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Drayton Harbor Watershed
Fecal Coliform
Total Maximum Daily Load

Water Quality Improvement Report

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For more information contact:

Washington State Department of Ecology

Water Quality Program
Regional/HQ Office Address
City, WA zip code

Phone: Regional/HQ WQ section secretary phone number

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

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

Cover photo: Northern shoreline of Drayton Harbor with Semiahmoo Spit and marina in background.

Project Codes and 1996 303(d) Water-body ID Numbers

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Numbers:

WA-01-0020	Drayton Harbor
WA-01-1002	Dakota (Rebel) Creek
WA-01-1450	California Creek

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Drayton Harbor Watershed
Fecal Coliform
Total Maximum Daily Load

Water Quality Improvement Report

by

Steve Hood
Water Quality Program
Bellingham Field Office

and

Nuri Mathieu
Environmental Assessment Program

Washington State Department of Ecology
Olympia, Washington 98504

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Abstract

Fecal coliform bacteria loading has impaired beneficial uses, including shellfish harvesting and primary contact recreation, in Drayton Harbor and many of its freshwater tributaries. Fecal coliform is a bacteria organism abundant in human and animal waste and indicates the potential presence of disease causing organisms or pathogens.

This total maximum daily load (TMDL) report includes a study of the bacteria impairment, indicates how much the bacteria needs to be reduced to meet water quality standards (load and wasteload allocations), and describes activities to achieve those reductions. Reductions are achieved by preventing human and animal waste from reaching surface waters.

During a study from December 2007 to December 2008, the Department of Ecology (Ecology) and a consultant working for Whatcom County collected bacteria and streamflow data from 34 sites throughout the watershed on 23 routine sampling events. As part of their shellfish growing area classification program, the Department of Health (DOH) collected FC samples from the harbor at 11 routine stations, as well as 3 new stations in Semiahmoo Bay added for the TMDL, on 10 occasions during the TMDL monitoring. Ecology analyzed the marine and freshwater data to determine how much the current levels of bacteria needed to be reduced to meet the water quality standards, both in the harbor and in the watershed.

This TMDL expresses load allocations as the fecal coliform concentrations, and percent reduction in concentrations, necessary to meet the concentration based water quality standards. Ecology developed a mass balance model of fecal coliform loads in Dakota and California Creek to determine the target fecal coliform concentrations within each basin that are necessary to meet marine water quality standards in the tidally influenced segment of each creek. Ecology used the statistical rollback method to calculate target reductions for fecal coliform concentrations in Cain Creek and two small harbor tributaries. Compliance with this TMDL will be based on meeting the water quality standards, load allocations, and wasteload allocations.

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Executive Summary

Introduction

Ecology is conducting a study in the Drayton Harbor watershed because of evidence that bacterial contamination is impairing beneficial uses in the area, such as shellfish harvesting and recreation.

The Washington State Department of Health (DOH) determines whether shellfish growing areas are safe for harvest. In 1988, DOH began closing the shellfish growing areas in Drayton Harbor based on a trend of deteriorating water quality. The closures ultimately resulted in the entire harbor being closed for harvest by 1999. In 2004, DOH upgraded the status of 575 acres in the central harbor from *Prohibited* to *Conditionally Approved*. The *Conditionally Approved* classification for shellfish harvest is based on the amount of rainfall.

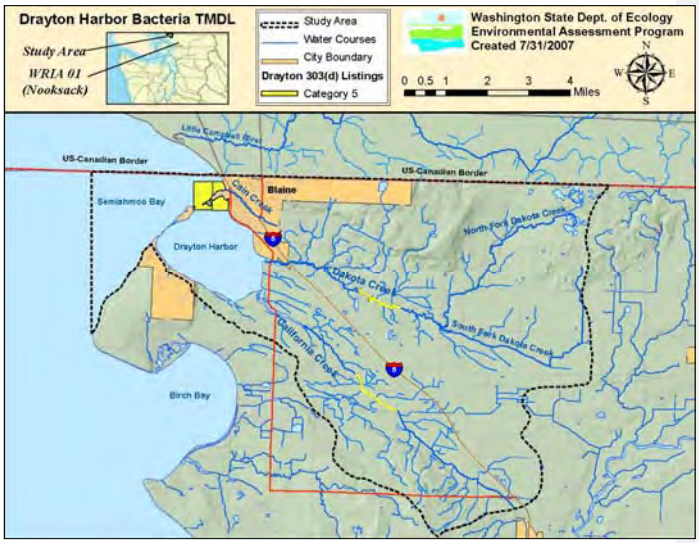

Figure E- 1. Map of Drayton Harbor TMDL study area.

Further source identification and cleanup efforts are needed to fully restore shellfish harvesting and other beneficial uses.

What is a Total Maximum Daily Load (TMDL)?

The federal Clean Water Act requires states to prepare a list of waterbodies that do not meet state water quality standards, which is called the "303(d) list". A Total Maximum Daily Load (TMDL) must be developed for each pollutant in each waterbody included on the 303(d) list. The TMDL study identifies pollution problems in the watershed, and then specifies how much pollution needs to be reduced or eliminated to achieve clean water. Then Ecology, with the assistance of other government agencies and the community, develops a implementation plan that describes actions to control the pollution. The implementation plan includes a monitoring plan to assess the effectiveness of the water quality improvement activities. The Water Quality Improvement Report (WQIR) consists of the TMDL study and implementation plan.

Watershed Description

Drayton Harbor is located in Whatcom County at the northwest corner of Washington State, just south of the US-Canada border (Figure E-1). A narrow 500-foot entrance connects the harbor to Semiahmoo Bay and the Strait of Georgia and restricts the inflow of seawater. Low tide exposes mudflats on over half the harbor and the remaining unexposed area is relatively shallow. Historically, the harbor has been used for commercial, recreational, and tribal shellfish harvesting. It is within the usual and accustomed fishing grounds of several tribes, including the Lummi Nation and the Nooksack Indian Tribe.

The harbor shoreline falls within the city of Blaine along the northeast and southwest shoreline (including the spit in between) and within unincorporated Whatcom County along the eastern and southern shoreline. The harbor contains the Blaine Harbor marina (both commercial and recreational use) and the Semiahmoo resort marina (recreational use only).

The Drayton Harbor watershed drains approximately 35,372 acres, 90% of which empties into either California or Dakota Creek before entering the harbor. In the Dakota and California Creek watersheds, the upper watersheds are dominated by agriculture, with a mix of single family "hobby farms" and commercial dairy farms. The middle and lower portions of the watersheds are characterized primarily by partially forested, low-density residential and small, non-commercial farms.

Cain Creek drains a large portion of the city of Blaine, north of the harbor and discharges to Semiahmoo Bay about ⅓ of a mile south of the US-Canada border. The creek has been heavily impacted by the development of Blaine and the construction of the I-5 freeway and serves as receiving waters to a number of storm drainages.

What needs to be done in this watershed?

Comment [NM1]: Joint report section still in progress. Don't review.

{Briefly summarize recommendations to bring the water body back to compliance with water quality standards. Include a brief summary of load and wasteload allocations, as appropriate.

Load allocations may be displayed in a table that describes parts of the watershed where they apply and should also be displayed on a map.
Will be brought forward from SIS after review by Drayton Harbor Shellfish Committee

The watershed (freshwater inputs) require large reductions in fecal coliform loading to meet the target fecal coliform concentrations necessary to protect beneficial uses in both the watershed and the harbor. Tables E-1-E-3 contains load allocations for non-point sources.

- Conclusions and recommendations
- Include summary for seasonal variation and future sources (growth)

- Implementation Summary (WQP staff writes this part)}

Why this Matters

{Briefly describe the importance of this project. Consult your PIO for messaging helps. Alternatively, you can incorporate the "why this matters" messaging in other appropriate sections of the Executive Summary, as well as the main body of the report.}

WQP Intranet has some examples that you can copy and paste into this document as part of the message.}

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What is a Total Maximum Daily Load (TMDL)

Federal Clean Water Act requirements

The Clean Water Act (CWA) established a process to identify and clean up polluted waters. The CWA requires each state to have its own water quality standards designed to protect, restore, and preserve water quality. Water quality standards consist of (1) designated uses for protection, such as cold water biota and drinking water supply, and (2) criteria, usually numeric criteria, to achieve those uses.

The Water Quality Assessment and the 303(d) List

Every two years, states are required to prepare a list of waterbodies that do not meet water quality standards. This list is called the CWA 303(d) list. In Washington State, this list is part of the Water Quality Assessment (WQA) process.

To develop the WQA, the Washington State Department of Ecology (Ecology) compiles its own water quality data along with data from local, state, and federal governments, tribes, industries, and citizen monitoring groups. All data in this WQA are reviewed to ensure that they were collected using appropriate scientific methods before they are used to develop the assessment. The list of waters that do not meet standards [the 303(d) list] is the Category 5 part of the larger assessment.

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

Category 2 – Waters of concern.

Category 3 – Waters with no data or insufficient data available.

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

- 4a. – Have an approved TMDL being implemented.
- 4b. – Have a pollution control program in place that should solve the problem.
- 4c. – Are impaired by a non-pollutant such as low water flow, dams, culverts.

Category 5 – Polluted waters that require a TMDL – the 303(d) list.

Further information is available at Ecology's Water Quality Assessment website.

The CWA requires that a Total Maximum Daily Load (TMDL) be developed for each of the waterbodies on the 303(d) list. A TMDL is numerical value representing the highest pollutant load a surface water body can receive and still meet water quality standards. Any amount of pollution over the TMDL level needs to be reduced or eliminated to achieve clean water.

TMDL process overview

Ecology uses the 303(d) list to prioritize and initiate TMDL studies across the state. The TMDL study identifies pollution problems in the watershed, and specifies how much pollution needs to be reduced or eliminated to achieve clean water. Ecology, with the assistance of local governments, tribes, agencies, and the community then develops a strategy to control and reduce pollution sources and a monitoring plan to assess effectiveness of the water quality improvement activities. Together, the study and implementation strategy comprise the *Water Quality Improvement Report* (WQIR).

Once the U.S. Environmental Protection Agency (EPA) approves the WQIR, a *Water Quality Implementation Plan* (WQIP) within one year. The WQIP identifies specific tasks, responsible parties, and timelines for reducing or eliminating pollution sources and achieving clean water.

Who should participate in this TMDL?

Comment [NM3]: Implementation section. Do not provide comments on this section.

Non-point source pollutant load targets have been set in this TMDL and described in Table X. Because non-point pollution comes from diffuse sources, all upstream watershed areas have potential to affect downstream water quality. Therefore, all potential nonpoint sources in the watershed must use the appropriate best management practices to reduce impacts to water quality. The area subject to the TMDL is shown in Figure X (add TMDL footprint map here or refer to it in the executive summary if it has been placed there.).

Similarly, all point source dischargers in the watershed must also comply with the TMDL.

Additional details to be incorportated after SIS has been reviewed by Drayton Harbor Shellfish Committee

{If appropriate, specify the larger organizations affected by the TMDL such as the county, tribes, municipalities, it is not necessary to list individual private citizens.}

Comment [NM4]: Implementation section. Do not provide comments on this section.

Elements the Clean Water Act requires in a TMDL

Loading capacity, allocations, seasonal variation, margin of safety, and reserve capacity

A water body's *loading capacity* is the amount of a given pollutant that a water body can receive and still meet water quality standards. The loading capacity provides a reference for calculating the amount of pollution reduction needed to bring a water body into compliance with the standards.

The portion of the receiving water's loading capacity assigned to a particular source is a *wasteload* or *load* allocation. If the pollutant comes from a discrete (point) source subject to a National Pollutant 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 diffuse (non-point) sources not subject to an NPDES permit, 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 pollutant sources is sometimes included as well.

Therefore, a TMDL is the sum of the wasteload and load allocations, any margin of safety, and any reserve capacity. The TMDL must be equal to or less than the loading capacity.

Surrogate measures

To provide more meaningful and measurable pollutant loading targets, this TMDL may also incorporate *surrogate measures* other than daily loads. EPA regulations [40 CFR 130.2(i)] allow other appropriate measures in a TMDL. See the Glossary section of this document for more information.

Potential surrogate measures for use in this TMDL are discussed below. The ultimate need for, and the selection of, a surrogate measure for use in setting allocations depends on how well the proposed surrogate measure matches the selected implementation strategy.

This TMDL is based on a percent reduction. The target geometric mean is another expression of the percent reduction. The target geometric mean has proven to be a useful tool to guide TMDL implementation and so the percent reduction expressed as a target geometric mean has been selected as a surrogate measure in this total maximum daily load for both load allocations and wasteload allocations.

Why Ecology Conducted a TMDL Study in this Watershed

Background

Ecology is conducting a TMDL study in this watershed because there is strong evidence of bacterial contamination that is affecting beneficial uses in the area, such as shellfish harvesting and recreation. Several study-area waterbodies are included on Ecology's 303(d) list of impaired waters, including Drayton Harbor, California Creek, Dakota Creek, and a small unnamed creek that drains to Drayton Harbor between the mouth of Dakota Creek and the city of Blaine (Table 1)(Ecology, 2007).

The Washington State Department of Health (DOH) determines whether shellfish growing areas are safe for harvest. In 1988, DOH began closing the shellfish growing areas in Drayton Harbor based on a trend of deteriorating water quality. The closures ultimately resulted in the entire harbor being closed for harvest by 1999. In 2004, DOH upgraded the status of 575 acres in the central harbor from *Prohibited* to *Conditionally Approved*. The *Conditionally Approved* classification for shellfish harvest is based on the amount of rainfall, where, if three quarters of an inch or more of rain falls in a 24-hour period, then shellfish harvesting is closed for six days.

Further source identification and cleanup efforts are needed to fully restore shellfish harvesting and other beneficial uses. The QA project plan (Mathieu and Sargeant, 2008) describes the study background, objectives, and methodology in greater detail.

Impairments addressed by this TMDL

The most sensitive beneficial use to be protected by this TMDL is shellfish harvesting in Drayton Harbor. Shellfish harvesting is threatened by high fecal coliform bacteria levels within the harbor.

Other significant beneficial uses to be protected by this TMDL include primary and secondary recreation in both marine and fresh waters; that is, people coming into contact with bacteria-contaminated water through boating, fishing, wading, swimming, and other water-related activities.

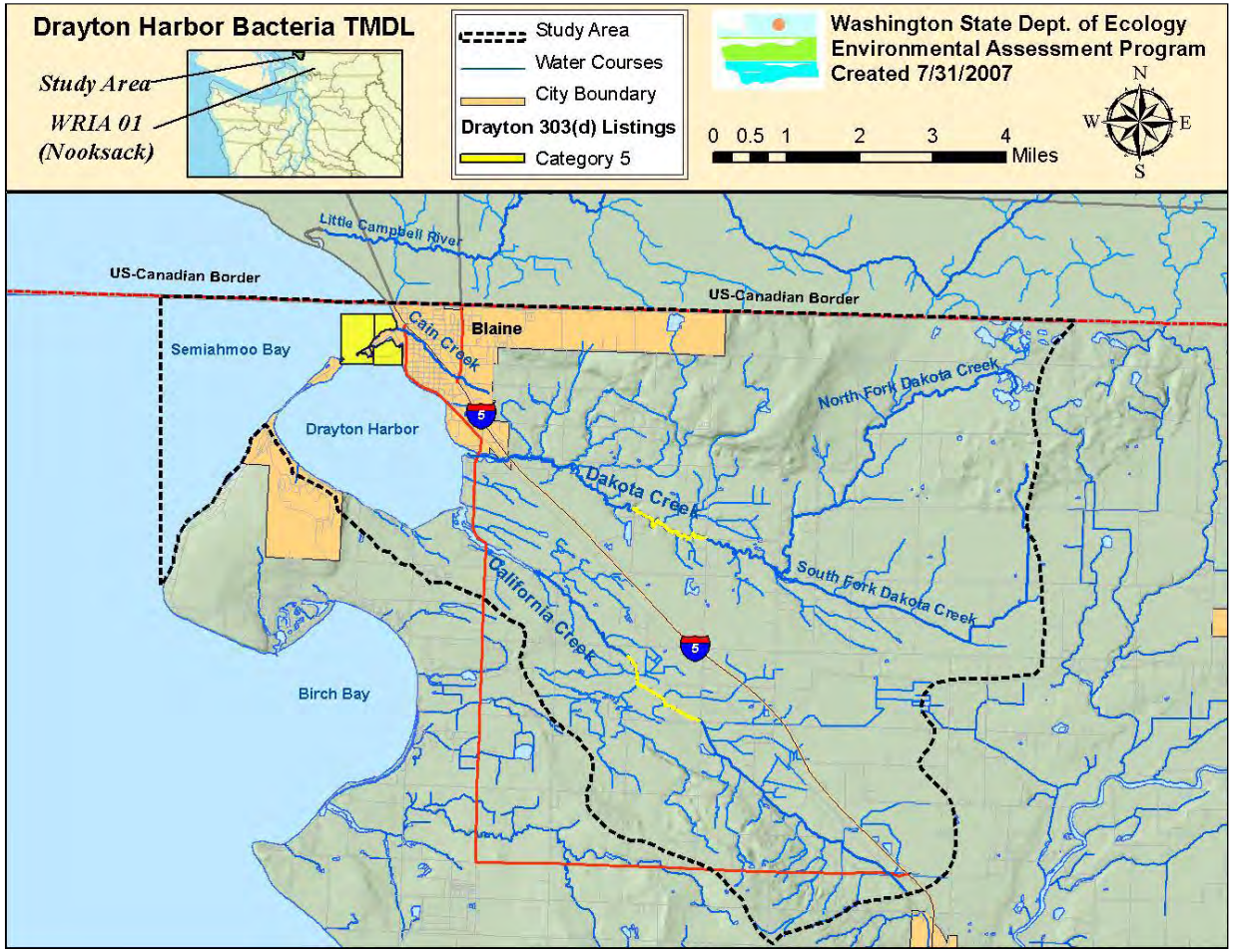

Figure 1. *Study area for the Drayton Harbor Watershed Bacteria Total Maximum Daily Load Study*

***Table 1**. Study area waterbodies on the 2004 303(d) list for Fecal Coliform.*

Waterbody	Listing ID	Township	Range	Section	Grid Cell		
					Number	Latitude	Longitude
Drayton Harbor	39052				48122J7J6	48.995	122.765
Drayton Harbor	39048				48122J7J5	48.995	122.755
Dakota Creek	39077	40N	01E	15			
California Creek	39060	40N	01E	27			
Unnamed Creek	42507	40N	01E	6			

This watershed has other water quality issues that will be addressed by this TMDL. In particular, the following additional Category 2 (waters of concern) listings for parameters other than fecal coliform occur in the study area. These listings are considered Category 2 because there are reported violations of state water quality standards, but there is either insufficient data or data collected without proper quality assurance procedures (Table 2).

***Table 2**. Study area waterbodies identified as Category 2 (waters of concern). Continuous data was collected to further assess these parameters of concern during this study.*

Waterbody	Parameter	Listing ID	Township	Range	Section
Dakota Creek	Dissolved oxygen	14009	40N	01E	08
Dakota Creek	Dissolved oxygen	7067	40N	02E	17
Dakota Creek	pH	14003	40N	01E	08
Dakota Creek	Temperature	13997	40N	01E	08
North Fork Dakota Creek	Dissolved oxygen	38996	40N	02E	17
South Fork Dakota Creek	Dissolved oxygen	7068	40N	02E	20
South Fork Dakota Creek	Dissolved oxygen	7069	40N	02E	19

Water Quality Standards and Numeric Targets

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 more detailed explanation of the applicable water quality standards is provided in the QA project plan (Mathieu and Sargeant, 2008).

Freshwater

- Washington State sets fecal coliform standards to maintain low rates of serious intestinal illness in people.
- Two applicable sets of criteria:
    - For fresh surface waters entering Drayton Harbor the primary contact recreation criteria applies:
        - Geometric mean less than or equal to 100 cfu/100 mL
        - No more than 10% of the samples greater than 200 cfu/100 mL
    - For fresh surface waters entering Semiahmoo Bay (includes Cain Creek) the extraordinary contact recreation criteria applies:
        - Geometric mean less than or equal to 50 cfu/100 mL
        - No more than 10% of the samples greater than 100 cfu/100 mL
- Compliance is based on meeting both the geometric mean and “no more than 10%” criteria.
- Ecology uses the 90th percentile value to represent the “no more than 10%” criterion, provided the data set has a log-normal distribution, in order to calculate percent reductions.

Marine waters

- Washington State set fecal coliform standards in Drayton Harbor to protect shellfish harvesting and primary contact recreation (swim and water play).
- Applicable criteria:
    - Geometric mean less than or equal to 14 cfu/100 mL
    - No more than 10% of the samples greater than 43 cfu/100 mL
- Compliance is based on meeting both the geometric mean and “no more than 10%” criteria.

Brackish waters

- The decision to use the fresh water or the marine water criteria is selected and applied based on vertically averaged daily maximum salinity, referred to below as "salinity."
    - The fresh water criteria are applied where 95% of the salinity values are less than or equal to 1 part per thousand (ppt) or when the “salinity” is less than 10 ppt.

- The marine water criteria are applied at all other locations where the salinity values are greater than 1 ppt or when the "salinity" is greater than or equal to 10 ppt.

The TMDL analysis section of this report includes a discussion of the applicable water quality standard was determined in brackish waters within the study area.

DOH Shellfish Growing Area Standards and Classifications

- The Washington State Department of Health (DOH) classifies commercial shellfish beds in Washington State using the National Shellfish Sanitation Program (NSSP) criteria:
  - Geometric mean less than or equal to 14 cfu/100 mL
  - No more than 10% of the samples greater than 43 cfu/100 mL
  - Statistics based on the last 30 samples collected.
- Figure 2 outlines classification areas for Drayton Harbor.
- Based on the results of the sanitary survey, one of four classifications is given to the growing area:
  - *Approved* – The growing area is approved for direct marketing of commercial harvest and does not pose a public health risk. There are no fully approved areas in Drayton Harbor.
  - *Conditionally Approved* – The area is approved, but only during predictable periods. Typically, shellfish harvesting is prohibited following a rainfall event of predetermined magnitude for the length of time it takes water quality to recover from the event. For example, the conditionally approved shellfish area in central Drayton Harbor is closed for 6 days when precipitation of 0.75 inches or greater falls over a 24-hour period.
  - *Restricted* – Restricted areas are not approved for direct commercial marketing, but due to limited pollution from non-human sources, shellfish can be relayed to an approved area for a specified amount of time to cleanse themselves before being sold commercially. There are no restricted areas in Drayton Harbor.
  - *Prohibited* – In these areas pollution from fecal material or other sources poses a health risk to shellfish consumers and commercial shellfish harvest is not allowed. The majority of Drayton Harbor, as well as the portion of Semiahmoo Bay outside the harbor, are classified as prohibited.

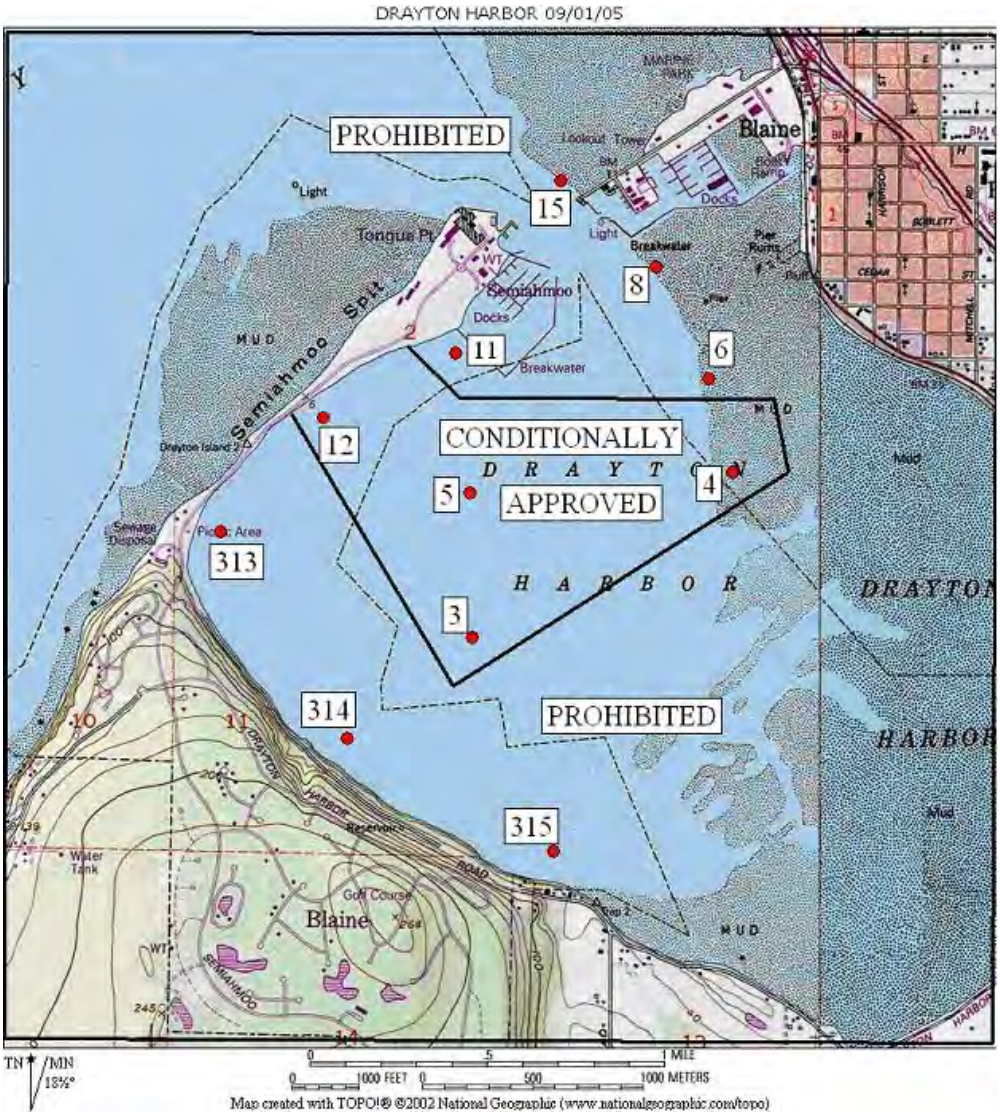

Figure 2. *DOH sampling stations and shellfish growing area classifications.*

Watershed Description

Drayton Harbor

Drayton Harbor is located in Whatcom County at the northwest corner of Washington State, just south of the US-Canadian border (Figure 1). A narrow 500-foot entrance connects the harbor to Semiahmoo Bay and the Strait of Georgia and restricts the inflow of seawater. Drayton Harbor's shallow nature results in the exposure of over 900 acres of mudflats at low tide, primarily within its eastern half. Historically, the harbor has been used for commercial, recreational, and tribal shellfish harvesting. It is within the usual and accustomed fishing grounds of several tribes, including the Lummi Nation and the Nooksack Indian Tribe.

The city of Blaine borders portions of the harbor along the north and southwest shoreline. The Blaine Marina, operated by the Port of Bellingham, is located at the northern edge of the harbor entrance. The marina contains approximately 600 boat slips, including permanent moorage and 700 square feet of visitor moorage (Port of Bellingham, 2007). The marina also houses several fish processing companies and a public wharf.

To the south of the entrance to Drayton Harbor are the Semiahmoo Resort and Marina, which lie at the north end of the Semiahmoo Spit. The narrow section of the spit, southwest of the Resort at Semiahmoo, is the Semiahmoo County Park, a public access park with beach walking trails. The current Blaine Wastewater Treatment Plant (WWTP) is located southwest of the park, at the neck of the spit.

The Drayton Harbor watershed is approximately 35,372 acres, 90% of which drains into either California or Dakota Creek (Callahan and Menzies, 2004) before entering the harbor. The watershed houses approximately 10,465 people (Callahan and Menzies, 2004) and hosts a wide variety of land uses including commercial and industrial development, low density residential land, commercial dairies and berry farms, non-commercial hobby farms, agriculture, surface mining, and forestland.

Dakota Creek

The Dakota Creek watershed accounts for about 52% of the Drayton Harbor drainage area and empties into the harbor near the southeastern boundary of the city of Blaine. The upper watershed is dominated by agriculture and commercial dairy farms, which are concentrated between the North and South Forks of Dakota Creek. Wetlands are also located throughout the upper watershed with several riparian planting projects recently completed by the Whatcom County Conservation District (CD). The middle and lower portions of the watershed are characterized primarily by partially forested, low-density residential and small, non-commercial farms.

California Creek

The drainage area of California Creek makes up 38% of the watershed and is similar to that of Dakota Creek, with the upper half consisting primarily of dairy farms and agriculture, while the lower portion is sparsely populated with residences and hobby farms. The mouth of California Creek is located approximately ¾ miles to the southeast of the mouth of Dakota Creek.

