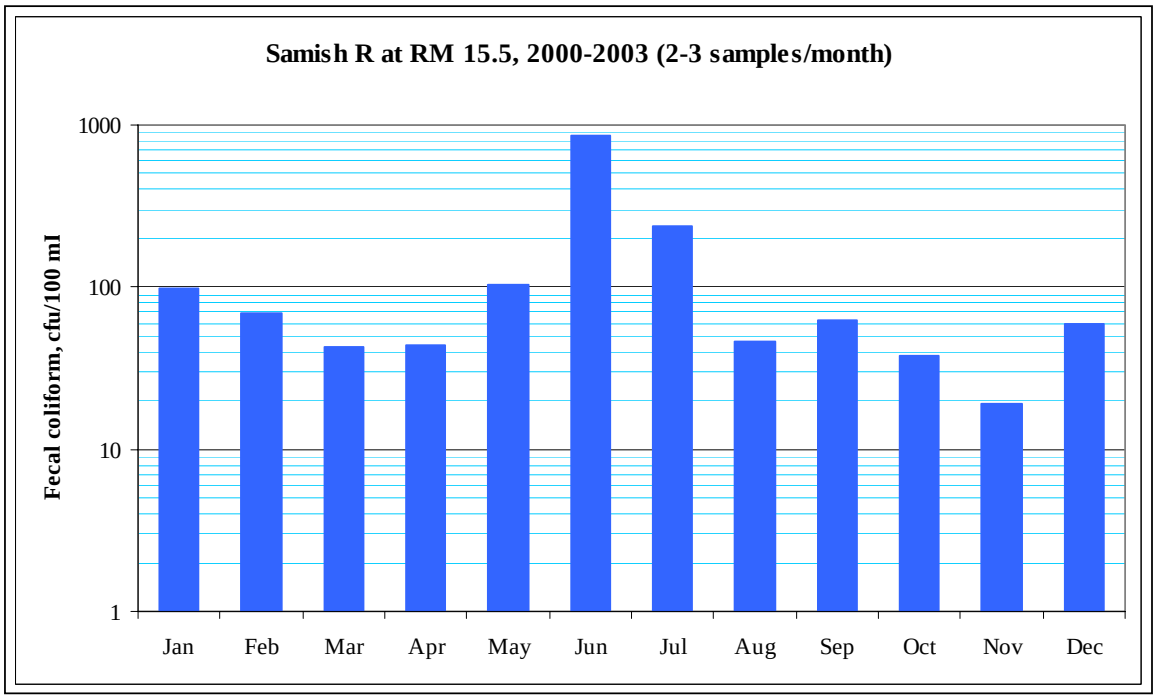
Dec


Samish R at RM 15.5, 2000-2003 (2-3 samples/month)
Fecal coliform, cfu/100 ml
1000
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Oct
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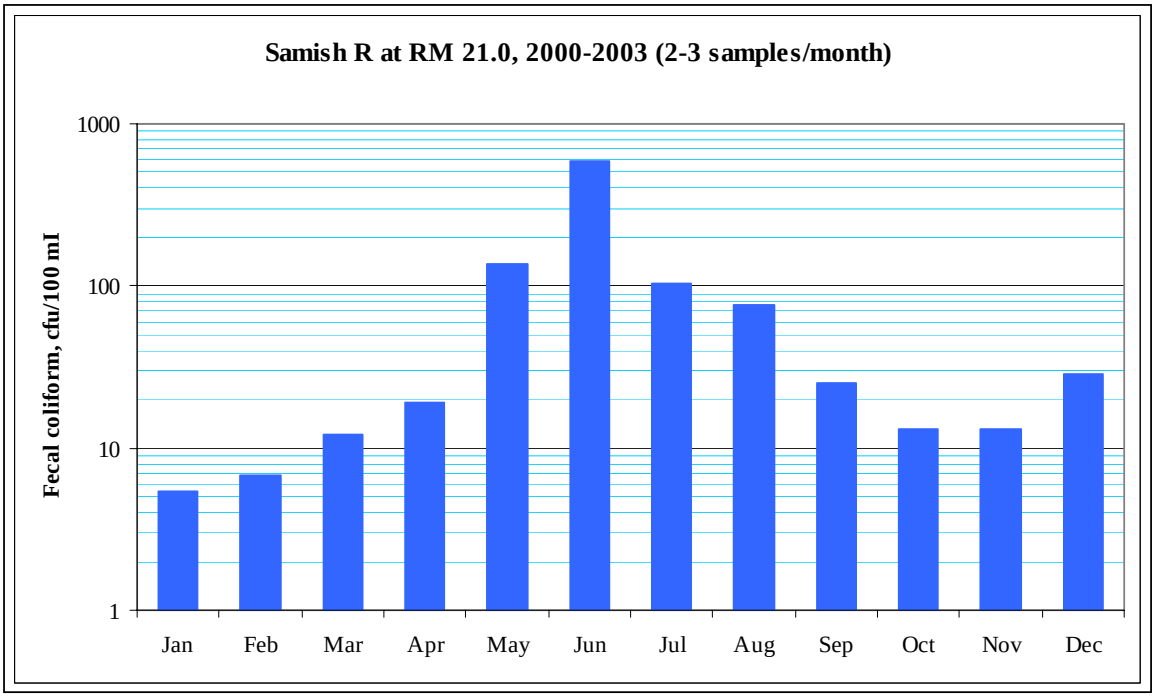
Samish R at RM 21.0, 2000-2003 (2-3 samples/month)
Fecal coliform, cfu/100 ml
1000
100
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Jan