Cain Creek

Cain Creek drains a large portion of the city of Blaine, north of the harbor. The headwaters begin in a minimally developed wetland area just south of the Blaine Airport and drain into the main channel which parallels the I-5 freeway through town. The creek discharges to Semiahmoo Bay due west of the intersection of Peace Portal and Marine Drive, approximately ⅓ of a mile south of the international border with Canada. The creek has been heavily impacted by the development of Blaine and the construction of the I-5 freeway and serves as receiving waters to a number of storm drainages (City of Blaine, 1995).

Climate

The climate of the Drayton Harbor watershed is characterized by mild maritime weather, influenced by prevailing southwest winds from the Pacific Ocean and Puget Sound. Occasionally, the prevailing wind shifts to a northeasterly wind which brings brisk cold weather in the winter and hot dry weather in the summer. These cold episodes can drop temperatures to below 0˚ F with a wind-chill of 50 below zero (City of Blaine, 1995).

The watershed is heavily influenced by precipitation, receiving approximately 40 inches a year. On average greater than 75% of the precipitation falls during the months of October to April (WRRC, 2007)(Table 3 and Figure 3).

***Table 3**. Monthly average climate data for the city of Blaine. Period of Record: 6/ 1/1948 to 12/31/2006. Washington Regional Climate Center.*

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (F)	42.4	47.0	51.0	56.8	63.3	68.3	72.1	71.9	66.5	57.4	48.8	43.4	57.4
Average Min. Temperature (F)	31.3	33.5	35.4	39.1	44.3	49.3	51.7	51.6	47.2	41.8	36.6	32.9	41.2
Average Total Precipitation (in.)	5.51	4.06	3.52	2.78	2.27	1.92	1.27	1.50	2.04	3.89	5.99	5.91	40.67
Average Total Snow Fall (in.)	5.4	2.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	4.4	13.8

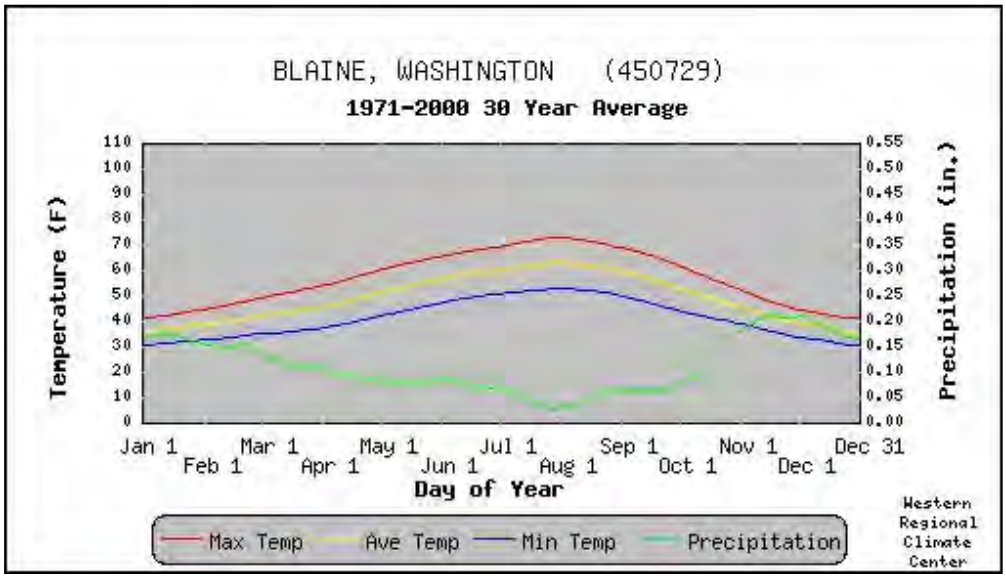

Figure 3. *29-day running average of daily temperature and precipitation in Blaine, WA.*

Geology

The geology of the area was primarily influenced by the repeated advance and retreat of glacial ice sheets from Canada. When the Vashon Drift retreated the lowlands of the Drayton Harbor watershed were covered by the sea. Both the glacial ice and the sea deposited sediments. Since then stream erosion and deposition have shaped the landscape (City of Blaine, 1995).

Potential sources of contamination

FC bacteria come from human and animal waste. Usually FC bacteria enter surface waters from treated sewage, failing septic systems, direct animal access (both wildlife and domestic animals) to streams, or deposition on the land that is washed into the streams by runoff from precipitation; however they can also be found in stormwater and industrial effluent.

Point Sources (Permit holders)

Fecal coliform (FC) bacteria can be present in the process wastewater and stormwater runoff discharged from the municipal and industrial activities in the watershed. Fecal coliform bacteria and potential contaminants from industrial and municipal sources are regulated by various National Pollution Discharge Elimination System (NPDES) and general permits from Ecology.

Wastewater Treatment

Most homes within the city of Blaine and its Urban Growth Area discharge sewage to the Blaine wastewater treatment plant (WWTP) collection system. Wastewater is currently treated biologically in rotating contactors, followed by secondary clarification, and then disinfected with chlorine. Treated and disinfected wastewater is discharged into Semiahmoo Bay approximately ½ mile from the shore, via a submerged diffuser (Hoyle-Dodson, 1997). The plant holds an individual wastewater permit, which is regulated by Ecology.

Construction plans were approved in May 2008 for the new City of Blaine Lighthouse Point Water Reclamation Facility (WRF). The new facility will have increased capacity for wet weather events and future growth, including membrane bioreactor (MBR) technology, and will eventually replace the existing WWTP. The new WRF will be located along Marine Drive near the Blaine Marina. The outfall for the new facility will remain the same, but the sewage main that runs beneath the mouth of Drayton Harbor will carry treated effluent (Adolfson, 2006). In the next phase treated sewage from West Blaine will be pumped through a seamless pipe to the new facility for treatment.

Both marinas operate vessel marine sanitation device pump out stations which discharge to the Blaine WWTP.

Concentrated Animal Feeding Operations

The watershed currently has 11 active dairies with 7029 mature dairy animals (Pentzer, 2007), several commercial livestock operations, and numerous 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). In 2008, EPA issued its final rule for Concentrated Animal Feeding Operations (CAFO) regulations..

Stormwater

Washington State Department of Transportation (WSDOT) highways and facilities are required to be covered under a stormwater MS4 permit. The WSDOT controls state highway 548 (also known as Blaine Road within the study area), and Interstate 5.

Seafood Processors

Historically the Blaine marina has housed several seafood processors. The processors combined to form a consortium and no longer discharge to Blaine WWTP, but to a separate outfall at the mouth of Drayton Harbor. Currently, only one processor, Boundary Fish, discharges to Drayton Harbor

Wildlife and background sources

Migratory and other birds are often seen in fields and in the harbor 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.

Bird counts conducted by the Port of Bellingham (Hirsch, 2007) from October 2005 to September 2006 in the commercial portion of the Blaine Harbor:

- Ranged from 96 (low) in November 2005 to 802 (high) in July 2006.
- Gulls were the most common bird observed followed by cormorants and then pigeons. A small number of Canada geese, crows, and great blue herons were also spotted.
- The highest bird densities were observed on the breakwater surrounding Blaine Harbor and higher bird densities in spring and summer months were attributed to cormorant nesting on the rock portion of the breakwater.

According to Washington State Fish and Wildlife surveys (Berbells, 2006), marine bird and waterfowl densities are:

- In the winter, 400 – 1,000 birds per square kilometer throughout most of Drayton Harbor, with densities greater than 1,000 birds/ km^2 at the Blaine Marina and the mouth of California Creek.
- During the summer, densities remain above 1,000 birds/ km^2 at the marina and drop to 200 – 400 birds/ km^2 at California Creek. Bird densities are generally lower in the summer, except at the mouth of Dakota Creek where concentrations remain at 400 – 1,000 birds/ km^2.

The Washington State Department of Fish and Wildlife has identified three seal haulout sites within Drayton Harbor, one along the channels off Dakota Creek, one on the shoals and channels in central Drayton Harbor, and one on the floats at Semiahmoo Marina. Quantities at these haulout sites are less than 100, except for at the Semiahmoo Marina, which is estimated at 100 to 500 (Berbells, 2006).

Usually these sources are dispersed and do not elevate FC counts over state criteria. Sometimes birds and animals are locally concentrated and can cause elevated counts. Concentrated bird and wildlife presence in the watershed were noted during sampling surveys.

Nonpoint sources

Agriculture

Nonpoint sources of pollutants are usually dispersed and are not regulated under discharge permits. Several types of potential nonpoint sources are present in the study area. Range and pastured commercial livestock with direct access to streams can be a source of FC contamination. Poor livestock or pet manure management from non-commercial farms and residential areas is another source.

Fecal coliform bacteria from nonpoint sources are transported to surface water by direct and indirect means. Manure that is spread over fields during certain times of the year can enter streams via direct spray and surface runoff. 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.

The Whatcom Conservation District recently conducted a livestock windshield survey and identified approximately 233 animal keeping sites in the Drayton Harbor Watershed. Of these sites, there were 136 horse sites, 79 cattle sites, and less than ten sites each of sheep, goat, llama/alpaca, and swine (Berbells, 2006).

On-site septic systems

Malfunctioning or antiquated on-site septic systems (OSS) can allow fecal coliform bacteria to seep into waterways.

In 1997-98, Whatcom County Health Department inspections identified 54 failing systems out of 252 OSS systems inspected. The inspections were conducted within priority drainage areas of Drayton Harbor identified as having elevated bacteria counts by a Western Washington University study. Of the 54 systems that failed, all but one has been repaired (DHSPD, 2007).

During a 2006 shoreline survey, DOH evaluated OSS systems along the Drayton Harbor shoreline and found that the majority of the systems were older, gravity-fed systems. Eight developed parcels were identified as potential sources of pollution, however none of these systems were found to be impacting the harbor (Berbells, 2006).

Other nonpoint sources

Road runoff, pet waste, disposable diapers, wood waste and other nonpoint sources can add FC bacteria to the waters flowing to Drayton Harbor as well.

Goals and Objectives

Project goal

The goal of the overall TMDL project is to ensure that both impaired marine and freshwater within the study area will attain water quality standards.

Project objectives

Study objectives are as follows:

- Establish load allocations for nonpoint sources and wasteload allocations for point sources to meet water quality standards and protect beneficial uses, including primary contact recreation and shellfish harvesting.
- Identify and characterize fecal coliform bacteria concentrations and loads from all significant tributaries, point sources, and drainages into Drayton Harbor under various seasonal or hydrological conditions, including stormwater contributions.
- Identify location of sources of fecal coliform to Dakota, California, and Cain Creeks.
- Identify relative contributions of FC loading to Drayton Harbor so clean-up activities can focus on the largest sources.

Ecology Study Methods

Ecology developed a quality assurance (QA) project plan for the *Drayton Harbor Watershed Fecal Coliform Bacteria Total Maximum Daily Load: Phase 1 Water Quality Study Design* (Mathieu and Sargeant, 2008) to provide background information and detailed description of monitoring and sample processing activities. The QA project plan was reviewed by the technical advisory group and approved for sampling on December 6, 2007.

Fixed network TMDL Sampling

Overview

Sampling began on December 11, 2007 and continued until January 13, 2009. Table 4 lists the 23 routine TMDL sampling surveys, approximately bi-monthly, partitioned into either a dry season or wet season group based on streamflows and monthly rainfall. Additionally shoreline surveys were conducted in January 2008, May 2008, and January 2009. Details are included in the results section of this report and Appendix D.

Table 4.Sampling Dates for the Drayton Harbor Watershed Fecal Coliform TMDL.

Wet Season	Dry Season
December 11-12, 2007	April 30, 2008
December 18, 2007	May 12, 2008
January 15, 2008	May 28, 2008
January 28, 2008	June 12, 2008
February 6, 2008	June 24, 2008
February 19, 2008	July 7, 2008
March 3, 2008	July 21, 2008
November 3-5, 2008	August 4, 2008
November 17-18, 2008	August 27, 2008
December 2-3, 2008	September 2, 2008
December 15-16, 2008	September 21-22, 2008
	October 13-14, 2008

Sampling locations

FC bacteria and streamflow data were collected from 34 sites in the watershed. Table 5 lists the corresponding location identification, description, and latitude/longitude of the sampling sites.

Table 5. Site IDs, descriptions, and coordinates for the Drayton Harbor Watershed Fecal Coliform TMDL sampling sites.

Site ID	Description	Latitude (˚N)	Longitude (˚W)
Dakota Creek Watershed			
1-TribDak-S2	Tributary to South Fork Dakota Creek at Sunrise Rd	48.94463	122.59646
1-TribDak-S1	Tributary to South Fork Dakota Creek at Delta Line Rd	48.94784	122.61629
1-SFDak-2.2	South Fork Dakota Creek at Sunrise Rd	48.94306	122.59647
1-TribDak-N2	Tributary to North Fork Dakota Creek near Delta Line Rd	48.96554	122.61708
1-NF-Dak-2.5	North Fork Dakota Creek at Delta Line Road	48.96971	122.61579
1-TribDak-N1	Tributary to North Fork Dakota Creek at Haynie Rd	48.97131	122.62618
1-NF-Dak-0.1	North Fork Dakota Creek at Custer School Rd	48.95107	122.63790
1-SF-Dak-0.2	South Fork Dakota Creek at Custer School Rd	48.95033	122.63792
1-Dak-4.9	Dakota Creek at Valley View Rd	48.95715	122.65964
1-TribDak-5	Tributary to Dakota Creek (Haynie Creek) at Valley View Rd	48.96520	122.66007
1-Dak-3.1	Dakota Creek at Giles Street	48.96272	122.68204
1-TribDak-3	Tributary to Dakota Creek at Rogers Rd	48.97034	122.69307
1-TribDak-4	Tributary to Dakota Creek at Hoier Rd	48.97195	122.70018
1-TribDak-2	East tributary to Dakota Creek at Blaine-Lynden Rd	48.97911	122.70841
1-TribDak-1	West tributary to Dakota Creek at Blaine-Lynden Rd	48.97915	122.71960
1-Dak-0.1	The mouth of Dakota Creek at SR 548/Blaine Rd	48.97231	122.72936
California Creek Watershed			
1-TribCal-4	Tributary to California Creek at Bay Rd	48.90633	122.64965
1-Cal-6.2	California Creek at Bruce Rd	48.90928	122.64406
1-TribCal-5	Tributary to California Creek at Main St in Custer	48.91725	122.64927
1-Cal-5.0	California Creek at Valley View Rd	48.92136	122.66039
1-TribCal-3	Tributary to California Creek at Arnie Rd	48.92110	122.68400
1-Cal-3.1	California Creek at Birch Bay-Lynden Rd	48.93575	122.68878
1-TribCal-2	Tributary to California Creek at Kickerville Rd	48.94953	122.70449
1-TribCal-1	Tributary to California Creek at Fleet Rd	48.94850	122.72206
1-Cal-0.8	California Creek at SR548/ Blaine Rd	48.95468	122.72617
1-Cal-0.1	The mouth of California Creek at Drayton Harbor Rd	48.95827	122.73005
1-Cal-SD1	Outfall to California Creek at its mouth	48.96217	122.73289
1-TribCal-0	Tributary to California Creek @ SR548/ Blaine Rd	48.96230	122.73235
Cain Creek Watershed			
1-Cain-1.3	Cain Creek at Pipeline Rd near airport	48.98768	122.73432
1-Cain-0.4	Cain Creek below beaver dam near Blaine Trade Center	48.99295	122.74513
1-Cain-0.01	The mouth of Cain Creek	48.99697	122.75463
1-Cain-SD1	Outfall to Semiahmoo Bay near the mouth of Cain Creek	48.99712	122.75439
Direct Drainages to Drayton Harbor			
1-TribDray-1	Tributary to harbor at Hall St & Dearborn Rd	48.96813	122.73312
1-Dray-SD4	36" culvert to harbor east of Albert St and Peace Portal Dr	48.98246	122.73935

Methods

Field sampling and measurement methods and protocols are summarized in Table 6 and described in the QA project plan (Mathieu and Sergeant, 2008) in greater detail.

Table 6. Measurement and sampling methods and protocols.

Parameter	Measurement/ Sample Type	Lab Method	Protocol
Fecal Coliform-MF	Grab Sample	SM 9222D	EAP012 (Mathieu, 2006a); EAP015 (Joy, 2006)
Fecal Coliform-MPN	Grab Sample	SM 9221 E2	EAP012 (Mathieu, 2006a); EAP015 (Joy, 2006)
Temp, DO, pH, Conductivity	Hydrolab Sonde	n/a	EAP033 (Swanson, 2007)
DO	Winkler	SM4500OC	EAP035 (Mathieu,2006b)
Flow	Instantaneous	n/a	EAP024 (Sullivan, 2006)
Flow	Continuous	n/a	Ecology's Watershed Technical Support Unit protocols (Ecology, 2000)

Data quality methods

Data quality methods and associated criteria are summarized below and described in the QA project plan (Mathieu and Sargeant, 2008) in greater detail.

- Fecal Samples:
  - Ecology staff collected replicate samples in the field for twenty percent of all FC samples.
  - Replicate samples were compared to the measurement quality objectives (MQOs) in Table 7 to assess data quality.
- Hydrolab Measurements:
  - Calibrated Hydrolabs before each run and post-checked afterwards using conductivity/pH buffer solutions and the air saturation calibration method for dissolved oxygen.
  - Post calibration values were compared to data quality criteria (Table 8).
  - Sampling staff conducted a field replicate at one or more site each day, where both sampling teams' Hydrolabs were compared against each other at the same site and time.
  - Replicate Hydrolab measurements were compared to MQOs in Table 7.

Table 7. Measurement Quality Objectives (MQO) for field replicates and lab duplicates.

Analysis	Method/Equipment	Field Replicate MQO	Lab Duplicate MQO	Reporting Limits and Resolution
Field Measurements				
Discharge Volume	Marsh McBirney Flow-Mate Flowmeter	10% RSD	n/a	0.01 ft/s
Water Temperature[1]	Hydrolab MiniSonde®	+/- 0.2° C	n/a	0.01° C
Specific Conductivity	Hydrolab MiniSonde®	10% RSD	n/a	0.1 umhos/cm
pH	Hydrolab MiniSonde®	10% RSD	n/a	1 to 14 SU
Dissolved Oxygen	Hydrolab MiniSonde® (Clark cell)	10% RSD	n/a	0.1 - 15 mg/L
Dissolved Oxygen[1]	SM4500OC (Winkler)	+/- 0.2 mg/L	n/a	0.1 mg/L
Laboratory Analyses				
Fecal Coliform – MPN	MPN 9221 E2	50% of replicate pairs < 20% RSD 90% of replicate pairs <50% RSD[2]	40% RPD	1.8 MPN/100 mL
Fecal Coliform – MF	SM 9222D	50% of replicate pairs < 20% RSD 90% of replicate pairs <50% RSD[2]	40% RPD	1 cfu/100 mL

[1] as units of measurement, not percentages.
[2] replicate results with a mean of less than or equal to 20 cfu/100mL will be evaluated separately.

Table 8. Hydrolab post-calibration data quality criteria.

Parameter	Units	Accept	Qualify	Reject
pH	std. units	< or = ± 0.25	> ± 0.25 and < or = ± 0.5	> ± 0.5
Conductivity*	µS/cm	< or = ± 5%	> ± 5% and < or = ± 15%	> ± 15%
Dissolved Oxygen**	% saturation	< or = ± 5%	> ± 5% and < or = ± 10%	> ± 10%

Data collection

Data collection followed the procedures outlined in the QA Project Plan (Mathieu and Sargeant, 2008) with the exception of a few instances (Table 9).

Table 9. Deviations from QA Project Plan in data collection.

QAPP said:	Completed:	Reason
4-5 shoreline surveys	3 shoreline surveys	Unable to catch a dry season storm event.
4-5 marina surveys	2 marina surveys	Staff and analytical resources diverted to MST sampling project in Blaine Marina only.
Salinity surveys by kayak	1 bridge survey	The bridge survey showed that even at a very low tide the mouths of the creeks had a high enough salinity to be considered marine water.
3 continuous Hydrolab surveys	1 continuous Hydrolab survey	Limited staff time. Data collection was secondary to bacteria data collection and related to low-priority project objectives.

Shoreline and marina surveys

In addition to the larger tributaries, the Drayton Harbor shoreline has numerous small drainage/discharge points including stormwater outfalls, unnamed tributaries, and other drainage features. In order to better assess the contribution of FC loading from these drainages, Ecology conducted 3 shoreline discharge surveys. Fecal coliform samples and flow measurements (ore estimates) were collected from sites around the shoreline.

In support of the TMDL, staff from DOH and the Puget Sound Restoration Fund (PSRF) collected samples during two intensive FC surveys in Blaine Harbor and Semiahmoo marinas, one during a wet season rain event on 1/14/2008 and one during dry conditions on 5/27/2008. The DOH lab analyzed the samples using the MPN method.

Continuous Hydrolab deployments

Ecology conducted continuous diel monitoring for pH, DO, conductivity, and temperature at ten sites on Dakota, California, and Cain Creek using Hydrolab DataSondes®.

The goal of the deployments was to assess whether each watershed was impaired for temperature, dissolved oxygen, and pH. Exceedences of dissolved oxygen and pH may serve as the basis for 303(d) (Category 5) listings in the 2012 Water Quality Assessment. Category 5 listings for temperature are based on a 7 day average daily maximum. Since Ecology deployments lasted three days at most, the temperature data will only be used to generate Category 2 (waters of concern) listings. A detailed temperature study of Category 2 listings is necessary to assess compliance with WQ standards.

Microbial source tracking in Blaine Harbor marina

Ecology conducted a microbial source tracking (MST) study in Blaine Harbor marina from September 2008 to January 2009. Details of the MST study are outlined in the QAPP addendum (Mathieu, 2008). In summary:

- Ecology collected water samples during six sample events at five sites (Table 10).
- The DOH laboratory analyzed samples for FC concentrations using the MPN method
- The Institute for Environmental Health (IEH) performed ribotyping MST analysis to determine the species or source of origin of *E. coli* strains isolated from the water samples.
    - The quality control data provided by IEH was deemed insufficient to assess the usability of the data, so no results are presented in this report. EPA has submitted a cancellation order for the contract. Further discussion is provided in the data quality results section.
- EPA's Manchester Laboratory performed the *Bacteroides* host specific polymerase chain reaction (HSPCR) MST analysis on a sub-set of samples. The HSPCR analysis is capable of detecting the presence of human and ruminant specific DNA markers for *Bacteroides*.
    - *Bacteroides* is a type of bacterial organism found in the gut of warm blooded animals.
    - The method matches DNA strains of *Bacteroides* found in water samples with the known markers specific to human and ruminant strains of *Bacteroides.*
- Table 11 summarizes the laboratory methods.

Table 10. Location names, descriptions, and coordinates for Blaine Harbor marina MST Study.

Site name	Alias	Site description	Lat (˚N)	Long (˚W)
BlaineMarina-3	3	Near entrance outside marina	48.99081	122.76553
BlaineMarina-1	1	Near entrance inside marina	48.99123	122.76472
BlaineMarina-R	R	Near corner of breakwater	48.99051	122.76318
BlaineMarina-D	D	Commercial marina at Westman Marine dock	48.99188	122.76135
BlaineMarina-Q	Q	Recreational moorage	48.99357	122.7563

Table 11. Analytical methods, preservation, and holding times.

Parameter	Description	Method	Lab	Container	Preservation	Holding Time
Fecal coliform	Most probable number	SM 9221E	DOH	PE, 250 mL, sterile	10˚C, dark	Max 24 hours
HSPCR	PCR- 2 marker	MEL SOPs	EPA -MEL	PE, 250 mL, sterile	10˚C, dark	Max 24 hours
Ribotyping	2-enzyme	IEH SOPs	IEH	Isolated from FC sample	10˚C, dark	Max 24 hours

HSPCR= host specific polymerase chain reaction
SM= Standard Methods
PE= polyethylene

Information and data from sources outside of Ecology

DOH Shellfish Growing Area Classification Sampling

During the course of the TMDL DOH and the Drayton Harbor Shellfish Protection District collected samples at 11 stations in Drayton Harbor, as well as the 3 new stations in Semiahmoo Bay (Table 12), during ten sampling events. Stations 3-5 and 12 are classified *Conditionally Approved* for shellfish harvest. Stations 6, 8, 11, and 15 are classified as *Prohibited* and stations 313-315 are currently *Unclassified*.

The DOH laboratory analyzed the water samples using the most-probable number (MPN), five-tube fermentation method (Standard Methods 9221 E(a) using A-1 medium).

The DOH dataset provided supporting information to this study; however no DOH data was used to calculate the TMDL.

Table 12. Marine sites within the TMDL study area sampled by DOH.

Site ID	Site Description
DOH Station 3	Drayton Harbor (DH) at south corner of conditionally approved shellfish area
DOH Station 4	DH at east corner of conditionally approved shellfish area
DOH Station 5	DH near center of conditionally approved shellfish area
DOH Station 6	DH north of DOH #4, outside conditionally approved shellfish area
DOH Station 8	DH approximately 1000 ft SE of entrance to Blaine Marina
DOH Station 11	DH just SW of Semiahmoo Marina breakwater
DOH Station 12	DH at west corner of conditionally approved shellfish area
DOH Station 15	DH approximately 1000 ft NW of entrance to Blaine Marina
DOH Station 313	DH near picnic area at neck of Semiahmoo Bay; currently unclassified area
DOH Station 314	DH southwest of conditionally approved area; currently unclassified area
DOH Station 315	DH southeast of conditionally approved area; currently unclassified area
Semiah-NW	Semiahmoo Bay at northwest corner of the TMDL study area boundary
Semiah-Tower	Semiahmoo Bay near the international border tower
Semiah-WWTP	Semiahmoo Bay west of WWTP outfall

Nooksack Indian Tribe TMDL Support Study

Through EPA funding, the Nooksack Indian Tribe (NIT) collected data in 2009 to augment the TMDL study. Additional data were collected to provide information on fecal bacteria inputs from potential sources around the mouth of Drayton Harbor and along the shoreline of Semiahmoo Bay northward to the Canadian border. The study included three components:

- A series of shoreline surveys
- Marine sampling adjacent to the Semiahmoo Bay shoreline from the Canadian border south to Drayton Harbor
- Circulation studies of the Cain Creek outflow.

The study was designed to meet data credibility requirements and produce useable data for the TMDL analysis. Details of the study design, methods, and data quality objectives are provided in the QAPP: Addendum to Drayton Harbor Watershed Fecal Coliform TMDL; Phase I, Water Quality Study Design (Appendix to be added later). Appendices to the QAPP are available upon request.

The study is currently in the reporting phase and the data generated is still draft data. Sampling and data quality results will be integrated into this report before publication.

Northwest Indian College Sampling

Since 1998, Northwest Indian College (NWIC) has collected monthly FC samples on 11 sites within the study area of the TMDL. The NWIC sites include: 5 on Dakota Creek, 3 on California Creek, the

mouth of an unnamed creek on the 303(d) list, the mouth of Cain Creek, and an outfall that discharges to Cain Creek at its mouth.

Over the course of the TMDL, NWIC collected samples on ? occasions. The TMDL QAPP contains a summary of historical data from 1998 to 2007. The NWIC dataset provided supporting information to this study; however no NWIC data was used to calculate the TMDL.

Whatcom County 2009 follow-up monitoring

In 2009 Whatcom County Public Works collected FC samples at 25 of the TMDL sites in the Dakota and California creek basins, as well as 5 additional sites in the California basin. TMDL locations sampled are identified in the results section of this report. Table 13 describes the location of the five additional stations.

This dataset provided supporting information to this study; however none of the data was used to calculate the TMDL.

Table 13. Additional Whatcom County 2009 water quality monitoring sites.

Site ID	Site Description
Cal 0.8*	California Creek at Kickerville Bridge
CA6	Upstream side of cross culvert at Arnie Road, west of Bruce Rd
CA9	Upstream side of cross culvert at Fox and Vista
CA15	Upstream side of cross culvert at Portal, south of Farris
CA14c	Cross culvert at Brown Road, west of railroad

Analytical Approach

Seasonal Source Assessment

Ecology conducted a seasonal source assessment to determine if there was a clear wet or dry season (i.e., runoff and non-runoff period). The QA project plan identified:

- The wet season as November to February, based on the months when FC counts were highest in Drayton Harbor.
- The dry season as May to September, based on the months when FC counts were highest in the freshwater tributaries.

The final determination of wet and dry seasons was made by factoring in the flow regime of Dakota and California Creeks and the monthly precipitation totals during the study period (Figure 4). Changes to wet and dry season periods included:

- The dry period was extended to include late April and October.
    - Although October did see a substantial increase in precipitation from September (from 0.8" to 3.0"), the streamflows were near (and returned to) dry season baseflow before (and after) storm events.
    - The conditions during the sample event on 4/30/2008 were closer to those during May (slowly declining flow near baseflow) as opposed to early April (higher flows with more frequent precipitation).
- The wet season was extended to include March.
    - Streamflow and precipitation conditions on the 3/3/2008 sampling event were more similar to winter baseflow conditions than summer baseflow conditions.

While streamflows were near dry season baseflow at the beginning of November, over 3" of rain accumulated from 10/30/2008 to 11/4/2008. The samples collected from 11/3/2008 to 11/5/2008 represented a "first flush" event for the wet season.

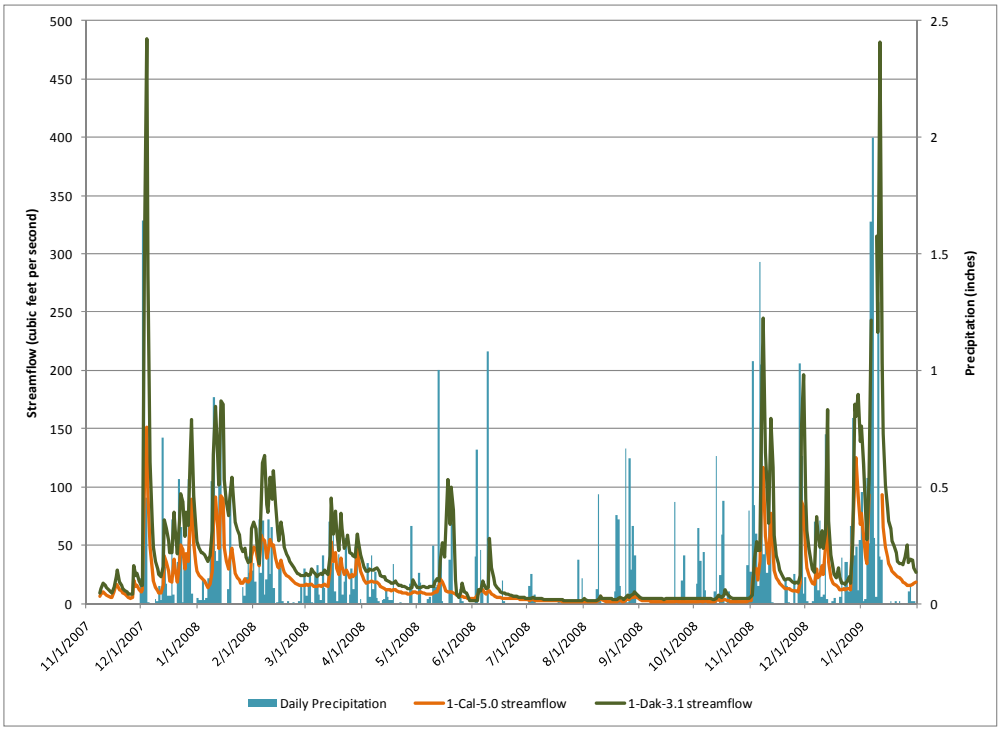

Figure 4. Continuous streamflow from Dakota Creek at Giles Road and California Creek at Valley View Road plotted against and daily precipitation values at the mouth of Bertrand Creek.

Modeling framework

Statistical tests for significant changes between stations

Ecology used two different types of statistical tests to determine whether or not there was a significant change in either flow or fecal coliform (or both) between two sites. Tests were performed between a given station and the nearest downstream station on the same creek.

Paired t-test

The paired t-test is a commonly used parametric test for evaluating differences in matched pairs (the values for the two stations on a given sampling date). A parametric test assumes that the paired differences follow a normal distribution. If the differences do not follow a normal distribution, then the t-test loses power by inflating the estimate of standard deviation and making deviations from a zero difference difficult to discern (USGS, 2005). Fecal coliform

counts were first log-transformed and then tested for a log-normal distribution. All datasets showed log-normal distribution, so the t-tests were conducted.

Wilcoxon signed rank test

The Wilcoxon signed rank test isa non-parametric statistical test used to determine whether or not the median difference between paired observations is equal to zero. Both the the paired t-test and the Wilcoxon singed rank test were used to determine if a significant change in streamflow or fecal coliform concentrations occurred between two stations.

Beales FC Load Estimates

To calculate the seasonal fecal coliform loads, a Beales ratio estimator formula (Dolan et al., 1981) was used at sites with adequate pollutant and streamflow data. The Beales formula provides a better annual or seasonal estimate of pollutant loads compared to the average instantaneous load obtained from a few sampling events. The average instantaneous load was calculated when continuous discharge data were absent or could not be estimated from nearby gaging data. Beales FC load were calculated to show the general loading pattern in each watershed and provide comparison to the loading estimates calculated by the mass balance model.

Statistical Rollback Method

Although TMDL studies normally express allocations as pollutant loads (pollutant concentration multiplied by streamflow), this approach does not always work well for bacteria TMDL studies. An allocation of FC bacteria pollutant loads in terms of "numbers of bacteria per day" is awkward and challenging to understand. Instead of managing FC bacteria pollution in terms of total load, Ecology has used the Statistical Rollback Method (Ott, 1995) to manage the distribution of FC bacteria counts. The approach relates the analysis to the water quality concentration standard better and has proven successful in past FC bacteria TMDL assessments.

The statistical roll-back method was used to establish FC bacteria reduction targets at all sampling sites that had sufficient sampling size (>5 samplings). The roll-back method assumes that the distribution of FC bacteria concentrations follows a log-normal distribution. The cumulative probability plot of the observed data gives an estimate of the geometric mean and 90th percentile which can then be compared to the FC bacteria concentration targets outlined in the 'Loading Capacity' section. The roll-back procedure is described in greater detail in Appendix F.

It is important to remember that the FC bacteria TMDL targets are only in place to assist water quality managers in assessing the progress toward compliance with the FC bacteria water quality criteria. Compliance is measured as meeting water quality criteria. Any water body with FC bacteria TMDL targets is expected to meet both the applicable geometric mean and 'not more than 10 percent of samples' criteria and also to meet beneficial uses for the category.

FC Mass Balance Model

This study used a steady-state FC mass-balance approach to set freshwater FC target values for sites in the Dakota and California Creeks basins that would meet marine FC standards downstream. To do this Ecology:

1. Determined the FC freshwater boundary target values for the most downstream freshwater site for each creek (1-Dak-3.1 and 1-Cal-3.1, respectively) that would meet marine standards when the mixture of river and bay water reached 10 ppt salinity.
2. Developed and evaluated a flow balance.
3. Developed mass balances for FC bacteria concentrations and loads.
4. Calculated and applied a first-order decay rate for bacteria in the creeks.
5. Developed TMDL mass balances by reducing major loading sources until the FC levels in the river at the downstream boundaries (1-Dak-3.1 and 1-Cal-3.1) met the FC freshwater boundary target values.

The analytical framework for this approach is described in greater detail in the 'TMDL Analysis' section of this report.

Ecology Study Results and Discussion

Ecology loaded all project data to its online Environmental Information Management (EIM) database. EIM also contains information about the study and sampling stations (including links to an online interactive map).

To access the data:

- Go to: www.ecy.wa.gov/eim/
- Click 'Search for data' link
- Click 'Search by user study ID' link
- Enter '**NMat0001**' into the 'User Study ID' field
- Click 'Results' link to view results online or 'Download' link to download a spreadsheet.

Data tables for the project are located in Appendix E. Detailed results are provided for each basin in Appendix E.

Quality assurance results

Ecology Sources

In general, data quality met the objectives outlined in the QA Project Plan. Detailed QA results are included in Appendix E. Results are summarized briefly below.

- Hydrolab *in situ* data quality results
    - Compared the post-calibration and side-by-side Hydrolab results to their respective criteria and either qualified or rejected the measurements where appropriate.
        - Temperature: 5% of data qualified, no data rejected.
        - Conductivity: 25% of data qualified, 4% of data rejected.
        - pH: 16% of data qualified, 10% of data rejected.
        - Dissolved Oxygen: 33% of data qualified, 3% of data rejected
- Hydrolab deployment continuous data quality results
    - Overall, data quality was acceptable. Some results were qualified or adjusted:
        - Qualified data due to exceedance of post-calibration criteria for:
            - Specific conductivity at five sites
            - pH at one site
        - Qualified dissolved oxygen data at two sites based on Winkler DO check criteria.
        - Truncated initial pH data at five sites where pH probes with low-ionic strength reference (LISREF) probes were deployed.
        - Removed a small amount of DO data at 1-Cal-5.0 due to power failure issues.
        - Corrected DO data at three sites based on a linear regression to Winkler checks.
- Precision results
    - Field staff collected field replicates for FC, streamflow, and Hydrolab measurements.

    - All parameters, with the exception of FC-MPN results, met their quality objectives.
    - FC-Most probable number (MPN) results failed to meet the precision criteria outlined in the QAPP. However, the MPN precision results showed less variability than those from three previously completed TMDLs (Joy, 2004; Pelletier and Seiders, 2000; Seiders et al., 2001), indicating that the criteria were likely too stringent and that MPN precision was within the range of variability observed during other TMDL studies.
- Manchester QA/QC results
    - Out of 703 FC samples Ecology's Manchester Environmental Laboratory (MEL) qualified 160 samples.
    - The majority of these samples (95) were qualified because they were analyzed just outside of the 24 hour holding time. All samples qualified for holding time were analyzed within 30 hours.
- Completeness results
    - Of the 750 sampling opportunities, 47 samples were not collected because there was either no or too little flow to collect a sample. These samples were not counted against overall completeness.
    - Ecology field staff missed 10 total sampling opportunities that may have been avoidable resulting in an overall completeness percentage of 98.6%.

EPA Manchester Laboratory – MST PCR Data Quality

Quality control procedures were followed according to the California Creek and Drayton Harbor Microbial Source Tracking Pilot Study Monitoring Plan (HCS, 2006) and the Drayton Harbor Watershed Fecal Coliform TMDL Phase 1: Water Quality Study Design (Ecology, 2008). The EPA Region 10 Laboratory followed their quality assurance project plan that was developed for the Drayton Harbor Pilot MST Study (EPA, 2006).

The PCR result s met the study quality objectives and were deemed useable. Detailed data quality results are discussed in the Phase 2 MST report (HCS, 2009).

Institute for Environmental Health (IEH) – Ribotyping Data Quality

IEH provided draft results for the ribotyping which did not include any data quality information. In particular, the positive control (PC) sample results were not provided. IEH reported that the first two PC samples they received did not have any colonies on the plate and were therefore not analyzed. For the third PC sample, IEH had a record of receiving the sample, but no record of analyzing it (Ma, 2010). Without any data quality information to support the draft results, Ecology determined the dataset unusable. Consequentially, no ribotyping results are provided in this report.

Nooksack Indian Tribe TMDL Support Study Data Quality

The study findings are still preliminary. A full data quality assessment will be included in the project report and appended to this report at a later date.

Freshwater results

Dakota Creek

Link to Dakota Creek Basin Maps

Table 14 contains FC geometric mean and 90th percentile statistics for the Dakota Creek basin mainstem sites over the entire study period, as well as for both the wet and dry season. Table 14 contains statistics for the Dakota Creek basin tributaries.

Table 14. FC geometric mean and 90th percentile statistics, including wet and dry season, for the mainstem of Dakota Creek.

	All samples			Wet Season			Dry Season		
Station ID	n	Geo-mean	90th %tile	n	Geo-mean	90th %tile	n	Geo-mean	90th %tile
1-Dak-0.1-MF	22	29	258	11	86	438	11	9	43
1-Dak-0.1-MPN	21	55	452	10	166	761	11	20	113
1-Dak-3.1	23	63	198	11	68	257	12	58	160
1-Dak-4.9	23	63	213	11	63	286	12	64	161
1-NF-Dak-0.1	23	85	351	11	76	406	12	94	312
1-SF-Dak-0.2	23	50	290	11	42	480	12	59	133

Note: Highlighted (shaded) cells indicate sites above water quality criteria.

Table 15. FC geometric mean and 90th percentile statistics, including wet and dry season, for the Dakota Creek basin tributaries.

	All samples			Wet Season			Dry Season		
Station ID	n	Geo-mean	90th %tile	n	Geo-mean	90th %tile	n	Geo-mean	90th %tile
1-TribDak-S2	14	160	1123	4	n/a	n/a	10	247	815
1-TribDak-S1	16	141	1094	4	n/a	n/a	12	202	1385
1-SFDak-2.2	14	105	1126	4	n/a	n/a	10	141	461
1-TribDak-N2	23	207	1446	11	80	589	12	483	1286
1-NF-Dak-2.5	23	144	723	11	85	526	12	234	734
1-TribDak-N1	23	101	645	11	88	365	12	124	1521
1-TribDak-5	23	58	267	11	28	70	12	114	501
1-TribDak-3	23	199	585	11	118	274	12	320	800
1-TribDak-4	23	116	524	11	51	112	12	270	1060
1-TribDak-2	23	209	1143	11	98	244	12	422	2496
1-TribDak-1	17	143	601	11	150	438	6	131	947

Note: Highlighted (shaded) cells indicate sites above water quality criteria.

Fecal Coliform Loading

Ecology calculated Beales seasonal load estimates for all sites with adequate data. Figure 5-6 display the load balance for the Dakota Creek basin below the confluence of the north and south

forks. Residual FC loads represent some combination of the unmeasured FC load and the variability associated with bacteria samples and flow measurements.

During one storm event where the hydrograph was changing rapidly, samples were collected from the upper watershed on 11/4/2008 and from the lower watershed on 11/5/2008, resulting in a large discrepancy in the FC load balance. To account for this issue, Ecology did not include the November 4-5, 2008 sampling event in the Beales load calculation or mass balance model. However, the sampling event was still used to calculate the geometric mean and 90th percentile calculations for individual sites to assess compliance with water quality criteria and target values.

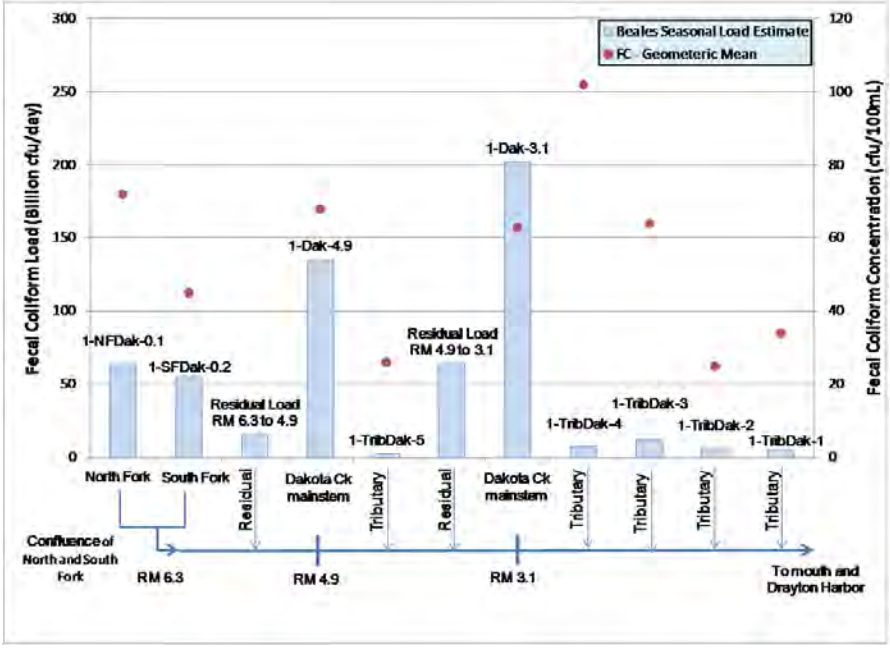

Figure 5.Wet season fecal coliform load balance for Dakota Creek.

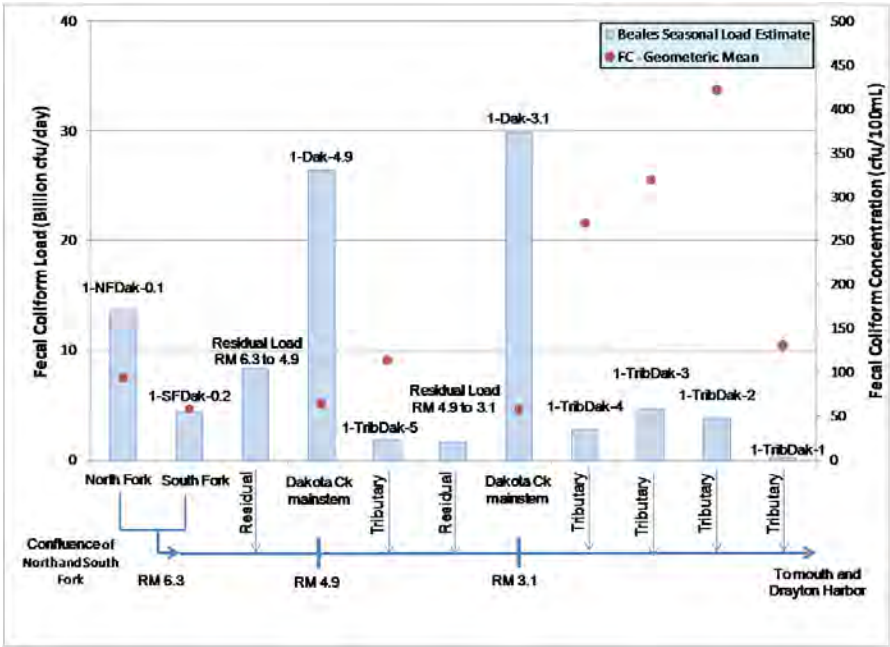

Figure 6. Dry season fecal coliform load balance for Dakota Creek.

California Creek

Link to California Creek Basin Maps

Table 16 contains FC geometric mean and 90th percentile statistics for the California Creek basin mainstem sites over the entire study period, as well as for both the wet and dry season. Table 17 contains statistics for the California Creek basin tributaries.

Table 16. FC geometric mean and 90th percentile statistics, including wet and dry season, for the mainstem of California Creek.

	All samples			Wet Season			Dry Season		
Station ID	n	Geo-mean	90th %tile	n	Geo-mean	90th %tile	n	Geo-mean	90th %tile
1-Cal-0.1	23	27	149	11	61	266	12	13	48*
1-Cal-0.1-MPN	22	40	265	10	91	364	12	20	127
1-Cal-0.8	23	34	140	11	37	199	12	31	103
1-Cal-3.1	23	68	351	11	31	149	12	141	404
1-Cal-5.0	22	100	693	10	36	256	12	234	697
1-Cal-6.2	23	119	608	11	54	268	12	243	689

Note: Highlighted (shaded) cells indicate sites above water quality criteria.

Table 17. FC geometric mean and 90th percentile statistics, including wet and dry season, for the California Creek basin tributaries.

	All samples			Wet Season			Dry Season		
Station ID	n	Geo-mean	90th %tile	n	Geo-mean	90th %tile	n	Geo-mean	90th %tile
1-TribCal-5	23	119	1795	11	24	100	12	525	4460
1-TribCal-4	21	79	721	11	29	124	10	235	1913
1-TribCal-3	16	37	362	11	20	110	5	138	2021
1-TribCal-2	22	146	520	10	97	421	12	206	714
1-TribCal-1	15	17	148	11	13	93	4	n/a	n/a
1-TribCal-0	9	53	649						
1-Cal-SD1	20	6	56	11	3	11	9	15	210

Note: Highlighted (shaded) cells indicate sites above water quality criteria.

Fecal Coliform Loading

Ecology calculated Beales seasonal load estimates for all sites with adequate data. Figure 7-8 displays the load balance for the California Creek basin below CM 6.2. Residual FC loads represent some combination of the unmeasured FC loads and the error in load calculations.

During two storm events (11/4-5/2008 and 8/27/2008) FC loading in the upper watershed was much larger than in the lower watershed and, because the storm events had very large FC loads, skewed the average loading pattern. To account for this issue, Ecology did not include either sampling event in the Beales load calculation or mass balance model. However, the sampling

events were still used to calculate the geometric mean and 90th percentile calculations for individual sites to assess compliance with water quality criteria and target values.

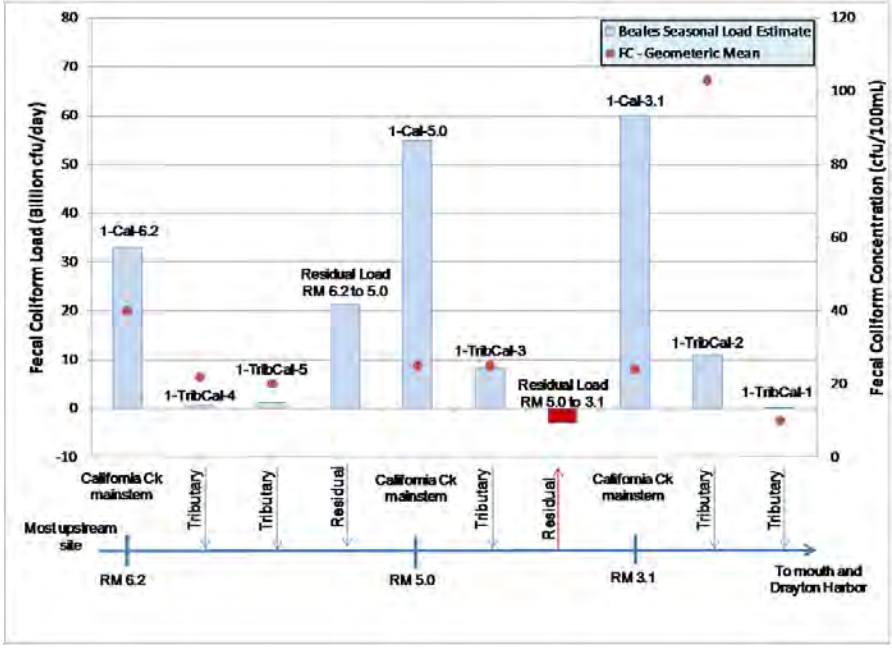

Figure 7. Wet season fecal coliform load balance for California Creek.

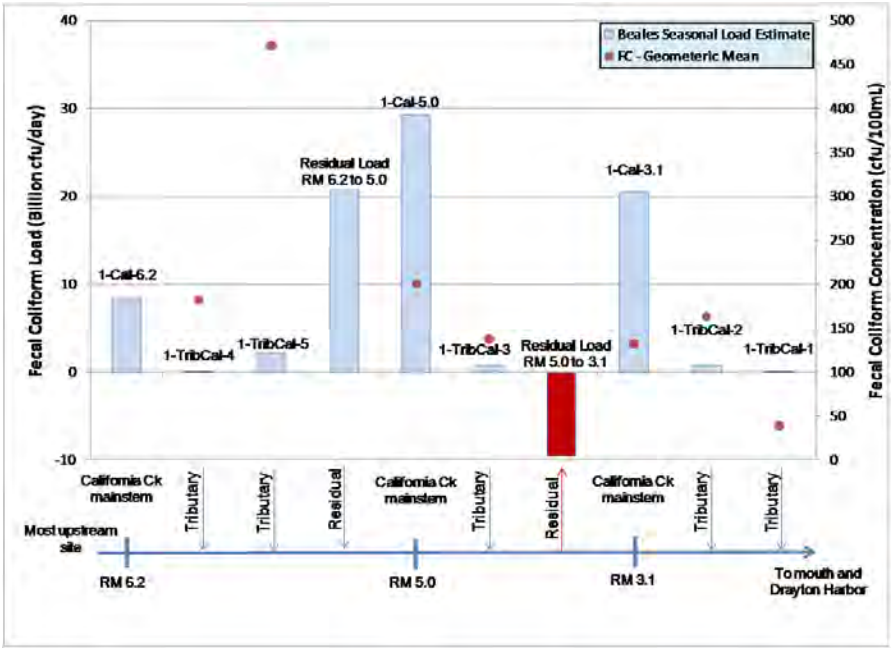

Figure 8. Dry season fecal coliform load balance for California Creek.

Cain Creek Basin

Table 18 contains FC geometric mean and 90th percentile statistics for the entire study period, as well as for both the wet and dry season.

Link to Cain Creek Basin Map

Table 18. FC geometric mean and 90th percentile statistics, including wet and dry season, for the Cain Creek basin.

	All samples			Wet Season			Dry Season		
Station ID	n	Geo-mean	90th %tile	n	Geo-mean	90th %tile	n	Geo-mean	90th %tile
1-Cain-1.3	18	25	191	11	12	74	7	78	330
1-Cain-0.4	23	302	1941	11	260	1885	12	347	2123
1-Cain-0.01	23	327	1799	11	250	1424	12	417	1740
1-Cain-0.01-MPN	22	439	2498	10	363	2515	12	515	2606
1-Cain-SD1	23	109	362	11	105	356	12	90	256

Note: Highlighted (shaded) cells indicate sites above water quality criteria.

Fecal Coliform Loading

Ecology calculated average seasonal load estimates for all sites with adequate data. Beales load estimates could not be calculated due to lack of continuous flow data and poor relationships with gaged flow stations. Figure 9 displays the load balance for the Cain Creek basin below CM 1.3. Ungaged FC loads represent some combination of the unmeasured FC loads and the error in load calculations.

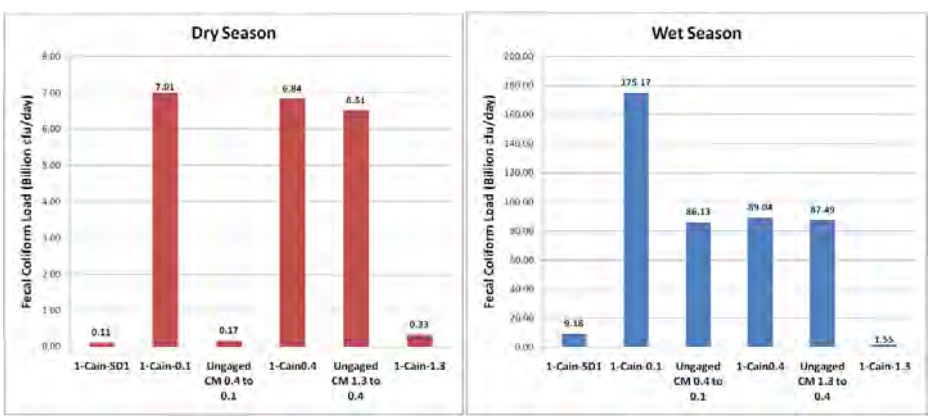

Figure 9. Fecal coliform load balance for both wet and dry seasons for Cain Creek. Note change in scale and range between charts.

Direct Tributaries to Drayton Harbor

In addition to California, Dakota, and Cain Creeks, Ecology monitored FC concentrations at two sites that drained directly to Drayton Harbor: 1-Dray-SD4 and 1-TribDry-1 (Figure 9).

1-Dray-SD4 is the unnamed creek listed on the 303(d) list for FC (Listing ID=42507). The site is located on the northeastern shoreline of Drayton Harbor near Peace Portal Drive and Albert Street and drains storm water from a residential portion of Blaine.

1-TribDray-1 drains to Drayton Harbor's eastern shoreline approximately halfway between the mouths of Dakota and California Creek. Ecology chose the site based on its proximity to Dakota and California.

Link to direct tributaries basin maps

Table 19 contains FC geometric mean and 90th percentile statistics for the entire study period, as well as for both the wet and dry season.

Table 19. FC geometric mean and 90th percentile statistics, including wet and dry season, for the direct tributaries to Drayton Harbor.

	All samples			Wet Season			Dry Season		
Station ID	n	Geo-mean	90th %tile	n	Geo-mean	90th %tile	n	Geo-mean	90th %tile
1-TribDray-1	15	87	737	11	75	873	4	n/a	n/a
1-Dray-SD4	18	31	264	11	16	108	7	93	511

Note: Highlighted (shaded) cells indicate sites above water quality criteria.

Fecal Coliform Loading

Ecology calculated average seasonal load estimates for all sites with adequate data. Beales load estimates could not be calculated due to lack of continuous flow data and poor relationships with gaged flow stations. Figure 10 displays the FC loads for the direct tributaries to Drayton Harbor.

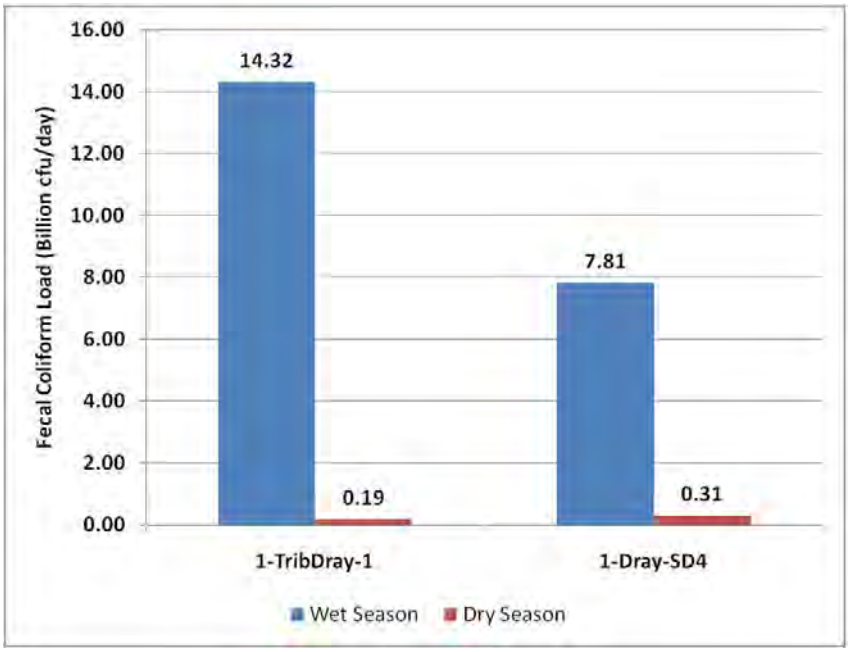

Figure 10. Average fecal coliform loading during the wet and dry seasons for the direct tributaries to Drayton Harbor.