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Jul
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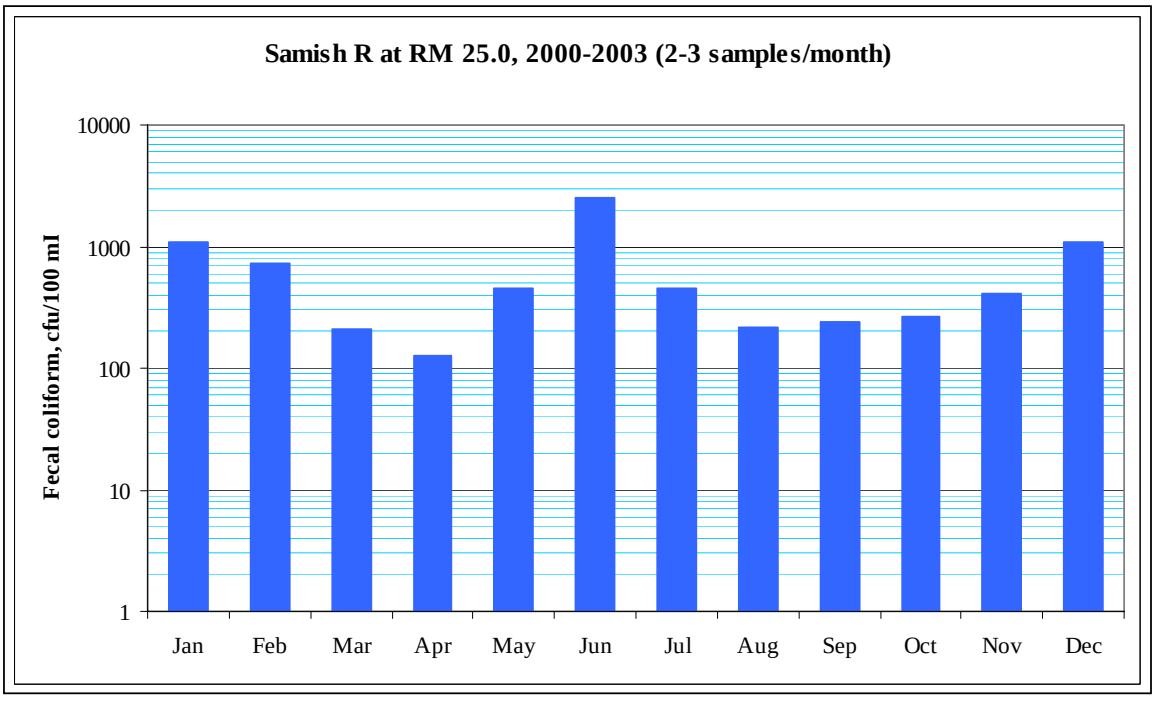
Sep
Oct
Nov
Dec


Samish R at RM 25.0, 2000-2003 (2-3 samples/month)
Fecal coliform, cfu/100 ml
10000
1000
100
10
1
Jan
Feb
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Apr
May
Jun
Jul
Aug
Sep
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Nov
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