Shoreline Surveys

Ecology conducted three surveys along the shoreline of Drayton Harbor on 1/14/2008, 5/27/2008, and 1/12/2009-1/13/2009. During the surveys, field staff collected 119 FC samples and measured flows (when possible) at 49 new shoreline discharges, as well as 7 routine TMDL sites located on the shore. Appendix E contains a site list and results table.

In general, the majority of the FC loading during the shoreline events originated from the 7 routine TMDL sites (Figure 11):

- January 14th, 2008 –
  - 7 TMDL sites = 95.1% of the measured FC load;
  - 35 non-TMDL sites sampled = less than 5% of the measured load.
- May 27th, 2008 -
  - 7 TMDL sites = 99.0% of the measured FC load;
  - 26 non-TMDL sites sampled = 1% of the measured load.
- January 12-13th, 2008 -
  - 7 TMDL sites = 94.7% of the measured FC load;
  - 36 non-TMDL sites sampled = less than 6% of the measured load.

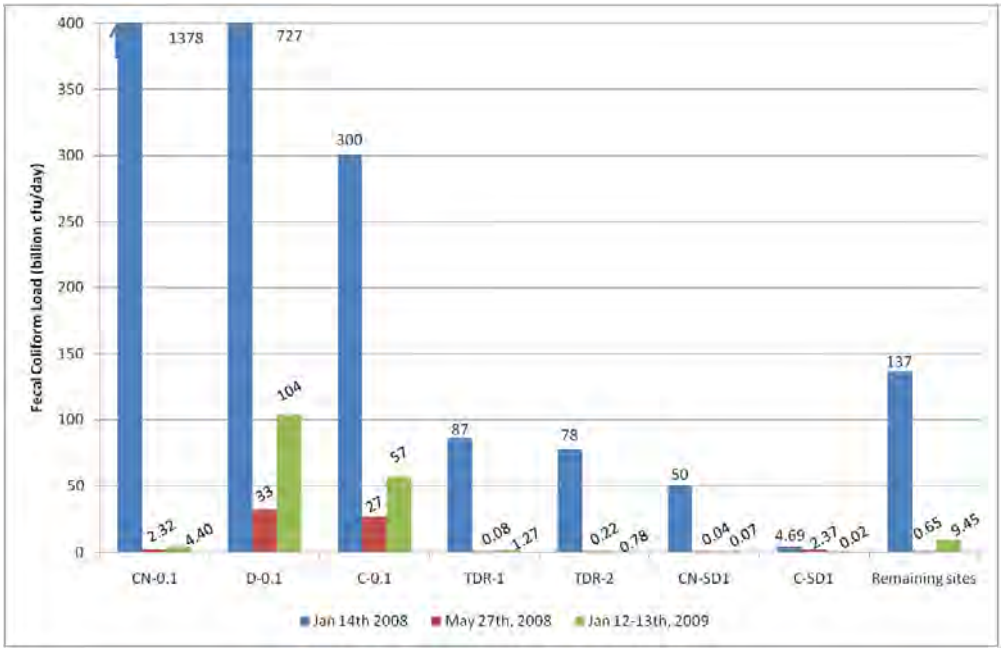

Figure 11.FC loading from measured shoreline survey sites.

Blaine WWTP Results

Table 26 shows the discharge monitoring report (DMR) results for the Blaine WWTP during the TMDL study period. No fecal coliform discharge violations occurred during the TMDL. Figure 12 displays the average FC loading during the TMDL for both wet and dry seasons.

Table 20. Permit compliance results for the Blaine WWTP during the TMDL study period.

Month	Weekly Geomean	Monthly Geomean	Violation
Dec-07	198	135	No
Jan-08	151	63	No
Feb-08	87	46	No
Mar-08	24	15	No
Apr-08	38	21	No
May-08	89	24	No
Jun-08	39	28	No
Jul-08	167	35	No
Aug-08	63	31	No
Sep-08	69	35	No
Oct-08	334	61	No
Nov-08	45	27	No
Dec-08	310	103	No
Jan-09	268	105	No

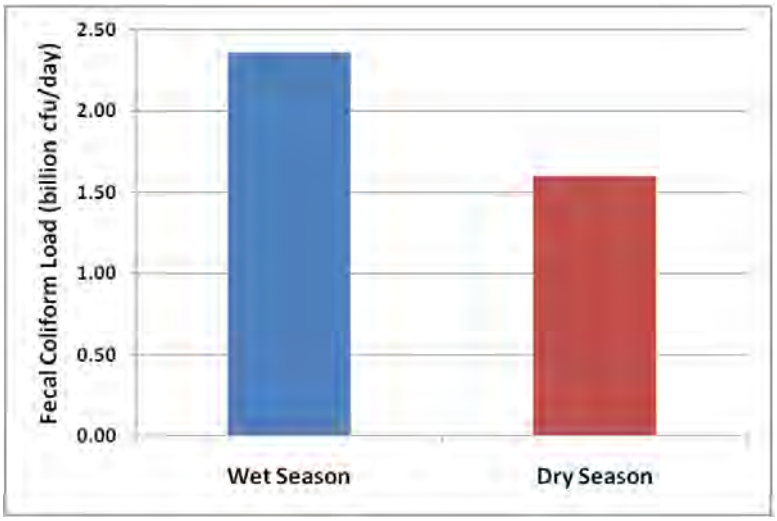

Figure 12. Comparison of average wet and dry season FC loads discharged by the Blaine WWTP during the TMDL study period.

Continuous Hydrolab Deployment Results

Appendix E contains continuous data plots for the Hydrolab deployments conducted in late July and early August of 2008.

Marine results

DOH Shellfish Growing Area Classification Sampling

Table 21 shows results from DOH sampling in the harbor during the TMDL (December 2007 to December 2008) compared to the data used for the 2008 shellfish growing area classification. The 2008 classification data shows substantially lower FC concentrations than the TMDL for two reasons: 1). The classification data is from the last 30 samples collected and; 2). Those last 30 samples exclude events where the antecedent rainfall was greater than 0.75" in the preceding 72 hours before sampling.

Table 21.DOH shellfish growing area classification sampling results during the TMDL and for 2008 classification.

	During TMDL			2008 DOH Classification data		
Site	**n**	**Geomean**	**90th Percentile**	**n**	**Geomean**	**90th Percentile**
3	10	9.0	145	30	6.8	33
4	10	7.1	52	30	7	33
5	10	7.4	90	30	6.5	45
6	10	12.9	120	32	7.1	42
8	10	21.1	395	31	24.9	187
11	10	8.7	64	31	5.9	25
12	10	6.0	43	30	6.4	35
15	10	13.5	134	31	9.9	52
313	10	6.6	68	30	5.4	32
314	10	7.6	52	30	6.4	38
315	10	7.4	62	30	7.4	43
Semiah-Tower	10	12.8	113	-------	-------	-------
Semiah-NW	10	3.1	13	-------	-------	-------
Semiah-WWTP	10	3.1	12	-------	-------	-------

Note: Highlighted (shaded) cells indicate sites above water quality criteria.

Figure 13 plots FC statistics for DOH marine stations during the TMDL. While all stations, with the exception of Site #12, exceed marine water quality criteria, Site #8 displays noticeably higher FC concentrations than the rest of the harbor.

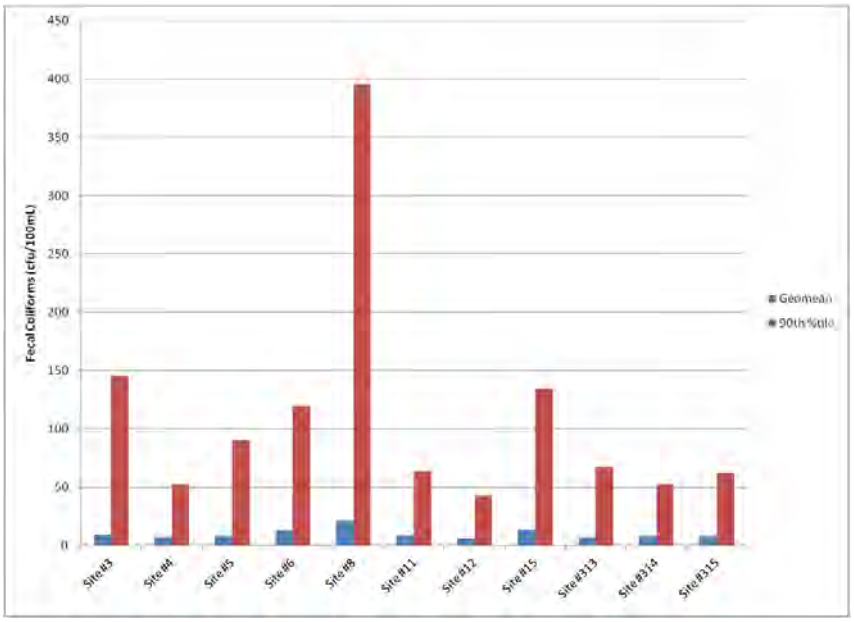

Figure 13. Marine FC concentrations in Drayton Harbor during the Drayton Harbor Watershed Fecal Coliform TMDL.

Ecology calculated a geometric mean for each DOH sample event (conducted during the TMDL) using the FC values from each site in the Harbor. This 'harbor geomean' represents a basic index of overall FC contamination in Drayton Harbor on a given sampling date.

Table 22 contains the harbor geomeans. The highest occurred on the 1/16/2008 sampling event after a large winter storm and during elevated flows.

Table 22. Harbor geomeans for DOH shellfish growing area sites.

Date	Tide Sampled	Harbor Geomean	Site with Highest FC Count
1/16/2008	Flood	178	Site 3 = 1600 cfu/100mL
2/6/2008	Ebb	56	Site 315 = 130 cfu/100mL
3/3/2008	Ebb	11	Site 8 = 920 cfu/100mL
4/30/2008	Ebb	3	Site 8 = 33 cfu/100mL
5/28/2008	Flood	2	Site 15 = 8 cfu/100mL
6/12/2008	Ebb	2	Site 11 = 11 cfu/100mL
9/10/2008	Flood	2	Site 8 = 4 cfu/100mL
10/14/2008	Ebb	5	Site 3 = 49 cfu/100mL
11/5/2008	Flood	17	Site 5 = 130 cfu/100mL
12/3/2008	Flood	15	Site 8, 15, & 313 = 33 cfu/100mL

Blaine Harbor and Semiahmoo Marina Results

Figures 14 and 15 show the sampling stations and results from the intensive FC surveys in Blaine Harbor and Semiahmoo marinas.

Figure 14. Blaine Harbor marina intensive FC survey locations and results.

Figure 15. Semiahmoo marina intensive FC survey locations and results.

Ecology also conducted a microbial source tracking (MST) study in Blaine Harbor marina from September 2008 to January 2009. Ecology collected water samples from the marina during six sample events.

Table 23 contains FC geometric means and 90th percentiles for each site. Appendix G contains the results of the MST study.

Table 23. FC statistics for MST sites collected during six surveys from September 2008 to January 2009.

Site	Geomean	90th %tile
Marina-1	74	247
Marina-3	59	659
Marina-D	63	359
Marina-Q	47	206
Marina-R	169	1113

Nooksack Indian Tribe TMDL Support Study- Preliminary Findings

The following are taken from a presentation of preliminary findings (HSC, 2010):

- Widespread and repeated presence of human fecal biomarkers at freshwater and marine sites
- Widespread and repeated presence of ruminant biomarkers at freshwater and marine sites. (Ruminants include cattle, sheep, goats, deer, giraffes, antelopes, and camels).
- Cain Creek fecal coliform geometric means continue to exceed Washington State standards.
- Eastern near-shore Semiahmoo Bay fecal coliform geometric means exceed Washington State standard for 7 of 10 sampling events.
- No significant difference in fecal coliform densities shown between tidal phases (p=0.28).
- Mapped data indicate localized contamination consistent with Hay study findings (Hay and Co, 2003).
- Drogues deployed at the Cain Creek mouth during ebb tides had end points primarily in Semiahmoo Bay approaching the border and none entered Drayton Harbor.
- Drogues deployed at border monument on flood tides travelled N. and E. across border and toward S.B shoreline (3x) or they travelled S. toward the Drayton Harbor mouth but did not approach the mouth (2x) .

Discussion

Freshwater

Dakota Creek Basin

Table 24 contains paired T-tests and Wilcoxon Sign Rank tests for statistical significance between each site on Dakota Creek and the corresponding downstream site.

Table 24. Results of statistical tests to identify significant (at α= 0.05) changes in FC concentrations and flows between stations on the mainstem of Dakota Creek.

Stretch	FC concentration (cfu/100mL)		Flow (cubic feet/second)	
	Mean Change[1]	p-value	Mean Change	p-value
Wet Season				
(1-NFDak-0.1 + 1-SFDak-0.2) to 1-Dak-4.9	-10	0.53 (0.33)	+6.59	**0.03 (0.01)**
1-Dak-4.9 to 1-Dak-3.1	+5	0.86 (0.63)	+13.50	**0.05 (0.04)**
1-Dak-3.1 to 1-Dak-0.1	+18	0.21 (0.43)	n/a	n/a
Dry Season				
(1-NFDak-0.1 + 1-SFDak-0.2) to 1-Dak-4.9	-22	**0.03 (0.03)**	+2.27	**0.01 (0.01)**
1-Dak-4.9 to 1-Dak-3.1	-6	0.51 (0.60)	+2.84	**0.00 (0.01)**
1-Dak-3.1 to 1-Dak-0.1	-49	**0.00 (0.00)**	n/a	n/a

Note: Bold p-values (<0.05) indicate that the two means differ significantly.
P-values outside parentheses are for Wilcoxon test; those inside are for paired t-tests
[1] Change in geometric mean.

During the wet season, flows increased significantly from the confluence of the north and south forks to CM 4.9 (1-Dak-4.9) and from CM 4.9 to 3.1 (1-Dak-3.1). However, although the average FC load increased in both these stretches, the FC concentrations did not significantly increase or decrease. This suggests that the FC concentration of the incoming flow is not drastically lower or higher than the receiving waters. Over 50% of the FC load originated upstream of the confluence of the North and South Fork. The highest FC counts and loads occurred during the early November "first flush" storm event.

During the dry season FC concentrations decreased significantly within two stream reaches.

- From the confluence of the north and south forks to CM 4.9 the geometric mean decreased by 22 cfu/100mL (p=0.03).
    - A significant increase in flow occurred in this stretch and;
    - The average residual FC load was positive (increased), so:
    - The decrease suggests the incoming flow in this stretch likely had lower FC concentrations then the receiving waters.
    - Some portion of the decrease was likely due to the FC loss rate from mortality, predation, settling, and UV radiation.
- From CM 3.1 to 0.1 the geometric mean decreased by 49 cfu/100mL (p=0.00).
    - This decrease occurred within the tidal influence of the harbor and was likely due to some combination of the FC loss rate and dilution with marine water.

FC concentrations at 1-Dak-3.1 exhibited a moderate, but significant, correlation to 72 hour antecedent rainfall (r^2=0.54; p<0.05) in the wet season. The FC counts were greater than 100 cfu/100 mL whenever the 72 hour rainfall was greater than 0.42 inches and, conversely, whenever the 72 hour rain was greater than 0.4 inches the FC counts were greater than 100. Non-point stormwater runoff upstream of 1-Dak-3.1 is likely a significant source of FC contamination.

MST results for the PCR method identified human specific markers at four sites (1-TribDak-2, 1-TribDak-S2, 1-NFDak-2.5, and 1-TribDak-N1) during the three dry season sampling events. During the wet season, the MST results identified ruminant specific markers at three sites (1-TribDak-S2, 1- TribDak-S1, and 1-TribDak-N2) during the 11/4/2008 "first flush" storm event. Above average FC loads occurred at all three sites during this sampling event. EPA MEL identified the general *Bacteroides* marker in 50% of the samples collected in the Dakota Creek basin, while *Bacteroides* was absent from 25% of the basin samples.

California Creek Basin

Table 25 contains paired T-tests and Wilcoxon Sign Rank tests for statistical significance between each site on California Creek and the corresponding downstream site.

Table 25. Results of statistical tests to identify significant (at α= 0.05) changes in FC concentrations and flows between stations on the mainstem of California Creek.

Stretch	FC concentration (cfu/100mL)		Flow (cubic feet/second)	
	Mean Change[1]	p-value	Mean Change	p-value
Wet Season				
1-Cal-6.2 to 1-Cal-5.0	-18	0.11 (0.11)	+14.38	**0.00 (0.00)**
1-Cal-5.0 to 1-Cal-3.1	-5	0.52 (0.53)	+5.13	**0.04 (0.00)**
1-Cal-3.1 to 1-Cal-0.8	+6	0.45 (0.54)	n/a	n/a
1-Cal-0.8 to 1-Cal-0.1	+24	0.29 (0.31)	n/a	n/a
Dry Season				
1-Cal-6.2 to 1-Cal-5.0	-9	0.86 (0.81)	+3.31	**0.00 (0.00)**
1-Cal-5.0 to 1-Cal-3.1	-93	0.07 **(0.05)**	-0.48	0.25 (0.15)
1-Cal-3.1 to 1-Cal-0.8	-110	**0.00 (0.00)**	n/a	n/a
1-Cal-0.8 to 1-Cal-0.1	-18	**0.01 (0.01)**	n/a	n/a

Note: Bold p-values (<0.05) indicate that the two means differ significantly.
P-values outside parentheses are for Wilcoxon test; those inside are for paired t-tests
[1] Change in geometric mean.

During the wet season, flows increased significantly from 1-Cal-6.2 (CM 6.2) to 1-Cal-5.0 (CM 5.0) and from CM 5.0 to 1-Cal-3.1 (CM 3.1). However, although the average FC load increased from CM 6.2 to CM 5.0 and decreased from CM 5.0 to 3.1, the FC concentrations did not significantly increase or decrease. This suggests that the FC concentration of the incoming flow is not drastically lower or higher than the receiving waters.

During the dry season FC concentrations decreased significantly in three stretches:

- From CM 5.0 to 3.1 the geometric mean decreased by 93 cfu/100mL (p=0.05). A significant change in flow did not occur in this stretch, so the decrease likely represents a dry season FC loss rate due to mortality, predation, settling, and UV radiation.

- From CM 3.1 to 1-Cal-0.8 (CM 0.8) the geometric mean decreased by 110 cfu/100mL (p=0.00).
- From CM 0.8 to 1-Cal-0.1 (CM 0.1) the geometric mean decreased by 18 cfu/100mL (p=0.01).
- The decreases from CM 3.1 to 0.1 are within the tidal influence of the harbor and are likely due to some combination of the FC loss rate and dilution with marine water.

During both the wet and dry season there was an average positive residual (increased) FC load from CM 6.2 to CM 5.0 and an average negative residual (decreased) FC load from CM 5.0 to 3.1. The FC load increase from CM 6.2 to 5.0 is likely due to the significant flow increase in this stretch during both seasons. The source of the load decrease from 5.0 to 3.1 is likely due to the loss rate discussed above. Over 50% of the FC load originated upstream of California Creek at Bruce Rd (1-Cal-6.2). As with the upper Dakota basin, the highest FC counts and loads occurred during the early November "first flush" storm event.

FC concentrations at 1-Cal-3.1 exhibited a moderate, but significant, correlation to 72 hour antecedent rainfall (r^2=0.55; $p<0.05$) in the wet season. During the wet season, FC counts at the three freshwater mainstem sites (1-Cal-3.1, 1-Cal-5.0, and 1-Cal-6.2) were greater than 100 cfu/100 mL whenever the 72 hour rainfall was greater than 1.56 inches and conversely, whenever the 72 hour rain was greater than 1.56 inches the FC counts were greater than 100. FC Non-point stormwater runoff upstream of 1-Cal-3.1 is likely a significant source of FC contamination.

MST results for the PCR method identified human specific markers at two sites, twice at 1-TribCal-2 during the dry season and once during each season at 1-TribCal-4. The MST results identified ruminant specific markers once during each season:
- During the wet season at site CA14 during the 11/5/2008 "first flush" storm event.
- During the dry season at 1-TribCal-2 on 9/2/2008.

As with the Dakota Creek basin, EPA MEL identified the general *Bacteroides* marker in 50% of the samples collected in the California Creek basin, while *Bacteroides* was absent from 25% of the basin samples.

Cain Creek Basin

Table 26 contains paired T-tests and Wilcoxon Sign Rank tests for statistical significance between each site on Cain Creek and the corresponding downstream site.

Table 26. Results of statistical tests to identify significant (at α= 0.05) changes in FC concentrations and flows between stations in the Cain Creek basin.

Stretch	FC concentration (cfu/100mL)		Flow (cubic feet/second)	
	Mean Change[1]	p-value	Mean Change	p-value
Wet Season				
Cain-1.3 to Cain-0.4	+276	**0.00 (0.00)**	+1.82	**0.00 (0.04)**
Cain-0.4 to Cain-0.1	-6	0.61 (0.58)	+0.62	**0.00 (0.03)**
Dry Season				
Cain-1.3 to Cain-0.4	+269	**0.03 (0.01)**	+0.31	**0.00 (0.00)**
Cain-0.4 to Cain-0.1	+70	0.53 (0.76)	+0.08	**0.01 (0.00)**

Note: Bold p-values (<0.05) indicate that the two means differ significantly.
P-values outside parentheses are for Wilcoxon test; those inside are for paired t-test
[1] Change in geometric mean.

Ecology observed large significant increases in FC geometric means on Cain Creek from CM 1.3 to 0.4. During the wet season, about 50% of the FC load originated within this stretch and the geometric mean increased by 276 cfu/100mL (p=0.00). During the dry season, over 90% of the FC load originated within this stretch and the geometric mean increased by 269 cfu/100mL (p=0.01).

FC concentrations at 1-Cain-0.4 exhibited a moderate, but significant, correlation to 24 hour antecedent rainfall (r^2=0.42; p<0.05) in the wet season. FC stormwater runoff is likely a significant source of FC contamination; however, there were multiple occasions in the wet and dry season when there was little or no antecedent rainfall and FC concentrations were above water quality standards.

MST results for the PCR method identified a human specific marker on one occasion at 1-CainSD-1 during the dry season on 9/2/2008. The drainage area for this site is connected to the Blaine sewer collection system. The human marker may indicate an illegal cross-connection between the sewer and storm system.

EPA MEL identified the general *Bacteroides* marker in 70% of the samples collected, while *Bacteroides* was absent from 20% of the basin samples.

Direct Tributaries to Drayton Harbor

At 1-Dray-SD4, FC concentrations remained relatively low (below water quality standards) during the wet season. During the dry season FC concentrations were high (above water quality standards); however, the FC load contributed to the harbor was relatively small.

At 1-TribDray-1, the 90th percentile FC concentration was above water quality standards due to infrequent spikes in FC levels. On 11/18/2008, Ecology measured a FC concentration of 11,000 cfu/100mL and a FC load nearly equal to that from the mouth of Dakota and California Creeks put together. The cause of the spike is unknown.

The average wet season FC load from 1-TribDray-1 was approximately double that of 1-Dray-SD4 and one of the largest of the tributary sites for the TMDL. The source of the FC contamination is unknown and warrants investigation.

Shoreline Surveys

The majority of FC loading (greater than 94%) during each of the three surveys originated from the seven TMDL sites. This indicates that the routine TMDL monitoring captured the majority of loading to Drayton Harbor during sampling events with no shoreline survey. The majority of the loading from the TMDL sites came from the three major creeks: Dakota, California, and Cain.

Continuous Hydrolab Deployments

Table 27 depicts each continuous site's observed relationship to the water quality standards. The temperature criterion was exceeded for some portion of the deployment at all sites, except for 1-NFDak-0.1. Dissolved oxygen values were below water quality criteria at all sites. Continuous pH data was within the water quality standards at all sites.

The number of water quality standard exceedences indicates that actions to improve temperature and dissolved oxygen are needed for the watershed. If these values result in a Category 5 (303d list) listing on Ecology's Water Assessment, then a TMDL might be necessary. Reducing non-point sources of waste that cause fecal coliform contamination and re-establishing riparian buffers in the watershed will both reduce fecal coliform loading, as required by this TMDL, and improve temperature and dissolved oxygen levels.

Table 27. Continuous data compared to water quality standards.

Site	Temperature	pH	Dissolved Oxgyen
Cal-3.1	**Above**	In range	**Below**
Cal-5.0	**Above**	In range	**Below**
Cal-6.2	**Above**	In range	**Below**
Dak-0.1	**Above**	In range	**Below**
Dak-3.1	**Above**	In range	**Below**
Dak-4.9	**Above**	In range	**Below**
NFDak-0.1	Below	In range	**Below**
NFDak-2.5	**Above**	In range	**Below**
SFDak-0.2	**Above**	In range	**Below**
Cain-0.4	**Above**	In range	**Below**

Yellow highlighted (light shaded and bold) cells indicate potential violations of water quality standards. Green (dark shaded) cells indicate compliance with standards.

Blaine Wastewater Treatment Plant

It is unlikely that the Blaine WWTP has a significant impact on FC in Drayton Harbor:

- No permit discharge violations occurred during the course of the study.
- The fecal coliform load was relatively small compared to other measured sources.

- FC concentrations in Semiahmoo Bay east of the WWTP outfall (Semiahmoo-WWTP) were low during the course of the TMDL (Table 20).

The capacity of the new plant will be upgraded, meaning FC loading could increase with an increase in maximum effluent discharge; however, the upgrade to MBR treatment technology will counteract this effect and likely reduce FC loading below current levels.

Ungaged sources of fecal coliform

In the wet season, Ecology observed an unexplained increase in FC concentrations for tidally influenced segment of Dakota and California Creeks. This is unexpected, since a FC decrease might be expected in this stretch for several reasons:

- The FC concentrations from measured inputs within these segments were similar, and their FC loads relatively small in comparison, to the FC counts of the receiving freshwater.
- Saltwater mixing typically results in increased die-off of FC.
- Based on harbor concentrations, upstream freshwater concentrations, and salinity ratios (dilution), the FC concentrations at the mouths of Dakota and California should theoretically be much lower than FC concentrations measured during the TMDL.

A similar increase occurred from 2003 to 2007, based on NWIC data, but did not occur during 2009, based on data collected by Whatcom County. The cause of this increase is unknown, but may indicate a poorly mixed FC source in close proximity to the mouths of the creek.

Freshwater influence on harbor FC concentrations

Sources that discharge inside Drayton Harbor

Ecology compared the measured freshwater FC load for sources inside Drayton Harbor (Cain Creek not included) to the harbor geomean for each DOH sampling event (Figure 16). The comparison revealed a moderate to strong correlation (r^2= 0.70); however, similar FC loading on 2/6/2008 and 11/5/2008 resulted in two fairly different harbor geomeans (56 vs 17).

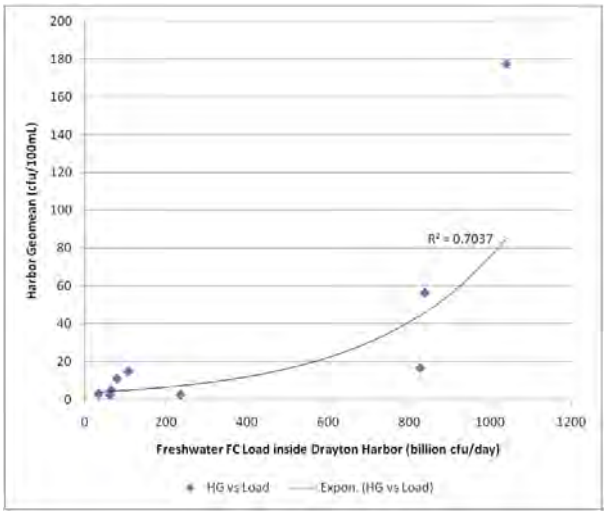

Figure 16. Relationship of freshwater FC loads to the Drayton Harbor geomean statistic.

Flow conditions of a similar magnitude to the mid-January sampling event (>150 million gallons per day) occurred during less than 5% of the year.

Little Campbell River

The Little Campbell River (LCR) drains over 18,000 acres of primarily agricultural land, with increasing urban development, immediately north of the Drayton Harbor watershed and U.S.-Canadian border (Zevit et al, 2008). The mouth of the LCR discharges to Semiahmoo Bay approximately three quarters of a mile north of the border and one and half miles north, and slightly west, of the entrance to Drayton Harbor.

A water quality monitoring study conducted from 2005 to 2007 showed high levels of fecal coliform in the LCR watershed. During the wet season (November 2006 to March 2007), the Ministry of Environment collected 20 fecal coliform samples on a weekly basis at several sites on the LCR mainstem. The furthest downstream site revealed high fecal coliform counts and loads with:

- A geometric mean of 399 cfu/100mL and a 90th percentile of 1,636 cfu/100mL.
- An average fecal coliform load of 2,260 billion cfu/day. The LCR wet season FC load appears to be much larger than the FC load from the Drayton Harbor watershed:
    - Approximately an order of magnitude higher than the average FC loading from Dakota Creek.
    - Greater than twice the maximum FC load measured during the TMDL for California and Dakota Creek combined.

Of the three sites in Semiahmoo Bay sampled during the TMDL, the site between the mouth of LCR and the entrance to Drayton Harbor (Semiah-Tower) had the highest FC counts with a 90th percentile of 113 cfu/100mL.

Low FC counts at the DOH station Semiah-NW (geomean=3.1, 90th percentile= 13) indicate that marine water from Semiahmoo Bay likely dilutes LCR relatively quickly; However, the magnitude of FC loads measured and the high FC counts at Semiah-Tower indicate that LCR could have a significant impact on water quality in Drayton Harbor. Results from the Semiahmoo Bay circulation model support this conclusion, which showed that larger FC loading events from LCR could elevate FC counts in Drayton Harbor (Hays and Co, 2003).

The model results indicated that during January 2001 the majority of Drayton Harbor was exposed to fecal coliform contamination from LCR approximately 1 to 4 days out of the month, depending on the area. Given the large amount of antecedent precipitation and high flows in Dakota and California Creek, it is likely that FC counts measured in Drayton Harbor on 1/16/08 were influenced by FC loading from the LCR.

Cain Creek and nearby storm drain

Cain Creek exhibited high FC concentrations throughout the course of the TMDL study. In addition, FC loading was very high and on some occasions even higher than FC loading from Dakota and California Creek.

Similar to the Little Campbell River, Cain Creek discharges to Semiahmoo Bay and likely dilutes relatively quickly; however, the dispersion and mixing dynamics of FC from Cain Creek are poorly characterized and could contribute to FC contamination in Drayton Harbor, particularly at the stations near the entrance.

Blaine Harbor and Semiahmoo Resort Marinas

Fecal Coliform intensive marina surveys

During the intensive marina FC surveys:

- January 14, 2008:
    - FC contamination was present at most sites, with FC concentrations greater than 43 cfu/100mL at 13 out of 16 sites.
    - Concentrations were:
        - Highest in the commercial area of the Blaine Habor marina, ranging from 240 to 920 cfu/100mL.
        - High in the Semiahmoo Marina, ranging from 49 to 170 cfu/100mL.
        - Lowest in the recreational area of the Blaine Habor marina, ranging from 23 to 79 cfu/100mL.
- May 27, 2008:
    - Only a few sites had clear FC contamination, with FC concentrations greater than 43 cfu/100mL at 6 out of 16 sites.
    - Concentrations were:

- Again, highest in the commercial area of the Blaine Habor marina, ranging from 22 to 350 cfu/100mL.
- Very low in the Semiahmoo Marina, ranging from below the detection limit (1.8 cfu/100mL) to 4.5 cfu/100mL.
- Relatively low in the recreational area of the Blaine Habor marina, ranging from 4.5 to 49 cfu/100mL.

During the January 2008 survey, the source of FC contamination could have originated from either within or outside the marinas, given that FC concentrations were elevated in the harbor on the 1/16/08 DOH survey. However, concentrations were much higher in the commercial area of the Blaine Harbor marina, indicating that it may have been a source. This pattern was also evident during the May 2008 survey when counts were relatively low in both marinas except the commercial area of Blaine Harbor marina where counts were again high.

The May 2008 survey was conducted the week after Memorial Day weekend, when recreational use was elevated. While the recreational area of the Blaine marina did have relatively low counts, they were slightly elevated (49 cfu/100mL) near the public boat launch.

Blaine Harbor Marina MST study

Fecal coliform concentrations were very high in the Blaine Harbor marina during the MST study, particularly at station Marina-R near the corner of the breakwater. When tested against stations Marina-1 and Marina-D (the two stations nearest to Marina-R), while FC counts at Marina-R were generally higher than both stations neither relationship proved statistically significant ($p=0.11$ and $p=0.17$, $n = 5$ respectively). There may have been too few data points to show a clear relationship.

Specific PCR markers were only identified on two occasions:

- The human specific marker was identified on September 2, 2008 at site Marina-R. This event occurred the week after Labor Day weekend and, while the concentration was only 33 cfu/100mL, the result indicates a possible illegal on board septic discharge into the marina waters.
- Both the human and ruminant specific markers were identified on September 22, 2008 at site Marina-D. Again, the result may indicate an illegal boat discharge, while the ruminant source could have originated from outside the marina.

The general *Bacteroides* marker was indentified in two-thirds of the PCR samples analyzed. Without the ribotyping results, it is unclear what species these bacteria strains may have originated from. Possible nearby sources include seagulls, cormorants, waterfowl, rats, seals, and illegal boater discharges.

Conclusions

- **Fecal coliform bacteria levels exceed water quality standards, almost ubiquitously, throughout the entire Drayton Harbor watershed.** The discharge of waste from humans and animals does not come from a few sources or "hot spots" in the watershed, but, rather, occurs systemically throughout.
- **The majority of the fecal coliform loading comes from the upper watersheds of Dakota and California Creek.** While fecal bacteria pollution occurs throughout the watershed the largest relative portion of that pollution comes from upstream of Bruce Rd on California Creek (1-Cal-6.2) and upstream of the confluence of the north and south forks on Dakota Creek. In both upper watersheds, agriculture is the dominant land use and all residences use onsite septic systems.
- **Cain Creek greatly exceeds FC water quality standards and, under certain conditions, contributes a relatively large FC load to Semiahmoo Bay.** A large amount of bacteria pollution is entering the creek between CM 1.3 at Pipeline Rd (1-Cain-1.3) and CM 0.4 behind the Blaine Trade Center (1-Cain-0.4). Recent PCR MST sampling discovered multiple Human biomarkers in Cain Creek indicating that human sewage is potentially entering the creek in this stretch.
- **Shoreline surveys indicate that the majority of the fecal coliform load (≈95%) discharging inside the harbor comes from the seven monitored TMDL sites.** If the load allocations are met at these seven sites, the majority of freshwater bacteria pollution originating inside the harbor will likely be eliminated.
- **Recent monitoring in the Little Campbell River watershed showed high concentrations and loads of bacteria discharging to Semiahmoo Bay.** Based on the model of Semiahmoo Bay (Hay and Co, 2003) the larger wet season FC loads from Little Campbell River may negatively impact FC concentrations in Drayton Harbor.
- **The Blaine Harbor marina exhibited very high FC concentrations during the eight events that the marina was sampled, including events when concentrations in the harbor were low.** One or more FC sources are likely originating from within the marina.The highest FC concentrations in Drayton Harbor continued to occur at DOH station #8 and #15.
- **Temperature and Dissolved Oxygen levels that likely violate water quality standards were observed in Dakota, California, and Cain Creeks; observed pH levels met water quality standards.**
- **A clear relationship between freshwater FC sources and FC concentrations in Drayton Harbor cannot be established without more detailed data regarding flushing, circulation patterns, and marine and freshwater mixing.**
- **Dakota, California, and Cain creeks all need large reductions in FC to meet water quality standards.**

Recommendations

The top priority for available resources should be source identification and elimination in the Cain Creek basin (for the City of Blaine) and the upper Dakota and California Creek basins (in Whatcom County).

The goal should be to first meet the new load and wasteload allocations outlined for the freshwater sources in the watershed. Once that is accomplished, if fecal coliform contamination is still present in Drayton Harbor, then other freshwater FC sources should be further investigated.

- FC source identification monitoring should start in the following drainages (in order of priority):
    - Cain Creek between CM 1.3 at Pipeline Rd and CM 0.4 behind the Blaine trade center. Very large FC loads originated in this relatively short stretch of creek.
    - Wet season sources in the North and South Forks of Dakota Creek. Over 50% of the FC load to Dakota Creek at Giles Rd came from the upper watershed.
    - Wet season sources upstream of California Creek at Bruce Rd (1-Cal-6.2).
    - Unmeasured wet season sources within the tidally influenced segments of Dakota and California Creek.
    - Tributary drainages for Dakota and California Creek.
    - Direct tributary drainages to Drayton Harbor.
- A three dimensional fecal coliform model of Semiahmoo Bay, Drayton Harbor, and the mouths of Dakota and California Creek is needed to relate freshwater FC inputs to high FC concentrations in the harbor.
- FC sediment sampling (paired with overlying water column FC samples) in the Drayton Harbor mudflats, particularly along the banks of the tidally influenced segments of Dakota and California. These sediments may serve as a reservoir and source of FC during tidal wetting and subsequent resuspension of sediments.
- Efforts should be taken to deter bird populations within the commercial area of the marina, on the east (rock portion) breakwater, and at the public wharf. Large numbers of birds and visible bird feces have been observed at all three locations.
    - A marine ornithologist should be consulted to determine the feasibility of relocating cormorant nesting habitat to a less sensitive location nearby.
    - Consideration should be given to rerouting stormwater from impervious surfaces in the marina to an onsite treatment feature or features, the new Blaine water reclamation facility, or a consolidated outfall to Semiahmoo Bay.
- Long-term monitoring should include:
    - FC samples at TMDL sampling stations, or NWIC stations at a minimum.

- Sampling dates in the watershed should be coordinated with DOH sampling in the harbor and occur either the day before or the day of DOH sampling.
- Ecology should reinstall the Dakota Creek continuous flow gage and equip with telemetry as a long-term WRIA 1 coastal stream station. California Creek flows could be regressed from the Dakota Creek station.
- The combination of FC and flow in the watershed coordinated with DOH marine sampling would provide a better understanding of how FC loads from the watershed affect FC concentrations in the harbor.

Fecal Coliform TMDL Analysis

Analytical framework

Cain Creek and direct drainages to Drayton Harbor

Ecology used the statistical rollback method (Ott, 1995) to predict the percent reductions in FC concentrations necessary to meet the applicable water quality standards for sites in the Cain Creek drainage area and the two direct discharges to Drayton Harbor (1-TribDray-1 and 1-Dray-SD4). The rollback method is described in greater detail in Appendix F.

California and Dakota Creeks

Method

Ecology used a steady-state FC mass-balance approach to set freshwater FC target values for sites in the Dakota and California Creeks basins. This approach was adapted from the FC mass balance model used in the Skagit Bay TMDL (Pickett, 1997) to set targets on the Skagit River to protect water quality in Skagit Bay. To develop the FC mass balance, Ecology:

1. Determined the FC freshwater boundary target values for the furthest downstream freshwater site for each creek (1-Dak-3.1 and 1-Cal-3.1, respectively) that would meet marine standards when the mixture of river and bay water reached 10 ppt salinity (Table 28).
2. Evaluated the flow balance for each survey and then for the seasonal average flow at each site (Table 29). Any unaccounted for increase in flow was considered a 'residual' input (which could include ground water inputs and any cumulative error in the flow balance).
3. Developed mass balances for FC bacteria concentrations and loads.
4. Calculated a first-order decay rate for bacteria in the creeks based on natural mortality, temperature, salinity, and time of travel.
5. Adjusted the mass blances to account for the decay rate, unmeasured loading sources, and for dynamic effects during the surveys (Tables 30 and 31).
6. Developed TMDL mass balances by reducing upstream loading sources until the FC levels in the river at the downstream boundaries (1-Dak-3.1 and 1-Cal-3.1) met the FC freshwater boundary target values (Tables 32 and 33).

Freshwater Boundary Target Values

For the TMDL analysis, Ecology evaluated compliance with applicable water quality standards within the tidally influenced segments of Dakota and California Creek. Within these segments, the creeks are considered part of the Drayton Harbor estuary and are subject to marine water

quality standards at the point where the salinity reaches 10 ppt or greater (see Water Quality Standards section).

Since the 10ppt line is dynamic, changing constantly as a function of tidal movement and river flow, Ecology developed a FC "freshwater boundary target value (FBTV)." The FBTV was applied at the downstream freshwater boundary of both creeks (1-Dak-3.1 and 1-Cal-3.1) to protect marine FC standards in the Drayton Harbor estuary, including the mouths of both creeks. Table 28 shows the analysis used to develop the FBTVs.

Table 28. Method and calculations for determining fecal coliform freshwater boundary target values for Dakota and California Creek.

FC Marine Water Quality Standards (when Salinity ≥10 ppt)	
Geometric Mean = 14 cfu/100 mL	90th Percentile of Data = 43 cfu/100 mL
Salinity in parts per thousand (ppt)	
Semiahmoo Bay = 28 ppt (Median)	1-Cal-3.1 = 0.13 ppt; 1-Dak-3.1= 0.11 ppt
% Marine water at 10 ppt Salinity = 35.4%%	Freshwater at 10 ppt Salinity = 64.6%
Semiahmoo Bay FC Background Levels- Wet Season	
Geometric Mean = 2.7 cfu/100 mL	90th percentile = 20 cfu/100 mL
Wet Season Equations	
(2.7 cfu/100mL*0.354) + (T_{GM}*0.646)=14 cfu/100mL	(20 cfu/100mL*0.354) + (T_{90}*0.646)=43 cfu/100mL
FC Freshwater Boundary Target Values - Wet Season	
Geometric Mean (T_{GM})= **20** cfu/100 mL	90th percentile (T_{90})= **56** cfu/100 mL
Semiahmoo Bay FC Background Levels- Dry Season	
Geometric Mean = 1.8 cfu/100 mL	90th percentile = 2.0 cfu/100 mL
Dry Season Equations	
(1.8 cfu/100mL*0.354) + (T_{GM} *0.646)=14 cfu/100mL	(2.0 cfu/100mL*0.354) + (T_{90}*0.646)=43 cfu/100mL
FC Freshwater Boundary Target Values - Dry Season	
Geometric Mean (T_{GM})= **21** cfu/100 mL	90th percentile (T_{90})= **65** cfu/100 mL

TGM= Geometric Mean Freshwater Boundary Target Value; T90= 90th percentile Freshwater Boundary Target Value

Flow Balance

To develop the flow balances (Table 29), direct measurements of flow were used for all survey stations where accurate data were collected. However, flow data were not collected or usable for some surveys at a number of stations. When flow data was missing, Ecology predicted flows based on a regression equation with a nearby station with similar hydrology. A seasonal average flow was developed for each station based on regression with the continuous flow stations at 1-Dak-3.1 and 1-Cal-5.0.

Table 29. Flow balance for Dakota and California Creek basins.

Station Name	RM	Wet Season Average Flow		Dry Season Average Flow	
		Input	River	Input	River
California Creek Basin					
California at Bruce Rd	6.2		15.38		1.56
TribCal-4	6.0	0.64	16.02	0.03	1.59
TribCal-5	5.4	1.54	17.56	0.33	1.92
Residual flow 6.2 to 5.0		16.21	33.77	3.34	5.27
California at Valley View Rd	5.0		33.77		5.27
TribCal-3	4.0	4.82	38.59	0.16	5.43
Residual flow 5.0 to 3.1		0.91	39.50	-0.34	5.09
California at BB-Lynden Rd	3.1		39.50		5.09
1-TribCal-2	1.8	2.76	42.26	0.18	5.27
1-TribCal-1	1.0	0.55	42.81	0.02	5.29
California at Blaine Rd	0.8		42.81		5.29
California at the mouth	0.1		42.81		5.29
Dakota Creek Basin					
South Fork Dakota Creek at the mouth	0.2	18.34		2.42	
North Fork Dakota Creek at the mouth	0.1	24.70		2.77	
Dakota Creek below confluence	6.3		43.04		5.19
Residual flow 6.3 to 4.9		5.50	48.54	3.85	9.05
Dakota Creek at Behme Rd	4.9		48.54		9.05
1-TribDak-5	4.6	5.3	53.81	1.3	10.31
Residual flow 4.9 to 3.1		12.12	65.93	0.72	11.03
Dakota Creek at Giles Rd	3.1		65.93		11.03
1-TribDak-3 & 4	1.7		65.93		11.03
1-TribDak-2	1.1	7.31	73.24	0.98	12.01
1-TribDak-1	0.9	3.40	76.64	0.30	12.31
Dakota Creek at the mouth	0.1	0.8	77.40	0.0	12.36

During the dry season there was a decrease in flow (-0.34 cfs) between 1-Cal-5.0 and 1-Cal-3.1; however, the decrease was not significant based on the paired statistical tests and was within the typical error margins for flow (10% RSD).

Fecal Coliform Mass Balance

To develop a final FC mass balance, Ecology:

- Used the average seasonal flow balance and the FC geometric mean and 90th percentile from each site to calculate FC mass balances for each scenario.
- Applied a first-order decay rate to model bacterial die-off. This approach has been used with success by other researchers (Thomann and Mueller, 1987; Mancini, 1978).
    - The equation that predicts the bacteria concentration after a time period of duration t (C_t) as a function of the initial concentration (C_0) is of the form:

- $C_t = C_0 e^{(-Kt)}$.
    - Where K = first-order rate coefficient for decay of FC, d^{-1}; and t = time in days
- The decay rate coefficient K was determined by the equation:
    - $K = (0.8 + (0.006*PS))*\theta^{(T-20)}$
    - Where PS= percent seawater, θ= temperature correction factor, and T=temperature.
    - A θ of 1.07 was used as recommended by Mancini (1978).

- Adjusted the original mass balances based on the decay rate. To apply the decay rate, Ecology calculated a simple time of travel estimate based on the average seasonal velocity at the upstream site and the distance traveled.
- Adjusted the FC mass balances again to more closely match observed results by estimating the FC levels of unmeasured sources (Tables 30 and 31) for:
    - Geometric means by:
        - Using the range of GM values observed in the basin.
        - Adjusting the GM values for unmeasured inputs to obtain a best fit for observed vs. predicted at the two mainstem sites by minimizing the total error between each site and distributing the error equally between both mainstem sites.
    - 90th percentiles by:
        - Using the range of observed standard deviations in FC counts for each basin.
        - Calculating a 90th percentile based on the standard deviation value that minimized the total error for each site and distributed the error equally between both mainstem sites.
    - FC levels were only estimated to provide a reference of whether a FC reduction might be needed (and if so, how big of a reduction) from the unmeasured drainages to meet the target values in the receiving waters.

Table 30. FC mass balance for the Dakota Creek basin. Includes estimated concentrations for residual flow inputs.

		Wet Season- Geomean					Wet Season- 90th Perecentile				
		Counts (cfu/100mL)			Load billion cfu/day		Counts (cfu/100mL)			Load billion cfu/day	
			River					River			
Station Name	RM	In	Ob	MB	Input	Balance	In	Ob	MB	Input	Balance
SF Dakota Creek at the mouth	0.2	42			18.84		459			205.94	
NF Dakota Creek at the mouth	0.1	71			42.90		277			167.39	
Dakota below confluence	6.3			59		61.75			355		373.32
Residual flow 6.3 to 4.9		78			10.49	72.24	193			25.96	399.28
Dakota at Behme Rd	4.9		63	59		70.18		286	327		387.89
1-TribDak-5	4.6	28		56	3.61	73.47	70		300	9.04	395.15
Residual flow 4.9 to 3.1		81			24.02	97.49	200			59.42	454.57
Dakota at Giles Rd	3.1		68	59		95.27		257	275		444.23
1-TribDak-3 & 4	1.7	89			15.92	108.91	190			33.98	472.91
1-TribDak-2	1.1	98			8.14	115.75	244			20.27	491.18
1-TribDak-1	0.9	150			2.79	118.06	438			8.16	490.59
Dakota Creek at mouth	0.1					115.95					490.59
		Dry Season- Geomean					**Dry Season- 90th Perecentile**				
		Counts (cfu/100mL)			Load billion cfu/day		Counts (cfu/100mL)			Load billion cfu/day	
			River					River			
Station Name	RM	In	Ob	MB	Input	Balance	In	Ob	MB	Input	Balance
SF Dakota Creek at the mouth	0.2	59			3.50		133			7.88	
NF Dakota Creek at the mouth	0.1	94			6.37		312			21.16	
Dakota below confluence	6.3			78		9.87			229		29.04
Residual flow 6.3 to 4.9		59		70	5.56	15.43	148		194	13.91	42.95
Dakota at Behme Rd	4.9		64	61		13.51		161	170		37.59
1-TribDak-5	4.6	114		66	3.53	16.74	501		207	15.51	52.27
Residual flow 4.9 to 3.1		59		66	1.04	17.78	148		203	2.60	54.87
Dakota at Giles Rd	3.1		58	59		15.90		160	182		49.06
1-TribDak-3 & 4	1.7	345			8.24	23.00	859			20.53	66.05
1-TribDak-2	1.1	422			3.12	25.50	2496			18.47	82.74
1-TribDak-1	0.9	131			0.15	22.75	947			1.08	74.41
Dakota Creek at mouth	0.1					22.75					74.41

In = FC concentration of tributary or other input.
Ob = Observed FC concentration
MB = Calculated FC concentration based on Mass Balance model.

Table 31. FC mass balance for the California Creek basin. Includes estimated concentrations for residual flow inputs.

		Wet Season- Geomean					Wet Season- 90th Percentile				
		Counts (cfu/100mL)			Load billion cfu/day		Counts (cfu/100mL)			Load billion cfu/day	
			River					River			
Station Name	RM	In	Ob	MB	Input	Balance	In	Ob	MB	Input	Balance
California at Bruce Rd	6.2		54	54		20.32		268	268		100.85
TribCal-4	6.0	29		53	0.45	20.70	124		238	1.93	102.44
TribCal-5	5.4	24		50	0.91	21.40	100		268	3.78	105.18
Residual flow 6.2 to 5.0		32		41	12.69	34.09	235		240	93.25	198.43
California at Valley View Rd	5.0		36	41		33.86		256	239		197.10
TribCal-3	4.0	20		38	2.36	35.66	110		219	12.97	206.81
Residual flow 5.0 to 3.1		20		37	0.44	36.10	147		217	3.26	210.07
California at BB-Lynden Rd	3.1		34	37		35.57		215	214		206.94
1-TribCal-2	1.8	97			1.30	30.53	421			28.46	231.23
1-TribCal-1	1.0	13			0.00	30.00	93			1.24	228.45
California at Blaine Rd	0.8					30.39					230.15
California at the mouth	0.1					29.49					224.55
		Dry Season- Geomean					**Dry Season- 90th Percentile**				
		Counts (cfu/100mL)			Load billion cfu/day		Counts (cfu/100mL)			Load billion cfu/day	
			River					River			
Station Name	RM	In	Ob	MB	Input	Balance	In	Ob	MB	Input	Balance
California at Bruce Rd	6.2		226	226		8.65		545	545		20.86
TribCal-4	6.0	235		222	0.16	8.63	1913		558	1.32	21.74
TribCal-5	5.4	525		263	4.25	12.36	4415		499	3.08	23.50
Residual flow 6.2 to 5.0		120		172	9.82	22.18	416		447	34.06	57.57
California at Valley View Rd	5.0		200	165		21.27		435	428		55.21
TribCal-3	4.0	138		147	0.54	19.57	2021		432	7.88	57.30
Residual flow 5.0 to 3.1				157	0.00	19.57			460	0.00	57.30
California at BB-Lynden Rd	3.1		141	142		17.72		404	417		51.86
1-TribCal-2	1.8	206			0.90	15.71	714			3.11	46.47
1-TribCal-1	1.0	39			0.02	13.61	235			0.12	40.31
California at Blaine Rd	0.8					15.09					44.63
California at the mouth	0.1					11.70					34.65

In = FC concentration of tributary or other input.
Ob = Observed FC concentration
MB = Calculated FC concentration based on Mass Balance model.

Loading capacity

EPA defines "Loading capacity" as the maximum amount of FC bacteria pollution a water body can assimilate and still meet the Washington State water quality standard. Because the FC bacteria water quality standard is based on statistical targets, this FC bacteria TMDL uses statistical targets to define loading capacities.

For Dakota and California Creeks, the loading capacity was determined to be the freshwater FC concentrations necessary to meet marine water quality standards in the tidally influenced segment at the mouth of each creek. For 1-Cal-3.1 and 1-Dak-3.1, the applicable statistical targets are the freshwater boundary target values (Table 35). For sites upstream of these stations, the applicable statistics are the target values necessary to meet the freshwater boundary target values downstream (Tables 32-33), as determined by FC mass balance model.

For the remaining sites the load capacity is equivalent to the applicable statistics from the two-part FC bacteria criteria of the water quality standards:

- A geometric mean less than:
    - 50 cfu/100mL for the Cain Creek basin.
    - 100 cfu/100mL for 1-TribDray-1 and 1-Dray-SD4

- No more than 10% of the samples to exceed:
    - 100 cfu/100mL for the Cain Creek basin.
    - 200 cfu/100mL for 1-TribDray-1 and 1-Dray-SD4
    - This TMDL uses the 90th percentile of the sample distribution to evaluate compliance with this criterion.

Ecology developed seasonal statistics for each site using current data collected from the TMDL study, then compared these statistics to the applicable target value, and, finally, calculated the percent reduction required to meet the applicable target value.

The percent reduction values in Tables 34-36 indicate the relative degree the water body is currently out of compliance (i.e., how far it is over its capacity to receive FC loads and still allow for safe recreation and shellfish harvesting). Sites representing reaches or tributaries that are at or below their loading capacity have a zero percent reduction value. Sites that require aggressive reductions in FC sources have high target percent reductions, while sites with minor problems have lower target percent reductions.

Table 32. FC loading capacity for Dakota Creek basin.

		Wet Season- Geomean					Wet Season- 90th Perecentile				
		Counts (cfu/100mL)			Load		Counts (cfu/100mL)			Load	
			River		billion cfu/day			River		billion cfu/day	
Station Name	RM	In		MB	Input	Balance	In		MB	Input	Balance
SF Dakota Creek at the mouth	0.2	21			9.42		59			26.47	
NF Dakota Creek at the mouth	0.1	21			12.69		59			35.65	
Dakota below confluence	6.3			21		22.11			59		62.12
Ungaged 6.3 to 4.9		21			2.82	24.94	59			7.94	70.06
Dakota at Behme Rd	4.9			20		24.23			57		68.06
1-TribDak-5	4.6	21		20	2.71	26.83	59		57	7.62	75.37
Ungaged 4.9 to 3.1		21			6.23	33.05	59			17.49	92.86
Dakota at Giles Rd	3.1			20		32.30			56		90.75
1-TribDak-3 & 4	1.7	20			3.58	35.11	56			10.02	98.60
1-TribDak-2	1.1	20			1.66	36.35	56			4.65	102.07
1-TribDak-1	0.9	20			0.37	36.57	56			1.04	102.68
Dakota Creek at mouth	0.1					35.92					100.85
		Dry Season- Geomean					**Dry Season- 90th Perecentile**				
		Counts (cfu/100mL)			Load		Counts (cfu/100mL)			Load	
			River		billion cfu/day			River		billion cfu/day	
Station Name	RM	In		MB	Input	Balance	In		MB	Input	Balance
SF Dakota Creek at the mouth	0.2	27			1.60		83			4.92	
NF Dakota Creek at the mouth	0.1	27			1.83		83			5.63	
Dakota below confluence	6.3			27		3.43			83		10.55
Ungaged 6.3 to 4.9		27		27	2.55	5.98	83		83	7.83	18.37
Dakota at Behme Rd	4.9			24		5.23			73		16.08
1-TribDak-5	4.6	27		24	0.84	5.95	83		73	2.57	18.29
Ungaged 4.9 to 3.1		27		24	0.48	6.43	83		73	1.46	19.76
Dakota at Giles Rd	3.1			21		5.75			65		17.67
1-TribDak-3 & 4	1.7	21			0.50	5.83	65			1.55	17.95
1-TribDak-2	1.1	21			0.16	5.83	65			0.48	17.94
1-TribDak-1	0.9	21			0.02	5.19	65			0.07	15.98
Dakota Creek at mouth	0.1					5.19					15.98

In = FC concentration of tributary or other input.
MB = Calculated FC concentration based on Mass Balance model.

Table 33. FC loading capacity for California Creek basin.

		Wet Season- Geomean					Wet Season- 90th Perecentile				
		Counts (cfu/100mL)			Load		Counts (cfu/100mL)			Load	
			River		billion cfu/day			River		billion cfu/day	
Station Name	RM	In		MB	Input	Balance	In		MB	Input	Balance
California at Bruce Rd	6.2		21	21		7.90		58	58		21.82
TribCal-4	6.0	21		21	0.33	8.20	58		53	0.90	22.66
TribCal-5	5.4	21		21	0.79	8.91	58		63	2.19	24.62
Ungaged 6.2 to 5.0		21		21	8.33	17.24	58		58	23.00	47.62
California at Valley View Rd	5.0			21		17.13			57		47.30
TribCal-3	4.0	21		20	2.48	19.32	58		57	6.84	53.36
Ungaged 5.0 to 3.1		21		20	0.47	19.78	58		57	1.29	54.64
California at BB-Lynden Rd	3.1			20		19.49			56		53.83
1-TribCal-2	1.8	20			0.27	19.29	56			3.79	56.32
1-TribCal-1	1.0	20			0.00	18.95	56			0.75	56.09
California at Blaine Rd	0.8					19.20					56.06
California at the mouth	0.1					18.63					55.13
		Dry Season- Geomean					**Dry Season- 90th Perecentile**				
		Counts (cfu/100mL)			Load		Counts (cfu/100mL)			Load	
			River		billion cfu/day			River		billion cfu/day	
Station Name	RM	In		MB	Input	Balance	In		MB	Input	Balance
California at Bruce Rd	6.2		26	26		0.99		80	80		3.06
TribCal-4	6.0	26		25	0.02	0.99	80		78	0.06	3.05
TribCal-5	5.4	26		24	0.21	1.14	80		75	0.65	3.52
Ungaged 6.2 to 5.0		26		25	2.13	3.27	80		78	6.54	10.06
California at Valley View Rd	5.0			24		3.14			75		9.65
TribCal-3	4.0	26		22	0.10	2.91	80		67	0.31	8.95
Ungaged 5.0 to 3.1				23	0.00	2.91			72	0.00	8.95
California at BB-Lynden Rd	3.1			21		2.63			65		8.10
1-TribCal-2	1.8	21			0.09	2.29	65			0.28	7.05
1-TribCal-1	1.0	21			0.01	1.99	65			0.03	6.13
California at Blaine Rd	0.8					1.91					5.89
California at the mouth	0.1					1.64					5.06

In = FC concentration of tributary or other input.
MB = Calculated FC concentration based on Mass Balance model.

Table 34. Target FC reductions necessary to meet FC load allocations for the California Creek basin. FC load allocations are presented as a target geomean and 90th percentile FC concentrations.

Station ID	Site Description	Observed FC (cfu /100mL)		FC Reduction	FC Load Allocation (cfu /100mL)	
		Geo-mean	90th %tile		Geo-mean	90th %tile
California Creek and Tributaries						
Wet Season (November to March)						
1-Cal-6.2	California Creek at Bruce Rd	54	268	**78%**	21	58
1-TribCal-4	Tributary to California Creek at Bay Rd	29	124	**53%**	21	58
1-TribCal-5	Trib to California Ck at Main St in Custer	24	100	**42%**	21	58
1-Cal-5.0	California Creek at Valley View Rd	36	256	**78%**	21	57
1-TribCal-3	Tributary to California Creek at Arnie Rd	20	110	**47%**	21	58
1-Cal-3.1	California Creek at Birch Bay-Lynden Rd	31	149	**62%**	20	56
1-TribCal-2	Trib to California Creek at Kickerville Rd	97	421	**87%**	20	56
1-TribCal-1	Tributary to California Creek at Fleet Rd	13	93	**40%**	20	56
1-Cal-0.8	California Creek at SR548/ Blaine Rd	37	199	n/a[1]	n/a[1]	n/a[1]
1-Cal-0.1	California Creek at Drayton Harbor Rd	91	364	n/a[1]	n/a[1]	n/a[1]
1-Cal-SD1	Outfall to California Creek at its mouth	3	11	0%	20	56
1-TribCal-0	Trib to California Ck @ SR548/Blaine Rd			n/a	20	56
Dry Season (April – October)						
1-Cal-6.2	California Creek at Bruce Rd	243	689	**89%**	26	80
1-TribCal-4	Tributary to California Creek at Bay Rd	235	1913	**96%**	26	80
1-TribCal-5	Trib to California Ck at Main St in Custer	525	4460	**98%**	26	80
1-Cal-5.0	California Creek at Valley View Rd	234	697	**90%**	24	75
1-TribCal-3	Tributary to California Creek at Arnie Rd	138	2021	**96%**	26	80
1-Cal-3.1	California Creek at Birch Bay-Lynden Rd	141	404	**85%**	21	65
1-TribCal-2	Trib to California Creek at Kickerville Rd	206	714	**91%**	21	65
1-TribCal-1	Tributary to California Creek at Fleet Rd	39	235	**72%**	21	65
1-Cal-0.8	California Creek at SR548/ Blaine Rd	31	103	n/a[1]	n/a[1]	n/a[1]
1-Cal-0.1	California Creek at Drayton Harbor Rd	20	127	n/a[1]	n/a[1]	n/a[1]
1-Cal-SD1	Outfall to California Creek at its mouth	18	256	**75%**	21	65
1-TribCal-0	Trib to California Ck @ SR548/Blaine Rd	68	749	**91%**	21	65

[1] Not a compliance site; compliance with water quality criteria is contingent on meeting target values at the freshwater boundary (at 1-Cal-3.1), meeting target values for non-point sources within the tidally influenced segment (1-TribCal-1, 1-TribCal-2, etc.), and controlling outside inputs that affect marine water concentrations.

Table 35. *Target FC reductions necessary to meet FC load allocations for the Dakota Creek basin. FC load allocations are presented as a target geomean and 90th percentile FC concentrations.*

Station ID	Site Description	Observed FC (cfu /100mL) Geo-mean	Observed FC (cfu /100mL) 90th %tile	FC Reduction	FC Load Allocation (cfu /100mL) Geo-mean	FC Load Allocation (cfu /100mL) 90th %tile
Dakota Creek and Tributaries						
Wet Season (November to March)						
1-TribDak-S2	Trib to SF Dakota Creek at Sunrise Rd	n/a	n/a	n/a	21	59
1-TribDak-S1	Trib to SF Dakota Ck at Delta Line Rd	n/a	n/a	n/a	21	59
1-SFDak-2.2	South Fork Dakota Creek at Sunrise Rd	n/a	n/a	n/a	21	59
1-TribDak-N2	Trib to NF Dakota Ck nr Delta Line Rd	80	589	**90%**	21	59
1-NF-Dak-2.5	NF Dakota Creek at Delta Line Rd	85	526	**89%**	21	59
1-TribDak-N1	Trib to NF Dakota Creek at Haynie Rd	88	365	**84%**	21	59
1-NF-Dak-0.1	NF Dakota Creek at Custer School Rd	76	406	**85%**	21	59
1-SF-Dak-0.2	SF Dakota Creek at Custer School Rd	42	480	**88%**	21	59
1-Dak-4.9	Dakota Creek at Valley View Rd	63	286	**80%**	20	57
1-TribDak-5	Trib to Dakota Ck at Valley View Rd	28	70	**25%**	21	59
1-Dak-3.1	Dakota Creek at Giles Street	68	257	**78%**	20	56
1-TribDak-3	Tributary to Dakota Creek at Rogers Rd	118	274	**83%**	20	56
1-TribDak-4	Tributary to Dakota Creek at Hoier Rd	51	112	**61%**	20	56
1-TribDak-2	east trib to Dakota at Blaine-Lynden Rd	98	244	**80%**	20	56
1-TribDak-1	west trib to Dakota at Blaine-Lynden Rd	150	438	**87%**	20	56
1-Dak-0.1	Dakota Creek at SR 548/Blaine Rd	166	761	n/a[1]	n/a[1]	n/a[1]
Dry Season (April – October)						
1-TribDak-S2	Trib to SF Dakota Creek at Sunrise Rd	247	815	**90%**	27	83
1-TribDak-S1	Trib to SF Dakota Ck at Delta Line Rd	202	1385	**94%**	27	83
1-SFDak-2.2	South Fork Dakota Creek at Sunrise Rd	141	461	**82%**	27	83
1-TribDak-N2	Trib to NF Dakota Ck nr Delta Line Rd	483	1286	**94%**	27	83
1-NF-Dak-2.5	NF Dakota Creek at Delta Line Rd	234	734	**89%**	27	83
1-TribDak-N1	Trib to NF Dakota Creek at Haynie Rd	124	1521	**95%**	27	83
1-NF-Dak-0.1	NF Dakota Creek at Custer School Rd	94	312	**73%**	27	83
1-SF-Dak-0.2	SF Dakota Creek at Custer School Rd	59	133	**54%**	27	83
1-Dak-4.9	Dakota Creek at Valley View Rd	64	161	**63%**	24	73
1-TribDak-5	Trib to Dakota Ck at Valley View Rd	114	501	**83%**	27	83
1-Dak-3.1	Dakota Creek at Giles Street	58	160	**64%**	21	65
1-TribDak-3	Tributary to Dakota Creek at Rogers Rd	320	800	**93%**	21	65
1-TribDak-4	Tributary to Dakota Creek at Hoier Rd	270	1060	**94%**	21	65
1-TribDak-2	east trib to Dakota at Blaine-Lynden Rd	422	2496	**97%**	21	65
1-TribDak-1	west trib to Dakota at Blaine-Lynden Rd	131	947	**93%**	21	65
1-Dak-0.1	Dakota Creek at SR 548/Blaine Rd	20	113	n/a[1]	n/a[1]	n/a[1]

[1] Not a compliance site; compliance with water quality criteria is contingent on meeting target values at the freshwater boundary (at 1-Cal-3.1), meeting target values for non-point sources within the tidally influenced segment (1-TribCal-1, 1-TribCal-2, etc.), and controlling outside inputs that affect marine water concentrations.

Table 36. Target FC reductions necessary to meet FC load allocations for the Cain Creek basin and the two direct drainages to Drayton Harbor. FC load allocations are presented as a target geomean and 90th percentile FC concentrations.

Station ID	Site Description	Observed FC (cfu /100mL)		FC Reduction	FC Load Allocation (cfu /100mL)	
		Geo-mean	90th %tile		Geo-mean	90th %tile
Cain Creek Watershed						
Wet Season (November to March)						
1-Cain-1.3	Cain Creek at Pipeline Rd near airport	12	74	0%	50	100
1-Cain-0.4	Cain Ck below beaver dam near BTC	260	1885	**95%**	50	100
1-Cain-0.01	The mouth of Cain Creek	234	1305	**92%**	50	100
1-Cain-SD1	Outfall to Semiahmoo Bay nr 1-Cain-0.01	119	677	**85%**	50	100
Dry Season (April – October)						
1-Cain-1.3	Cain Creek at Pipeline Rd near airport	78	330	**70%**	50	100
1-Cain-0.4	Cain Ck below beaver dam near BTC	347	2123	**95%**	50	100
1-Cain-0.01	The mouth of Cain Creek	438	1748	**94%**	50	100
1-Cain-SD1	Outfall to Semiahmoo Bay nr 1-Cain-0.01	86	240	**58%**	50	100
Direct drainages to the Drayton Harbor						
Wet Season (November to March)						
1-TribDray-1	Trib to harbor at Hall St & Dearborn Rd	76	763	**74%**	100	200
1-Dray-SD4	Trib to harbor E. of Albert & Peace Portal	19	135	0%	100	200
Dry Season (April – October)						
1-TribDray-1	Trib to harbor at Hall St & Dearborn Rd	111	296	**32%**	100	200
1-Dray-SD4	Trib to harbor E. of Albert & Peace Portal	101	503	**60%**	100	200

Load and Wasteload Allocations

Wasteload allocations

Wastewater Treatment Plants

A previous study, conducted by DOH, the Food and Drug Administration (FDA), and the Nooksack Tribe determined that, due to dilution and mixing, the current technology based permit limits for the current Blaine WWTP are protective of marine water quality (Meriwether and Kinney, 2006). The new Lighthouse Park Reclamation Facility is currently under construction and scheduled to begin operations in 2010.The new facility will have advanced membrane bioreactor treatment technology that should reduce FC loading significantly.

The wasteload allocation for the Blaine WWTP is set as the current technology based effluent limit outlined in the NPDES permit (Permit No. WA-002264-1) of:

- **Average Monthly = 200 cfu/100 mL**
- **Average Weekly = 400 cfu/100 mL**

The current permit expires on November 15, 2012, but will be modified before that time when the new facility is operational.

Stormwater

Fecal coliform stormwater loads in urban areas are considered capable of occurring at any time. Therefore, municipal stormwater FC wasteload allocations were not specifically reserved for a 'storm' season. Stormwater runoff was a significant FC loading source during both the wet and dry season in California, Dakota, and Cain Creeks. The stormwater wasteloads are based on the FC reductions necessary to achieve FC target values (Tables 34-36) in the nearest receiving waters.

Ecology did not directly measure stormwater outfalls from DOT during the TMDL; however, there are multiple DOT highways and facilities within the study area that have the potential to discharge stormwater to the study area. Within the study area DOT shall:

- Determine drainage paths for each outfall in the study area.
- The WLA for each outfall will correspond to the target values for the receiving waterbody segment.
- Outfalls that discharge within the tidally influenced segment of Dakota and California will need to meet the freshwater boundary target values.

Seafood Processors

The Blaine Seafood processors consortium NPDES permit was cancelled in August 2008 because only one processing operation was still discharging to Drayton Harbor, Boundary Fish. Boundary fish continues to process and discharge. A new permit for Boundary Fish is under development. The new permit, as well as any subsequent permits for new seafood processors in

the study area must insure that water quality in Drayton Harbor will not be impacted. As with previous permits, requirements for effluent disinfection, facility inspections, and discharge monitoring (including for flow and fecal coliform) should be included in the new permits.

Ultimately, Ecology recommends the effluent be diverted to the new Blaine wastewater treatment facility, once it is operational, which can provide superior treatment.

Load allocations

This TMDL study demonstrated that beneficial uses in both Drayton Harbor and its watershed are impaired by FC bacteria pollution. In order to meet the water quality standards in the harbor reductions in FC bacteria are needed throughout the study area.

The Clean Water Act states that FC waste load and load allocations may be expressed as loads, concentrations, or other appropriate measures [40 CFR 130.2(I)]. This TMDL expresses the load allocations in terms of percent reductions necessary to achieve concentration levels which are in accordance with the water quality standards. Washington State uses FC concentrations as an appropriate surrogate measure of meeting allocations because the FC concentrations can be directly compared to the water quality concentration-based standards.

For non-point sources, load allocations are equivalent to loading capacity values, as described in the previous loading capacity section (Tables 34-36). Load allocations are expressed in terms of target FC concentrations, at the stations downstream of non-point sources. The target reduction values must be met in order for nonpoint sources to meet their load allocations.

Reserve capacity for future growth

Since all tributaries fail to meet standards, no allocation for future growth is provided. Additional sources would only be accommodated through additional reductions in existing sources.

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 explicit (e.g., a portion of the load capacity is set aside specifically for the MOS); or implicit (e.g., 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 Drayton Harbor watershed 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 conservative assumptions contribute to the MOS:

- For the FC Mass Balance Model used for Dakota and California Creeks:
  - The FC loss rate used in the model does not account for loss from settling or ultraviolet radiation (death or injury from light).
    - This means, the model likely under predicts FC loss and over predicts FC concentrations.
    - Within the one reach (California Creek from CM 6.2 to 5.0) where an accurate loss rate was observed; the observed loss rate was over 2.5 times higher than the calculated loss rate used in the FC mass balance model.
  - For tributary inputs within the tidally influenced segments of the creeks:
    - Target values are set at a compliance site upstream of the mouth of the tributary (typically the nearest public access).
    - Additional FC loss should occur between the compliance station and the mouth of the tributary, assuming that sources within this stretch meet their load allocations.
  - The freshwater boundary target values are set upstream of the maximum 10 ppt line. Additional FC loss should occur between these stations and the point where marine water quality standards apply, particularly as the loss rate increases with the salinity. So, the FC concentration of the freshwater mixing at that point should be less than what is necessary to meet marine water quality standards.
- For sites where the statistical rollback method was used:
  - 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 90th percentile of the post-management condition.
  - 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 90th percentile is the critical criterion. In these cases, the high coefficient of variation of the log-normalized data can produce a 90th percentile value for the population greater than any of the sample results used to calculate the value.
  - Recommended load allocations were set downstream from suspected nonpoint sources. The reduction or elimination of 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.

Reasonable Assurance

Comment [NM5]: WQ program section. Do not review at thistime.

{WQP lead writes this section.

This section is required *only* if compliance with water quality standards will require pollutant reductions by both point and nonpoint sources. The purpose is to explain why we believe the nonpoint reductions will occur so it will not be necessary to place the entire burden on point sources.}

When establishing a TMDL, reductions of a particular pollutant are allocated among the pollutant sources (both point and nonpoint sources) in the water body. For the ~~water body and pollutant(s)~~ Drayton Harbor fecal coliform TMDL, both point and nonpoint sources exist. TMDLs (and related implementation plans) must show "reasonable assurance" that these sources will be reduced to their allocated amount. Education, outreach, technical and financial assistance, permit administration, and enforcement will all be used to ensure that the goals of this TMDL are met.

Ecology believes that the following activities already support this TMDL and add to the assurance that fecal coliform pollutant in the Drayton Harbor ~~water body~~ will meet conditions provided by Washington State water quality standards. This assumes that the activities described below are continued and maintained.

The goal of the Drayton Harbor ~~water body~~ Water Quality Improvement Report for ~~pollutant~~ fecal coliform is to help the waters of the basin meet the state's water quality standards. The following rationale helps provide reasonable assurance that the ~~water body~~Drayton Harbor nonpoint source TMDL goals will be met by ~~target date~~2015.

Details will be brought forward after review by Drayton Harbor Shellfish Committee review. {EPA requires some assurances that TMDL implementation measures will actually occur. To that end, responsible parties, regulatory authorities, detailed implementation measures and schedules, and funding mechanisms must be identified. To provide this assurance, include specific details of the people, actions, timelines, and funding to accomplish the stated goals here. For each major stakeholder, evaluate and detail the following types of activities underway or planned to reduce the contribution of nonpoint pollutants:

1. Describe ongoing nonpoint source control e.g. riparian restoration projects, nonpoint stormwater best management practices (BMPs).
2. Discuss efforts aimed at increasing awareness through educational efforts, for example, conservation district outreach, pamphlets, mailers, and workshops.
3. Describe technical assistance, available funding, and other voluntary efforts, for example, local surface water management programs, grant and loan programs.
4. Describe water quality monitoring to provide feedback for adaptive management of source control activities.
5. Describe the legal authority that governments at various levels hold over the polluting activities for example, ordinances and property tax reductions for conservation set-asides.}

xx
While Ecology is authorized under Chapter 90.48 RCW to impose strict requirements or issue enforcement actions to achieve compliance with state water quality standards, it is the goal of all participants in the water body TMDL process to achieve clean water through cooperative efforts.

{Discuss role of adaptive management in fine tuning expectations over time.}

xx

Comment [NM6]: WQ program section. Do not review at thistime.

Implementation Strategy

Comment [NM7]: WQ program section. Do not review at thistime.

{WQP lead writes this section.}

Introduction

{Include the following two paragraphs:}

This implementation strategy describes what will be done to improve water quality. It explains the roles and authorities of cleanup partners (those organizations with jurisdiction, authority, or direct responsibility for cleanup), along with the programs or other means through which they will address these water quality issues.

After the EPA approves this TMDL, interested and responsible parties work together to develop a detailed *Water Quality Implementation Plan*. The plan describes and prioritizes specific actions planned to improve water quality and achieve water quality standards.

What needs to be done?

{This list must show ALL implementation activities necessary to achieve compliance with water quality standards, not just those that have a willing implementer and timeline. List anticipated implementation activities, as well as specific and scheduled already on-going activities. This is flexible – if the community is ready, proceed with details on activities planned. Or, add more detail to this overview.}

The Drayton Harbor Shellfish Protection Committee has been successfully coordinating activities to reduce bacteria loading to Drayton Harbor. This strategy draws on their past plans and anticipates their continued leadership in implementing and montitoring this TMDL.

Several broad catagories of sources have been identified and responsibility for activitites to control those sources has also been identified.

On-Site Sewage Systems (OSS) are common in the rural areas of the study area. Homeowners are responsibly for operation and maintenance of the systems. Whatcom County Health Department has a program to track homeowner reports of inspections and requires an inspection for functionality and repairs is necessary at the time of title transfer. Whatcom County Health Department will continue to track homeowner compliance and report to the committee periodically.

Urban Stormwater Sources are primarily non point souces associated with stormwater runoff. The city of Blaine collects sewage from most of the homes in the urban area. The discharge city of any of the sewage prior to treatment and disinfection is prohibited under permit issued to the city. Both the city and county now require on-site stormwater stormwater treatment. This requires infiltration or dispersion over vegetated areas prior to collection to storm drainage systems. This allows soil microbes to consume fecal coliform bacteria in all but very large

storms. Public areas are addressed by providing mitts for collection of pet wastes (WITH ENFORMCEMENT FOR NON COMPLIANCE??) Annual reports on compliance and variances allowed will help the Drayton Harbor Shellfish Protection District work with the city and county to determine if targets are not being met if better compliance or stronger regulation is required.

Agriculture is the largest land use in the basin. The agricultural uses vary from small hobby farms with livestock such as horses and goats to commercial dairies and berry fields. Whatcom County allows agricultural uses within the standard buffers of streams through regulations in the Conservation Program on Agricultural Lands. Existing agricultural uses must have a plan to protect the critical areas. For the lowest insensity of agriculture the plan may be generated by the landowner and submitted to Whatcom county for approval. For medium intensity agriculture professionals design the plans. For the highest intensiy agriculture the operations are regulated by the Permits issued by the Washington Department of Ecology and implemented by the Washington Department of Agriculture. The Whatcom Conservation District has been instrumental in developing guidance for the development of the farm plans as well as taking a lead in developing and certifying plans for the highest impact agriculture. Maintaining an inventory of the land designated as agriculture under CPAL and that status of the plan development and implementation will be critical to demonstrating the resources needed by landownwers as well as the success of the program.

{If applicable, include the following Forest and Fish standard language:}

The state's forest practices regulations will be relied upon to bring waters into compliance with the load allocations established in this TMDL on private and state forestlands. As part of their agreement to the 1999 Forests and Fish Report :

http://www.dnr.wa.gov/Publications/fp_rules_forestsandfish.pdf

Ecology agreed to use the forest practices regulations to implement TMDLs. The effectiveness of the Forests and Fish program is being assessed through a formal adaptive management program. The success of this TMDL will be assessed using monitoring data from streams in the watershed.

Ecology will formally review the effectiveness of the forest practices program in 2009. As part of this review, Ecology will determine if the state's forest practices program can be relied on to bring water quality into compliance with the state water quality standards. If the current program is not deemed adequate, Ecology will suggest any needed changes to the Forest Practices Board, or revise this TMDL implementation plan as necessary, to achieve compliance.
The Washington State Department of Natural Resources (DNR) is encouraged to condition forest practices to prohibit any further reduction of stream shade, and not waive or modify any shade requirements for timber harvesting activities on state and private lands.

New forest practices rules for roads also apply. These include new road construction standards, as well as new standards and a schedule for upgrading existing roads. Under the new rules, roads must provide for better control of road-related sediments, provide better streambank

stability protection, and meet current best management practices. DNR is also responsible for oversight of these activities.

{If applicable, include the following example planning language:

SEPA/Planning Standard Language

Consider TMDLs during State Environmental Policy Act (SEPA) and other local land use planning reviews. If the land use action under review is known to potentially impact temperature and dissolved oxygen as addressed by this TMDL, then the project may have a significant adverse environmental impact. SEPA lead agencies and reviewers are required to look at potentially significant environmental impacts and alternatives and to document that the necessary environmental analyses have been made. Land use planners and project managers should consider findings and actions in this TMDL to help prevent new land uses from violating water quality standards. Ecology recently published a focus sheet on how TMDLs play a role in SEPA impact analysis, threshold determinations, and mitigation (http://www.ecy.wa.gov/biblio/0806008.html). Additionally, the TMDL should be considered in the issuance of land use permits by local authorities.}

Who needs to participate?

Participation will be required by landowners, city of Blaine Planning and Public Works departments, Whatcom County Planning and Health and Public Works departments, Whatcom County Conservation District and Lummi Nation and Nooksack Tribe.

Landowners are responsible for preventing contaminated runoff from leaving their property. This can be achieved by on-site stormwater management and respecting critical area buffers and in the case of agriculture following farm plans developed under the CPAL program described above.

City of Blaine Planning Department is responsible for issuing permit for new development that implements on-site stormwater management, and requiring the same in the cases of significant redevelopment in the city limits.

The city of Blaine Public Works Department is responsible for operation and maintenance of the sewage collection system to eliminate discharges of the collected sewage prior to treatment and disinfection.

Whatcom County Planning Department Department is responsible for issuing permit for new development that implements on-site stormwater management, and requiring the same in the cases of significant redevelopment for the unincorporated area. Whatcom County Planning also implements the Critical Areas Ordinance and CPAL programs.

Whatcom County Health Department is responsible for the oversight of landowner operation and maintenance of the On-Site Septic Systems.

Whatcom County Public Works is responsible for drainage of County Roads. During maintenance of the road drainage illicit discharges are discovered. Whatcom county public works has a responsibility to report violations to the appropriate authority. Whatcom County Public Works also manages the funds for Shellfish Protection Districts. The public works department will be responsible for contracts for water quality monitoring and dissemination of the data.

Whatcom County Conservation District provides technical assistance to landowners and to Whatcom County Planning on agricultural issues. Whatcom County Conservation District is to ensure that technical assistance provided is protective of water quality.

The Lummi Nation and Nooksack Tribe both have Usual and Acustomed Harvest areas located in the study area. They both have a responsibility to their members to ensure that harvest in the study area is safe.

What is the schedule for achieving water quality standards?

Water quality targets are anticipated to be met over the five years following the approval of the TMDL. Quarterly interim targets will be established to track adequate quarterly progress toward meeting the 5-year goal based on a constant percent reduction each quarter.

Monitoring progress

{This is an element of adaptive management. Monitoring implementation – tracking tables

The EAP technical lead makes general recommendations, and negotiates and reviews content with WQP lead for final draft. Set minimal monitoring to be done – targets to see if meeting goals.

The WQP lead works with locals on plan. Describe monitoring programs by other partners.

Define objectives of post-TMDL monitoring (EAP and WQP). Post-TMDL monitoring design may be conceptual at this point. Describe ongoing monitoring program to evaluate success of cleanup actions.

Define the adaptive real time feedback process to determine cleanup effectiveness & support adaptive management.

Include the following text:}

A monitoring program for evaluating progress is an important component of any implementation strategy. Monitoring is needed to keep track of what activities have or have not been done, measure the success or failure of target pursuit actions, and evaluate improvements in water

quality. Monitoring should also be done after water quality standards are achieved (compliance monitoring) to ensure that standards continue to be met.

The Drayton Harbor Shellfish Protection District will assemble data on implementation activities each quarter. Whatcom County Public Works will assemble data on Water Quality quarterly. Ecology will review both reports.

Monitoring implementation actions and how they will be maintained

Compliance monitoring will be needed when water quality standards are believed to be achieved.

Entities with enforcement authority are responsible for following up on any enforcement actions. Stormwater permittees and point source permittees are responsible for meeting the requirements of their permits. Those conducting restoration projects or installing best management practices (BMPs) are responsible for monitoring plant survival rates and maintenance of improvements, structures and fencing.

The *Water Quality Implementation Plan* will describe the coordinated monitoring strategy.

xx

Adaptive management

Natural systems are complex and dynamic. The way a system will respond to human management activities is often unknown and can only be described as probabilities or possibilities. Adaptive management involves testing, monitoring, evaluating applied strategies, and incorporating new knowledge into management approaches that are based on scientific findings. In the case of TMDLs, Ecology uses adaptive management to assess whether the actions identified as necessary to solve the identified pollution problems are the correct ones and whether they are working. As we implement these actions, the system will respond, and it will also change. Adaptive management allows us to fine-tune our actions to make them more effective, and to try new strategies if we have evidence that a new approach could help us to achieve compliance.

TMDL reductions should be achieved by 200x. {Describe interim targets in terms of concentrations and/or loads, as well as in terms of implemented cleanup actions.} These targets will be described in terms of percent reductions, concentrations, and implementation activities. Partners will work together to monitor progress towards these goals, evaluate successes, obstacles, and changing needs, and make adjustments to the implementation strategy as needed.

Ecology will use adaptive management when water monitoring data show that the TMDL targets are not being met or implementation activities are not producing the desired result. A feedback loop (Figure xx) consisting of the following steps will be implemented:

Step 1. The activities in the water quality implementation plan are put into practice.

Step 2. Programs and (best management practices) BMPs are evaluated for technical adequacy of design and installation.

This step is carried out each month. The Drayton Harbor Shellfish Protection district will assemble information from each implementing agency about status of compliance with existing plans and programs that can be used to help determin if better compliance with existing plans and programs, more rapid implementation of existing plans and programs or more stringent plans and programs are necessary.

Step 3. The effectiveness of the activities is evaluated by assessing new monitoring data and comparing it to the data used to set the TMDL targets.

This step is also carried out quarterly. Interim targets for each quarter will be compared to the measured water quality. At minimum water quality will be measured montly at the mouths of the major streams. If interim targets are not met additional sites will need to be sampled to target implementation actions on the main sources of contamination.

Step 3a. If the goals and objectives are achieved, the implementation efforts are adequate as designed, installed, and maintained. Project success and accomplishments should be publicized and reported to continue project implementation and increase public support.

Step 3b. If not, then BMPs and the implementation plan will be modified or new actions identified. The new or modified activities are then applied as in Step 1.

Additional monitoring may be necessary to better isolate the bacteria sources so that new BMPs can be designed and implemented to address all sources of bacteria to the streams.

It is ultimately Ecology's responsibility to assure that implementation is being actively pursued and water standards are achieved.

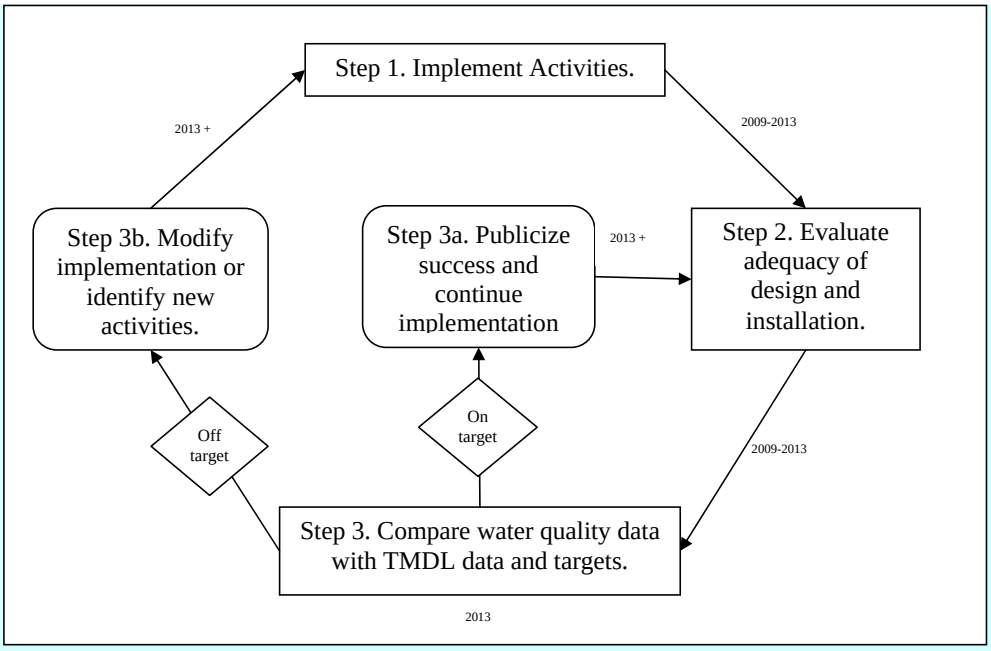

Figure xx. Feedback loop for determining need for adaptive management. *Dates are estimates and may change depending on resources and implementation status.*

See the *Monitoring Plan* section in this report.

xx

Potential funding sources

{Identify potential funding sources – national, state, and local.

Multiple sources of financial assistance for water cleanup activities are available through Ecology's grant and loan programs, local conservation districts, and other sources.

Refer to http://www.ecy.wa.gov/programs/wq/tmdl/TMDLFunding.html for a list and descriptions of funding sources. Choose ones appropriate to your project and include them here.}

xx

Summary of public involvement methods

{Identify what you did to get the public involved in the TMDL project process, including outreach and education activities.}

xx

Comment [NM8]: WQ program section. Do not review at this time.

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Appendices

Appendix A. Glossary, acronyms, and abbreviations

{Author, delete all terms that don't apply to this report.}

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 waterbodies (ocean waters, estuaries, lakes, and streams) that fall short of state surface water quality standards, and are not expected to improve within the next two years.

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

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

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

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

Fecal coliform (FC): That portion of the coliform group of bacteria which is present in intestinal tracts and feces of warm-blooded animals as detected by the product of acid or gas from lactose in a suitable culture medium within 24 hours at 44.5 plus or minus 0.2 degrees Celsius. Fecal coliform bacteria 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/100mL).

Geometric mean: A mathematical expression of the central tendency (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 10 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 water's 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 water body can receive and still meet water quality standards.

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

Municipal separate storm sewer systems (MS4): A conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, manmade channels, or storm drains): (1) owned or operated by a state, city, town, borough, county, parish, district, association, or other public body having jurisdiction over disposal of wastes, stormwater, or other wastes and (2) designed or used for collecting or conveying stormwater; (3) which is not a combined sewer; and (4) which is not part of a Publicly Owned Treatment Works (POTW) as defined in the Code of Federal Regulations at 40 CFR 122.2.

National Pollutant Discharge Elimination System (NPDES): National program for issuing and revising permits, as well as imposing and enforcing pretreatment requirements, under the Clean Water Act. The NPDES permit 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.

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

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

Surrogate Measures: To provide more meaningful and measurable pollutant loading targets, EPA regulations [40 CFR 130.2(i)] allow other appropriate measures, or surrogate measures in a TMDL. The Report of the Federal Advisory Committee on the Total Maximum Daily Load (TMDL) Program (EPA, 1998) includes the following guidance on the use of surrogate measures for TMDL development:

> *When the impairment is tied to a pollutant for which a numeric criterion is not possible, or where the impairment is identified but cannot be attributed to a single traditional "pollutant," the state should try to identify another (surrogate) environmental indicator that can be used to develop a quantified TMDL, using numeric analytical techniques where they are available, and best professional judgment (BPJ) where they are not.*

Total Maximum Daily Load (TMDL): A distribution of a substance in a water body 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.

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

Acronyms and Abbreviations

Following are acronyms and abbreviations used frequently in this report.

BMPs	Best management practices
cfs	Cubic feet per second
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
GIS	Geographic Information System software
NPDES	National Pollutant Discharge Elimination System
RM	River mile
TMDL	Total Maximum Daily Load (water cleanup plan)
WRIA	Water Resources Inventory Area
WWTP	Wastewater treatment plant

Units of Measurement

°C	degrees centigrade
cfs	cubic feet per second
ft	feet
mgd	million gallons per day
mL	milliliters
psu	practical salinity units
s.u.	standard units
µg/L	micrograms per liter (parts per billion)
µS/cm	microsiemens per centimeter, a unit of conductivity

Appendix B. Record of public participation

{This is required by EPA. WQP staff writes this section.}

Introduction

xx

Summary of comments and responses

xx

List of public meetings

xx

Outreach and announcements

{Include the following, if applicable:}

A 30-day public comment period for this report will be held from xx through xx, (year).

A news release was sent to all local media in the xx watershed area.

Advertisements were placed in the following publications:

- xx
- xx
- xx

Appendix C. Response to public comments

{Keep the following sentence in the draft report on the website:}

This appendix will be completed after the Public Comment period.

Appendix D. Basin Maps

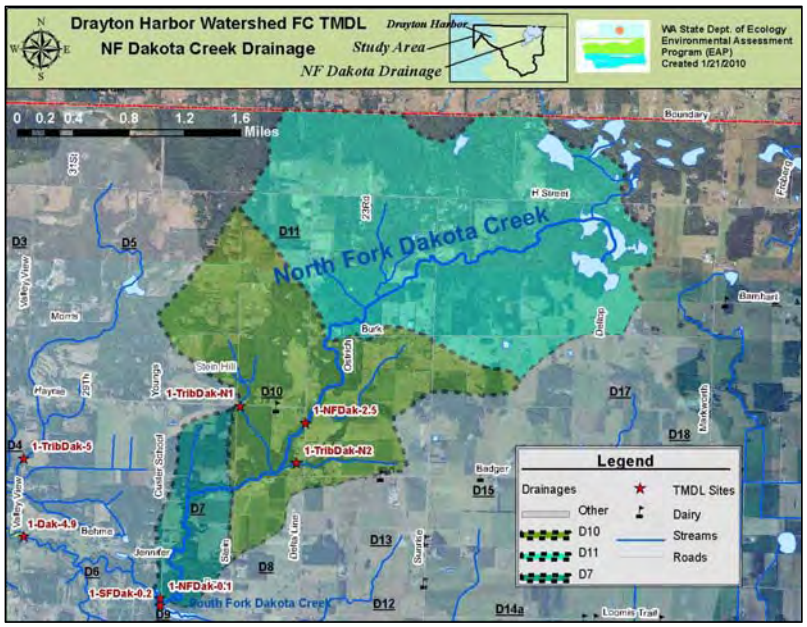

Figure D 1. Map of the North Fork of Dakota Creek basin including TMDL sampling sites and sub-drainages.

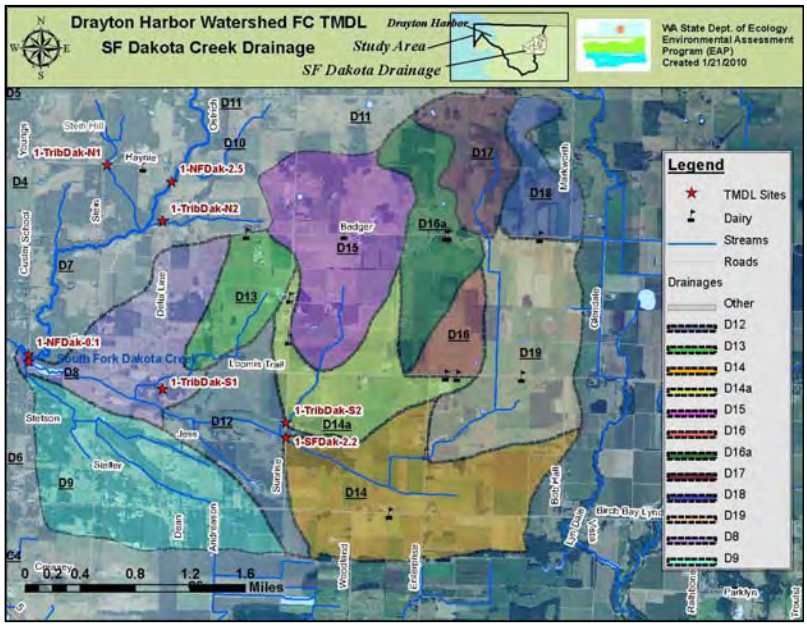

Figure D 2. Map of the South Fork of Dakota Creek basin including TMDL sampling sites and sub-drainages.

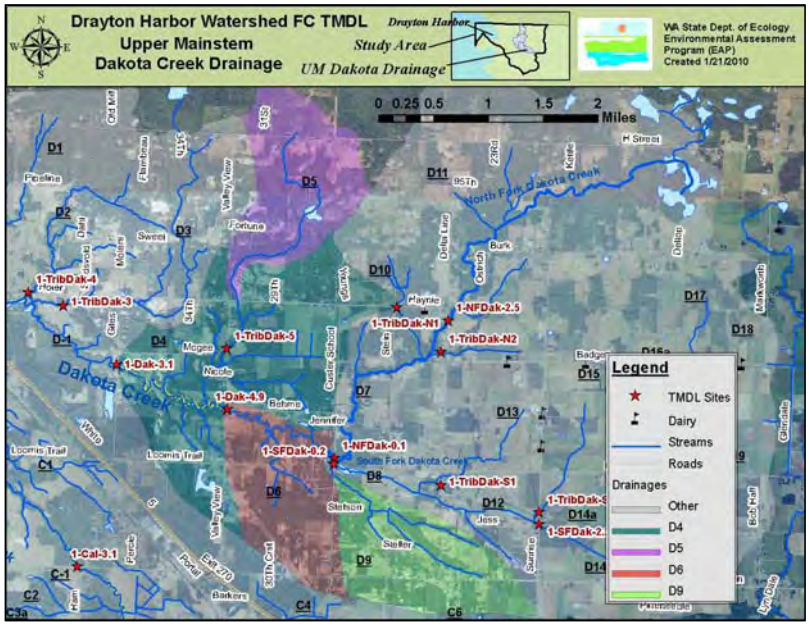

Figure D 3. Map of the upper mainstem Dakota Creek basin including TMDL sampling sites and sub-drainages.

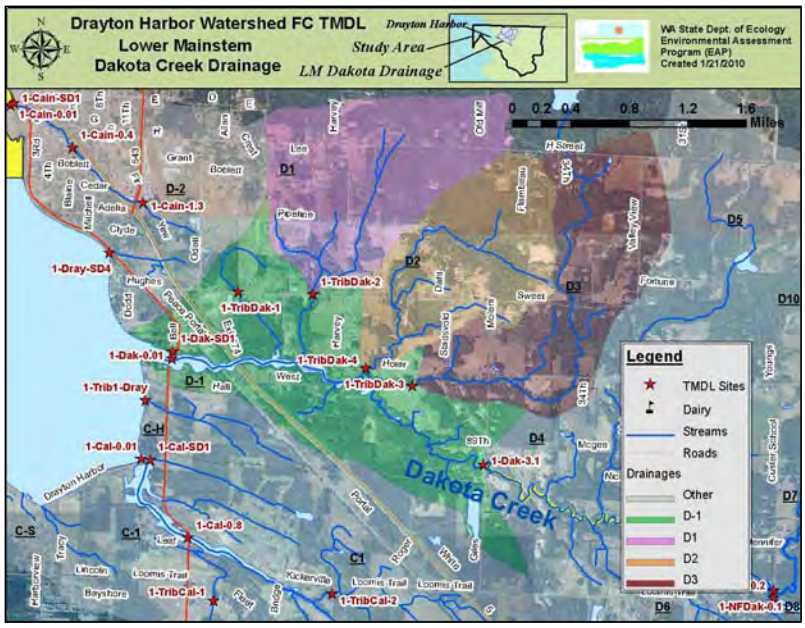

Figure D 4. Map of the tidal mainstem Dakota Creek basin including TMDL sampling sites and sub-drainages.

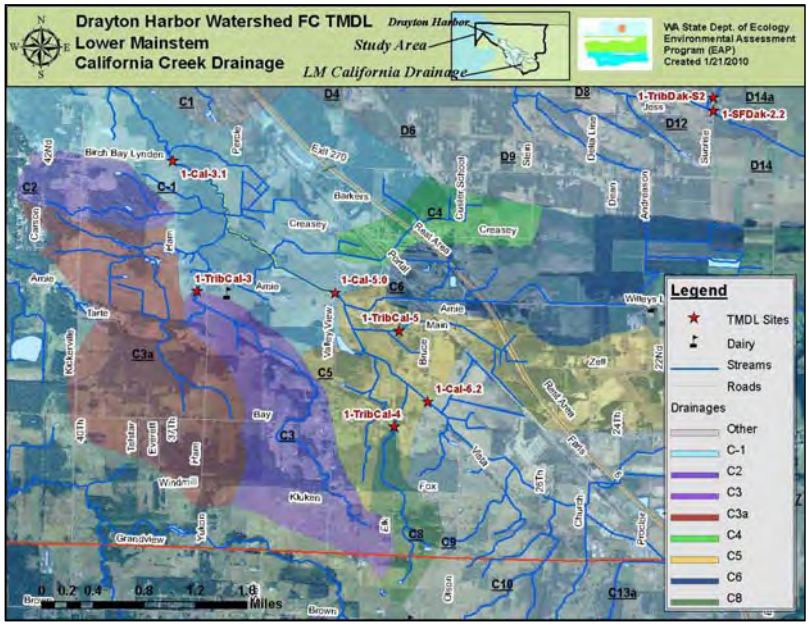

Figure D 5. Map of the lower mainstem California Creek basin with TMDL sampling sites and sub-drainages.

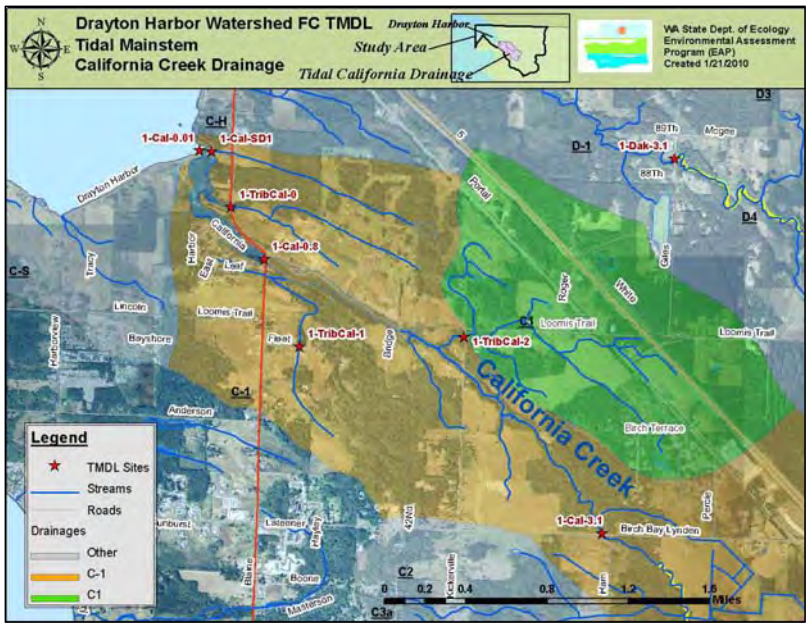

Figure D 6. Map of the tidal mainstem California Creek basin including TMDL sampling sites and sub-drainages.

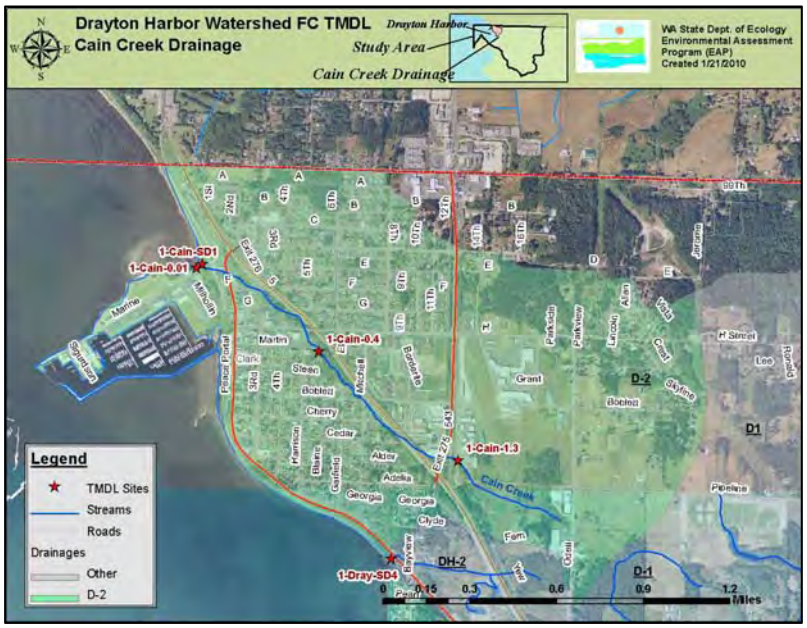

Figure D 7. Map of the Cain Creek basin including TMDL sampling sites and sub-drainages.

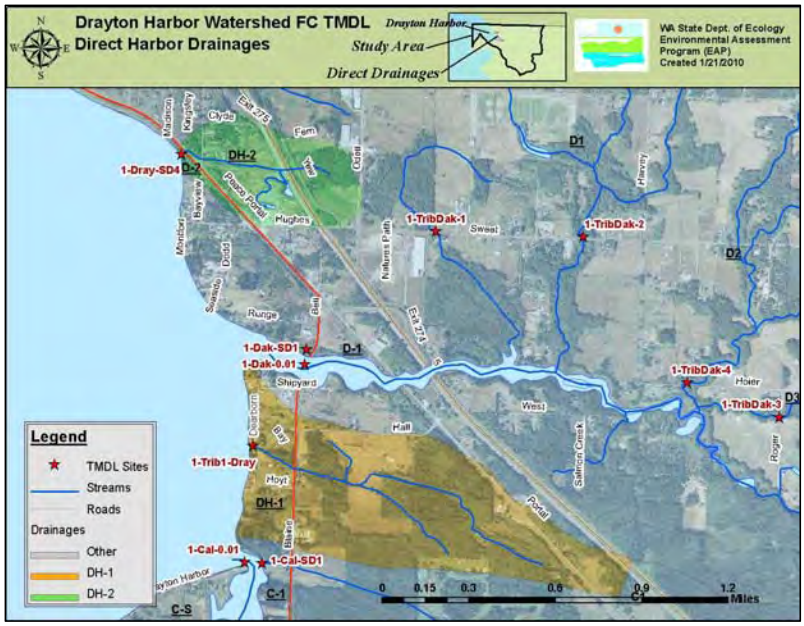

Figure D 8. Map of direct tributaries basins including TMDL sampling sites and sub-drainages.

Appendix E: Detailed study results

Quality Assurance Results

Hydrolab *in situ* data quality results

Ecology compared both the post-calibration and side-by-side Hydrolab results to their respective criteria and either qualified or rejected the measurements where appropriate. Table E1 summarizes the percentage of qualified or rejected measurements for each parameter.

Table E 1. Percentage of qualified or rejected Hydrolab measurements

Parameter	Total No. of Measurements	% Qualified	% Rejected
Temperature	741	5%	0%
Specific Conductivity	734	25%	4%
pH	733	16%	10%
Dissolved Oxygen	729	33%	3%

Hydrolab deployment continuous data quality results

Overall, the data quality for the continuous Hydrolab sonde deployments was acceptable. Some results were qualified or adjusted (Table E2). Due to data quality issues, Ecology:

- Qualified data due to exceedance of post-calibration criteria for:
  - Specific conductivity at five sites
  - pH at one site
- Qualified dissolved oxygen data at two sites due to exceedance of Winkler DO check criteria.
- Truncated initial pH data at five sites where pH probes with low-ionic strength reference (LISREF) probes were deployed. All five LISREF probes started with high values and took an extended amount of time (6 hours or longer) for probes to resume normal diurnal pattern.
- Removed dissolved oxygen data at 1-Cal-5.0. Near the end of the deployment the dissolved oxygen probe began to lose battery power and record intermittent low readings. Seven data points were removed from this period.
- Corrected dissolved oxygen data at three sites based on a linear regression to Winkler checks. The regression applied both a slope and bias correction to the data.

Comment [SoW9]: Describe in Methods

Comment [SoW10]: Show how you did this. What made you think the Winkler values were more accurate?

Table E 2. Data quality results summary for continuous Hydrolab deployments.

Site	Temperature	Specific Conductivity	pH	Dissolved Oxygen	Comments
Cal-3.1	A	QPC	A[1]	A	
Cal-5.0	A	A	A	A[2]	
Cal-6.2	A	QPC	A[1]	A[3]	DO biased low by 0.35
Dak-0.1	A	A	A	QW	
Dak-3.1	A	A	A	A[3]	DO biased high by 0.28
Dak-4.9	A	QPC	A[1]	QW[3]	DO biased low by 0.84
NFDak-0.1	A	A	A[1]	A	
NFDak-2.5	A	QPC	QPC[1]	A	
SFDak-0.2	A	A	A	A	
Cain-0.4	A	QPC	A	A	

1 = pH data truncated during extended low-ionic settling period
2 = DO probe displayed unsteady readings near end of deployment; removed affected data points and interpolated data gaps
3 = DO data adjusted based on linear regression with Winkler samples
A = acceptable data quality
QPC = qualified based on post calibration
QW = qualified based on Winkler checks

Precision results

Field staff collected field replicates for FC, streamflow, and Hydrolab measurements to assess precision. Results are summarized in Table E3.

FC-Most probable number (MPN) results failed to meet the precision criteria outlined in the QAPP. However, the MPN precision results showed less variability than those from three previously completed TMDLs (Joy, 2004; Pelletier and Seiders, 2000; Seiders et al., 2001), indicating that the criteria were likely too stringent and that MPN precision was within the range of variability observed during other TMDL studies.

Table E 3. Precision results for fecal coliform, streamflow and Hydrolab measurements.

Parameter	N	Median RSD	Median RSD Criteria	90th %tile RSD	90th %tile RSD criteria	Pass or Fail?
FC- Membrane Filter	116	19.4%	< 20%	49.2%	< 50%	Pass
FC- Most Probable Number(MPN)	16	38.2%	< 20%	78.1%	< 50%	Fail
FC-MPN- 3 completed TMDLs[1]	50	40.9%	n/a	89.5%	n/a	n/a
Discharge Volume (cfs)	20	9.54%	< 10%	n/a	n/a	Pass
Hydrolab- Temperature[2]	40	0.10	0.20	n/a	n/a	Pass
Hydrolab- Specific Conductance	40	1.08%	< 10%	n/a	n/a	Pass
Hydrolab- pH	40	3.38%	< 10%	n/a	n/a	Pass
Hydrolab- Dissolved Oxygen (DO)	40	3.74%	< 10%	n/a	n/a	Pass
Hydrolab DO vs. Winkler DO	82	3.60%	< 5%	n/a	n/a	Pass
Winkler- DO[2]	10	0.06	0.20	n/a	n/a	Pass

[1] Results are from the Skokomish River, Stillaguamish River, and Grays Harbor FC TMDLs
[2] Expressed as unit of measurement not %RSD

Manchester QA/QC results

Out of 703 FC samples Ecology's Manchester Environmental Laboratory (MEL) qualified 160 samples. MEL qualified:

- **95 samples** because they were analyzed outside of MEL's recommended 24 hour holding time. Due to transportation logistics MEL is unable to analyze samples collected before 10am the following day within 24 hours. Due to time constraints, a number of samples needed to be collected before 10 am each day. All samples qualified for holding time were analyzed within 30 hours.
- **26 samples** because there were greater than 150 colonies on the plate. Two or more bacteria could land in the same place during filtration; therefore the "true" values may be greater than or equal to the reported results.
- **23 samples** because there were background colonies on the plate. These non-motile, non-fecal colonies may interfere with the blue color produced by the fecal colonies; therefore the "true" values may be greater than or equal to the reported results.
- **14 samples** because there were spreader colonies on the plate. These motile, non-fecal colonies may interfere with the blue color produced by the fecal colonies; therefore the "true" values may be greater than or equal to the reported results.
- **2 samples** because the sample varied from the corresponding duplicate sample by greater than 40 percent relative percent difference (RPD).

Completeness results

The project goal for completeness was to collect and analyze 100% of the samples outlined in the QA project plan study design. For the routine TMDL monitoring Ecology staff collected 694 samples out of 750 potential sampling opportunities.

Comment [SoW11]: Wow, you strive for perfection!

Of these 750 opportunities, 47 samples were not collected because there was either no or too little flow to collect a sample. These were not counted against completeness, because the reason for not collecting a sample was outside the control of field staff.

Ecology field staff missed 10 total sampling opportunities that may have been avoidable resulting in an overall completeness percentage of 98.6%. Of these 10 missing samples:

- **7 samples** were not collected due to strong tidal influence at sites that are sampled for freshwater only. Avoiding sampling at high tide often proved difficult, particularly in the winter when low tides usually occurred after dark.
- **1 sample** was collected at the wrong location. Temporary field staff sampled the wrong waterbody on one occasion. The sampling error was discovered the next day and the error was corrected.
- **1 sample** was lost in the field or in transport. The field team remembers collecting the sample, but sample processing at MEL revealed it was missing.
- **1 sample** was collected, but accidently crossed out on the lab form, so the sample was not analyzed.

Fecal Coliform Results Tables

Table E 4. Fecal coliform results for the Dakota Creek mainstem.

Date	Dak-0.1 MF	Dak-0.1 MPN	Dak-3.1	Dak-6.8	SFDak-0.2	NFDak-0.1	NFDak-2.5
12/11/2007	285						
12/12/2007	84		20.5	40	16	45	63 J
12/18/2007	56	110	22	31	15	37	130
1/15/2008	250	130	150 J	160	160 J	88	49 J
1/28/2008	43/76*	49	40	66	17	84	36
2/6/2008	450 J	1100	250	270 J	300 J	245 J	200
2/19/2008	17.5	49	44	28	24	21.5	36
3/3/2008	11.5 U	145	88	120	405	34	108
4/30/2008	6	11	35	120	15	220	230
5/12/2008	5	9	72	150	160	97	260
5/28/2008	19	79	76	120	51	160	235
6/12/2008	9	33	270	180	100	415	280
6/24/2008	5	13	57	37	81	46	140
7/7/2008	6	13	61	63	65	420	180
7/21/2008	no sample		33	31	59	58.5	120
8/4/2008	1.5	6	28	48	60	92	120
8/27/2008	2.5	5	110	72	36	60	190
9/2/2008	19	23	21	16	32	20	140
9/22/2008	17	15	24	38	59	67.5	210
10/13/2008	110	540			120	39	3400 J
10/14/2008	110		160	76			
11/3/2008	1400	1600			650	2200 J	3700 J
11/5/2008	8		540 J	615 J			
11/17/2008	69.5	140			25 U	53	25
11/18/2008	31		29 J	15			
12/2/2008	130	70			1	75	67 J
12/3/2008	44		69 J	23			
12/15/2008	96	130					
12/16/2008	66		54	23 J	1 U	25 J	25

Table E 5. Fecal coliform results for the Dakota Creek basin tributaries.

Date	TribDak-1	TribDak-2	TribDak-3	TribDak-4	TribDak-5	TribDak-N1	TribDak-N2
12/12/2007	160	68	93	80	9	25	28 J
12/18/2007	250	80	340	100	29	54.5	44 J
1/15/2008	220	47	150	130	16.5	43 J	69 J
1/28/2008	445 J	84	130	39	17	125	170
2/6/2008	390	77	66	40	28	92	520 J
2/19/2008	150	27	32	21	19	29	12
3/3/2008	440	260	135	79	82	800	57
4/30/2008	150	46	101	91	9	57	430
5/12/2008	490	32	190	120	86	300	280 J
5/28/2008	54	1000 J	160	425	53	57	650
6/12/2008	350	970	210	945	52	430	300
6/24/2008	9	140	240	110	55	3 U	1300
7/7/2008	dry	340	220	220	295	dry	480
7/21/2008	dry	725	500	110	320	dry	300
8/4/2008	dry	480	330	1600 J	330	dry	260
8/27/2008	dry	900	730	600	170	375	3300
9/2/2008	dry	2800	1300	77	630	dry	180
9/22/2008	dry	280	430	640	160	dry	490
10/14/2008	400	1900	505	92	75	980	675
11/4/2008	54	230	265	84	63	500	2900
11/17/2008	46	205 J	69 J	27 J	45 J	37.5	23
12/4/2008	84	180	140	33	63	90.5	67 U
12/16/2008	42 J	77 J	140 J	31 J	14 J	92 J	35

Table E 6. Fecal coliform results for South Fork Dakota Creek basin.

Date	SFDak-2.2	TribDak-S1	TribDak-S2				
4/30/2008		63					
5/12/2008		1800 J					
5/28/2008	100 J	770	350				
6/12/2008	100 J	85	520 J				
6/24/2008	130	470	320				
7/7/2008	150	500	390				
7/21/2008	340	15	970				
8/4/2008	1100 J	110	255				
8/27/2008	150	470	120				
9/2/2008	33	170	31				
9/22/2008	96	850	170				
10/14/2008	88	23	240				
11/4/2008	6900 J	390	1400				
11/17/2008	4	12	9				
12/4/2008	25	62	50				
12/16/2008	10	18	14				

Table E 7. Fecal coliform results for the California Creek mainstem.

Date	Cal-0.1 MF	Cal-0.1 MPN	Cal-0.8	Cal-3.1	Cal-5.0	Cal-6.2	
12/11/2007	320		3	5	11 J	37 J	
12/18/2007	100	79	29	15	5	29.5 J	
1/15/2008	220	175	130	110	110	140 J	
1/28/2008	240/60*	170	160	22	33	86.5	
2/6/2008	100	180	88	49	48	84 J	
2/19/2008	17	17	46	14	10	11.5 J	
3/3/2008	10	17	12.5	24	12	16 J	
4/30/2008	2	5	15	35	140	85.5 J	
5/12/2008	36	79	89	180	120	140 J	
5/28/2008	8 J		32	235	100	200 J	
6/12/2008	3	2	56	280	340	140 J	
6/24/2008	14	11	19.5	240	170	235 J	
7/7/2008	16	17	13.5	200	190	280 J	
7/21/2008	13	64	68	280	430	230	
8/4/2008	16	70	45	54	200	235	
8/27/2008	31	79	84	300	1200	1200	
9/2/2008	29	49	53	40	66	180 J	
9/22/2008	3	2	3.5	73	255	140	
10/13/2008	5	11					
10/14/2008	39		24	240	830	1200	
11/3/2008	75	79					
11/5/2008	60		200	330	900	1100	
11/17/2008	33	49					
11/18/2008	28		18	96	100 J	50 J	
12/2/2008	23	140					
12/3/2008	8 J		11 J	8	38	23	
12/15/2008	81	240					
12/16/2008	77 J		54 J	31 J		46 J	

Table E 8. Fecal coliform results for the California Creek basin tributaries.

Date	Cal-SD1	TribCal-1	TribCal-2	TribCal-3	TribCal-4	TribCal-5	TribCal-0
12/11/2007	2 U	440	610 J	12	14 J	5 J	
12/18/2007	3	20	23	16	49	10	
1/15/2008	3	6	29	160	27 J	32 J	
1/28/2008	1 U	2	59	61	32	26	
2/6/2008	6	5	520	68	65	60	
2/19/2008	1 U	5 J	69	14	32	3	
3/3/2008	1	10	240	2	24	26	
4/30/2008	1 U	74	57	10	200 J	103	7
5/12/2008	1 U	24	320	120	34 J	160	
5/28/2008	63	7	100	3500 J	40 J	210 J	
6/12/2008	28	180	145	92	160 J	120	250
6/24/2008	1 U	dry	330	130	4600 J	80	54
7/7/2008	dry	dry	69	dry	480	2400 J	6
7/21/2008	dry	dry	300	dry	dry	14000 J	
8/4/2008	dry	dry	69	dry	dry	4100	
8/27/2008	88	dry	620 J	dry	2400	1700	1100 J
9/2/2008	44	dry	120	dry	245 J	400	92
9/22/2008	36	dry	790	dry	170	770	
10/14/2008	43	dry	185	dry	54	185 J	120
11/4/2008	6	110	235	3 U	410	115	150
11/17/2008	5	8	33	46	22 J	26	
12/4/2008	8 J	6	57	15.5	6	26	
12/16/2008	1 J	11 J	75 J	32 J	8 J	88 J	3 J

Table E 9. Fecal coliform results for the Cain Creek basin and direct tributaries to the harbor.

Date	Cain-0.1 MF	Cain-0.1 MPN	Cain-SD1	Cain-0.4	Cain-1.3	TribDray-1	Dray-SD4
12/11/2007	260		40	71 J	1 U	8	4
12/18/2007	180 J	540	190	96 J	69	55 J	24
1/15/2008	1200	1700	254.5	1800 J	15	175	123.75
1/28/2008	49/26*	110	140	71	8	29	5
2/6/2008	3200 J	1100	435	2100 J	60	41	74.5 J
2/19/2008	49.5 J	90	51	17 J	2	48	1
3/3/2008	92	70	420	180	31	61	80
4/30/2008	255 J	110	46	450	15 J	84	7
5/12/2008	147	130	74	620	29	340	34.5 J
5/28/2008	170		41	66	41	46	150
6/12/2008	200	350	110	240	83	81	260
6/24/2008	370	240	19	31	215	stagnant	120
7/7/2008	340	350	58	395	stagnant	stagnant	dry
7/21/2008	4800	9200	290	54	stagnant	stagnant	dry
8/4/2008	540	1600	84	1200 J	stagnant	stagnant	dry
8/27/2008	1000	920	110	1600	275	stagnant	dry
9/2/2008	66	205	76	190	stagnant	stagnant	dry
9/22/2008	470	540	340	2050	stagnant	stagnant	220
10/13/2008	1900	1600					
10/14/2008	1565 J		200	1400	200	stagnant	220
11/3/2008	1270 J	1950	830	1050	290		
11/5/2008	156 J		77 J	930	8 U	270	17
11/17/2008	50	49					
11/18/2008	300		140	560	3	11000 G	18.5
12/2/2008	380	340					
12/3/2008	300		18	830	19	26	15.5
12/15/2008	190	155					
12/16/2008	120		36	150	49 J	20	5.5

Detailed results by basin

North Fork of Dakota Creek

Three sub-drainages (D7, D10, and D11) make up the drainage area for the North Fork (NF) of Dakota Creek. Land use within these sub-drainages consists mostly of commercial agriculture and single-family residences, some with smaller "farms" using on-site septic systems. The NF of Dakota Creek originates from a series of wetlands near the Canadian border and flows through low gradient forest and pastures to its confluence with the South Fork of Dakota Creek at Custer School road.

Link to Figure D1 - NF Dakota Basin Map

Table E10 contains FC geometric mean and 90th percentile statistics for the entire study period, as well as for both the wet and dry season.

Table E 10. FC geometric mean and 90th percentile statistics, including wet and dry season, for the North Fork of Dakota Creek basin.

	All samples			Wet Season			Dry Season		
Station ID	**n**	**Geo-mean**	**90th %tile**	**n**	**Geo-mean**	**90th %tile**	**n**	**Geo-mean**	**90th %tile**
1-TribDak-N2	23	207	1446	11	80	589	12	483	1286
1-NF-Dak-2.5	23	144	723	11	85	526	12	234	734
1-TribDak-N1	23	101	645	11	88	365	12	124	1521
1-NF-Dak-0.1	23	85	351	11	76	406	12	94	312

Table E 11. Results of paired t-tests to identify statistically significant changes in FC concentrations and flows between stations in the North Fork Dakota Creek basin.

Stretch	**FC concentration (cfu/100mL)**		**Flow (cubic feet/second)**	
	Mean Change[1]	p-value	Mean Change	p-value
Wet Season				
NFD-2.5 to NFD-0.1	-9	0.60	+5.99	***0.05***
Upstream* to NFD-0.1	n/a	n/a	-1.57	0.69
Dry Season				
NFD-2.5 to NFD-0.1	-140	***0.04***	+0.86	***0.00***
Upstream to NFD-0.1	n/a	n/a	+0.30	0.25

*Upstream = combined flows or FC loads of NFD-2.5, TD-N1, TD-N2.
Bold p-values indicate a significant increase or decrease.

In the wet season, the NF Dakota Creek at the mouth displayed a moderate correlation (r^2=0.42; $p<0.05$) between 72hr antecedent rainfall and FC concentrations. Fecal contamination during wet weather may be tied to infrequent sources:

- During one large storm event (11/4/2008; 72hr rain = 1.60) very high FC counts (2200 cfu/100mL) were observed at the NFD-0.1, as well as the other sites in the watershed.
- During another large storm event (1/15/08; 72hr rain = 1.56) the FC counts were relatively low (88 cfu/100mL) at NFD-0.1 and throughout the watershed.

In the dry season, FC and 72hr rain showed little to no relationship (r^2=0.18; p>0.05). FC contamination during dry weather may result from intermittent sources not related to runoff (direct livestock access to stream, failing septic systems, wildlife, etc).

South Fork of Dakota Creek

The South Fork drainage area consists of 12 sub-drainages (D8-9, D12-19). Land use within these sub-drainages is primarily commercial agriculture with a total of 9 dairies in the SF Dakota basin. Remaining land use is largely rural residential with single-family houses and small "hobby" farms.

Soils in the SF Dakota drainage area are primarily of hydrologic soil group D; exhibiting high water tables, low infiltration rates, and very high runoff potential. Proper storage, application, and drainage of agricultural wastes (manure) are especially important in these types of soils to avoid contamination of surface waters.

Link to Figure D2 - SF Dakota Basin Map

Table E12 contains FC geometric mean and 90th percentile statistics for the entire study period, as well as for both the wet and dry season.

Table E 12. FC geometric mean and 90th percentile statistics, including wet and dry season, for the South Fork of Dakota Creek basin.

	All samples			Wet Season			Dry Season		
Station ID	**n**	**Geo-mean**	**90th %tile**	**n**	**Geo-mean**	**90th %tile**	**n**	**Geo-mean**	**90th %tile**
1-TribDak-S2	14	160	1123	4	n/a	n/a	10	247	815
1-TribDak-S1	16	141	1094	4	n/a	n/a	12	202	1385
1-SFDak-2.2	14	105	1126	4	n/a	n/a	10	141	461
1-SF-Dak-0.2	23	50	290	11	42	480	12	59	133

Table E 13. Results of paired t-tests to identify statistically significant changes in FC concentrations and flows between stations in the South Fork Dakota Creek basin.

Stretch	**FC concentration (cfu/100mL)**		**Flow (cubic feet/second)**	
	Mean Change[1]	p-value	Mean Change	p-value
Dry Season				
SFD-2.2 to SFD-0.2	-82	***0.02***	+0.58 (+57%)	***0.00***
Upstream to SFD-0.2	n/a	n/a	+0.18 (+13%)	0.59

Upper mainstem Dakota Creek

The upper mainstem Dakota Creek basin stretches from the confluence of the NF and SF of Dakota to Dakota Creek at Giles Rd (D-3.1). For the TMDL study it consists of four sub-drainages: D4, D5, D6, and D9 (drains to SF Dakota Creek just downstream of TMDL station at RM 0.2). The land use within this stretch is primarily rural residential and there is a larger proportion of wetlands within these sub-drainages than compared to surrounding ones.

Link to Figure D3 - Upper Mainstem Dakota Basin Map

Table E 14. FC geometric mean and 90th percentile statistics, including wet and dry season, for the Upper Mainstem Dakota Creek basin.

	All samples			Wet Season			Dry Season		
Station ID	n	Geo-mean	90th %tile	n	Geo-mean	90th %tile	n	Geo-mean	90th %tile
1-Dak-4.9	23	63	213	11	63	286	12	64	161
1-TribDak-5	23	58	267	11	28	70	12	114	501
1-Dak-3.1	23	63	198	11	68	257	12	58	160

During both the wet and dry seasons, flow increased significantly from both the confluence of the NF and SF Dakota to Dakota at Behme Rd (D-4.9) and from Dakota at Behme Rd to Dakota at Giles Rd (D-3.1). FC concentrations remained relatively stable indicating that unmeasured surface and groundwater inputs in this stretch had FC concentrations fairly similar to the mainstem of Dakota Creek.

The tributary at Valley View Rd (TD-5), locally known as Haynie Creek, was the only measured input within this stretch. In general, the Haynie Creek drainage had relatively low bacteria concentrations in the wet season (including during both large storm events) and high concentrations in the dry season from July to September.

Tidal mainstem Dakota Creek

Link to Figure D4 -Tidal Mainstem Dakota Basin Map

Table E 15. FC geometric mean and 90th percentile statistics, including wet and dry season, for the Tidal Mainstem Dakota Creek basin.

	All samples			Wet Season			Dry Season		
Station ID	n	Geo-mean	90th %tile	n	Geo-mean	90th %tile	n	Geo-mean	90th %tile
1-Dak-3.1	23	63	198	11	68	257	12	58	160
1-TribDak-3	23	199	585	11	118	274	12	320	800
1-TribDak-4	23	116	524	11	51	112	12	270	1060
1-TribDak-2	23	209	1143	11	98	244	12	422	2496
1-TribDak-1	17	143	601	11	150	438	6	131	947
1-Dak-0.1	22	29	258	11	86	438	11	9	43

Upper mainstem California Creek

The upper mainstem California Creek basin consists of the drainage area upstream of California Creek at Bruce Rd (1-Cal-6.2). The upper mainstem is comprised of five sub-drainages: C7, C9, C10, C13a, and C14. The land use within this basin is primarily agricultural and rural residential.

Table E 16. FC geometric mean and 90th percentile statistics, including wet and dry season, for the Upper Mainstem California Creek basin.

Station ID	All samples			Wet Season			Dry Season		
	n	Geo-mean	90th %tile	n	Geo-mean	90th %tile	n	Geo-mean	90th %tile
1-Cal-6.2	23	119	608	11	54	268	12	243	689

During the wet season, 1-Cal-6.2 exhibited relatively low FC concentrations, with the exception of the two large storm events:

- **150** cfu/100mL on 1/15/2008, with 1.56 inches of rain in the previous 72 hours.
- **1100** cfu/100mL on 11/4/2008, with 1.6 inches of rain in the previous 72 hours.

During the dry season, FC concentrations ranged from 86 to 280 cfu/100mL, with the exception of the two large storm events:

- **1200** cfu/100mL on 8/27/2008, with 0.63 inches of rain in the previous 24 hours.
- **1200** cfu/100mL on 10/14/2008, with 0.63 inches of rain in the previous 24 hours.

Lower mainstem California Creek

The lower mainstem California Creek basin stretches from California Creek at Bruce Rd (1-Cal-6.2) to California Creek at Birch Bay-Lynden Rd (1-Cal-3.1). The lower mainstem is comprised of eight sub-drainages: C8, C6, C5, C4, C3, C3a, C2, and the upper half of C-1. Land use within this bain is primarily agricultural and rural residential.

Link to Figure D5 -Lower Mainstem California Basin Map

Table E 17. FC geometric mean and 90th percentile statistics, including wet and dry season, for the Lower Mainstem California Creek basin.

Station ID	All samples			Wet Season			Dry Season		
	n	Geo-mean	90th %tile	n	Geo-mean	90th %tile	n	Geo-mean	90th %tile
1-Cal-6.2	23	119	608	11	54	268	12	243	689
1-TribCal-4	21	79	721	11	29	124	10	235	1913
1-TribCal-5	23	119	1795	11	24	100	12	525	4460
1-Cal-5.0	22	100	693	10	36	256	12	234	697
1-TribCal-3	16	37	362	11	20	110	5	138	2021
1-Cal-3.1	23	68	351	11	31	149	12	141	404

During the wet season:

- The pattern of FC concentrations on California Creek at Birch Bay-Lynden Rd (1-Cal-3.1) and Valley View Rd (1-Cal-5.0) was similar to the pattern at Bruce Rd (1-Cal-6.2). Again, FC concentrations were relatively low except during the mid-January and early-November storm events in 2008.
- FC concentrations did not increase downstream (actually decreased slightly, though not significantly).

- The three measured tributaries within this stretch (1-TribCal-5, 1-TribCal-4, and 1-TribCal-3) met water quality standards.

During the dry season:
- A significant change in FC concentrations did not occur between 1-Cal-6.2 and 1-Cal-5.0, despite a significant increase in flow and FC load
- 1-TribCal-3, 1-TribCal-4, and 1-TribCal-5 had very high FC concentrations.
- FC concentrations significantly decreased from 1-Cal-5.0 to 1-Cal-3.1, despite the fact that flow did not increase. As a result, the FC load decreased in this stretch (though not significantly).

Tidal mainstem California Creek

The tidal mainstem California Creek basin encompasses the drainage area between California Creek at Birch Bay-Lynden Rd (1-Cal-3.1) and the mouth of California Creek at Drayton Harbor Rd (1-Cal-0.1). The tidal mainstem is comprised of only two sub-drainages: C1 and the lower half of C-1. Land use within this stretch is primarily low density residential, but also includes the golf course which drains primarily via 1-Cal-SD1 and 1-TribCal-0.

Link to Figure D6 -Tidal Mainstem California Basin Map

Table E 18. FC geometric mean and 90th percentile statistics, including wet and dry season, for the Tidal Mainstem California Creek basin.

	All samples			Wet Season			Dry Season		
Station ID	n	Geo-mean	90th %tile	n	Geo-mean	90th %tile	n	Geo-mean	90th %tile
1-Cal-3.1	23	68	351	11	31	149	12	141	404
1-TribCal-2	22	146	520	10	97	421	12	206	714
1-TribCal-1	15	17	148	11	13	93	4	n/a	n/a
1-Cal-0.8	23	34	140	11	37	199	12	31	103
1-TribCal-0	9	53	649						
1-Cal-0.1	23	27	149	11	61	266	12	13	48*
1-Cal-0.1-MPN	22	40	265	10	91	364	12	20	127
1-Cal-SD1	20	6	56	11	3	11	9	15	210*

During the wet season:
- FC concentrations increased slightly (although not significantly) from 1-Cal-3.1 to California Creek at Blaine Rd (1-Cal-0.8) and from 1-Cal-0.8 to the mouth (1-Cal-0.1).
- 1-TribCal-2 contributed the largest measured FC load between 1-Cal-3.1 and 1-Cal-0.8 and FC concentrations at this site violated water quality standards.
- Saltwater heavily influenced FC concentrations at 1-Cal-0.8 (average measured salinity 14.23) and 1-Cal-0.1 (average measured salinity 20.1).

During the dry season:
- FC concentrations decreased significantly from 1-Cal-3.1 to 1-Cal-0.8 and from 1-Cal-0.8 to 1-Cal-0.1 (geomean dropped from 141 cfu/100mL to 13 cfu/100mL). A smaller proportion of

freshwater (lower flows = more saltwater dilution) and low dry season FC concentrations in Drayton harbor were likely responsible for the large decrease.

- Again, 1-TribCal-2 contributed the largest measured FC load source between 1-Cal-3.1 and 1-Cal-0.8 and FC concentrations at this site violated water quality standards.
- The majority of FC load came from upstream of 1-Cal-3.1.

Shoreline Survey Site Descriptions and Results Table

Table E 19. Shoreline survey site names, descriptions, and coordinates.

User Location ID	Location Description	Lat	Long
1-DrayShore-1	12" black plastic pipe near gate to old Drayton Harbor Rd at neck of Semiahmoo spit	48.97664	122.79069
1-DrayShore-2	3 larger seeps; trail was re-graded and seeps installed after 5-27-08	48.97638	122.79053
1-DrayShore-3	concrete culvert embedded in sloping bank along old Drayton Harbor Rd	48.97603	122.79031
1-DrayShore-4	12" metal culvert sticking out of sloping bank along old Drayton Harbor Rd	48.97467	122.78902
1-DrayShore-5	12" concrete culvert embedded in sloping bank along old Drayton Harbor Rd	48.97323	122.78744
1-DrayShore-6	12" metal culvert sticking out of sloping bank along old Drayton Harbor Rd	48.97219	122.78637
1-DrayShore-7	Small discharge sampled on the shore along old Drayton Harbor Rd	48.97158	122.78555
1-DrayShore-8	Small upturned metal pipe sticking out of sloping bank along old Drayton Harbor Rd	48.96996	122.78350
1-DrayShore-9	18" black plastic pipe embedded in sloping bank off old Drayton Harbor Rd	48.96925	122.78297
1-DrayShore-10	1-DrayShore-9 channel on shoreline, within tidal influence	48.96949	122.78263
1-DrayShore-11	Black flexible pipe on shore east of Old Drayton Harbor Rd and Bald Eagle Dr	48.96754	122.77882
1-DrayShore-12	small pipe east of location: 1-DrayShore-11	48.96702	122.77738
1-DrayShore-13	12" white pvc pipe discharging into rock pile	48.96658	122.77576
1-DrayShore-14	small pipe east of location: 1-DrayShore-13	48.96599	122.77399
1-DrayShore-15	Discharge on shore approximately 500 ft NE of Drayton Harbor Rd and Night Heron Dr; also sampled at 36" concrete culvert off Drayton Harbor Rd near lift station #8	48.96493	122.77161
1-DrayShore-16	Outfall embedded in sloping bank off Drayton Harbor Rd; under vegetation	48.96443	122.76967
1-DrayShore-17	Ditch going under Drayton Harbor Rd at large field west of intersection with Shintaffer Rd	48.96350	122.76646
1-DrayShore-18	12" metal pipe extends out from sloping bank; just west of D.Harbor Rd. & Shintaffer Rd.	48.96274	122.76459
1-DrayShore-19	18" concrete culvert under D.Harbor Rd, at Shintaffer Rd.	48.96251	122.76419
1-DrayShore-20	Trickling pipe just east of DS-0 and intersection of Drayton Harbor & Shintaffer Rd	48.96228	122.76386
1-DrayShore-21	18" plastic culvert under Drayton Harbor Rd	48.96175	122.76261
1-DrayShore-22	18" metal culvert under Drayton Harbor Rd	48.96142	122.76161
1-DrayShore-23	24"conrete culvert under Drayton Harbor Rd	48.96101	122.76012
1-DrayShore-24	24" concrete culvert under Drayton Harbor Rd	48.96044	122.75555
1-DrayShore-25	18" PVC pipe 0.3 miles NW of D. Harbor Rd. & Harborview Rd.	48.95943	122.75360
1-DrayShore-26	24" culvert under Drayton Harbor Rd	48.95852	122.75175
1-DrayShore-27	18"concrete culvert under Drayton Harbor Rd	48.95738	122.74891
1-DrayShore-28	24" culvert under Drayton Harbor Rd.	48.95727	122.74834
1-DrayShore-29	24" concrete culvert nr Harborview Rd	48.95726	122.74788
1-DrayShore-30	18"concrete culvert under Drayton Harbor Rd	48.95763	122.74736
1-DrayShore-31	18" metal culvert under Drayton Harbor Rd	48.95790	122.74643
1-DrayShore-32	Culvert under Drayton Harbor Rd, just north of KARI Radio sign	48.95838	122.74518
1-DrayShore-33	Concrete culvert under Drayton Harbor Rd; at Birch Bay visitor info sign	48.95881	122.74411
1-DrayShore-34	18” concrete culvert under Drayton Harbor Rd	48.95920	122.74291
1-DrayShore-35	24” concrete culvert under Drayton Harbor Rd	48.95969	122.74191
1-DrayShore-36	24” concrete culvert under Drayton Harbor Rd	48.96052	122.74012
1-Cal-0.1	Mouth of California Creek	48.96217	122.73289
1-Cal-SD1	Storm drain at California Creek	48.96230	122.73235

User Location ID	Location Description	Lat	Long
1-TribDray-1	Mouth of trib to Drayton Harbor@ Hall & Dearborn	48.96813	122.73312
1-Dak-0.1	Dakorta Creek @ SR 548/Blaine Rd	48.97231	122.72936
1-DrayShore-37	Small channel on north bank of Dakota Creek at the mouth, west of SR548	48.97270	122.72905
1-DrayShore-38	12"metal pipe sticking out of bank along shoreline	48.97783	122.73893
1-DrayShore-39	12" black pvc pipe sticking out of bank along shoreline	48.97837	122.73918
1-DrayShore-40	18" culvert embedded in bank	48.98116	122.73932
1-Dray-SD4	36" culvert on harbor shoreline, due east of Peace Portal Dr and Albert St.	48.98246	122.73935
1-DrayShore-41	36" culvert under railroad tracks due west of Madison & Peace Portal	48.98324	122.74056
1-DrayShore-42	24" culvert at the top of the bank	48.98544	122.74685
1-DrayShore-43	Outfall south of intersection of Peace Portal Drive and Harrison	48.98547	122.74686
1-DrayShore-44	36" metal culvert approximately 200 feet SW of Peace Portal and 4th	48.98618	122.74876
1-DrayShore-45	12" rusty culvert embedded in bank with orange discolartion in the channel	48.98620	122.74916
1-DrayShore-46	12" concrete culvert embedded in bank; partially filled in with gravel and silt	48.98693	122.75032
1-DrayShore-47	36" cuvlert approximately 400 feet west of Peace Portal and 3rd	48.98771	122.75130
1-DrayShore-48	Culvert discharging to east end of Blaine marina near the breakwater	48.99301	122.75269
1-DrayShore-49	Small channel discharges to east end of Blaine marina next to boat ramp	48.99365	122.75336
1-Cain-0.01	Mouth of Cain Creek; 60" culvert off of Marine Dr, just north of boatyard	48.99697	122.75463
1-Cain-SD1	Storm drainage outfall to Semiahmoo Bay, just north of the mouth of Cain Creek	48.99712	122.75439

Table E 20. Fecal coliform and flow results for shoreline survey sites.

User Location ID	January 14th, 2008		May 27th, 2008		January 12th-13th, 2009	
	FC (cfu/100mL)	Flow (ft^3/second)	FC (cfu/100mL)	Flow (ft^3/second)	FC (cfu/100mL)	Flow (ft^3/second)
1-DrayShore-1	490	0.01				
1-DrayShore-2					21	0.04
1-DrayShore-3	9	0.01				
1-DrayShore-4	75(46)	0.04	180(240)	0.01	2	0.01
1-DrayShore-5	34	0.03			54	0.01
1-DrayShore-6	28	0.13	25	0.01	4	0.11
1-DrayShore-7			65	0.01	6	0.09
1-DrayShore-8			1	0.01		
1-DrayShore-9	28	3.15	21	0.01	51	0.91
1-DrayShore-10	220	1.96				
1-DrayShore-11	1	0.01				
1-DrayShore-12	1	0.01				
1-DrayShore-13	56	0.82				
1-DrayShore-14	6	0.01				
1-DrayShore-15	140	2.92			48	1.46
1-DrayShore-16	8	0.82				
1-DrayShore-17	60	1.79			36	0.44
1-DrayShore-18	3400	0.06	7	0.01	17	0.01
1-DrayShore-19	280(240)	4.96	44	0.01	10	0.56
1-DrayShore-20	1000	0.02	110	0.01		
1-DrayShore-21	160	0.3	590	0.01	4	0.1
1-DrayShore-22	35	0.2	11	0.01	3	0.04
1-DrayShore-23	83	2.46	560	0.01	14	0.56

User Location ID	January 14th, 2008		May 27th, 2008		January 12th-13th, 2009	
	FC (cfu/100mL)	Flow (ft^3/second)	FC (cfu/100mL)	Flow (ft^3/second)	FC (cfu/100mL)	Flow (ft^3/second)
1-DrayShore-24	140	0.3			220	0.04
1-DrayShore-25	400	0.28			610	0.02
1-DrayShore-26	35	5.18	270	0.01	5	0.96
1-DrayShore-27	3	0.48			2	0.01
1-DrayShore-28	63	6.75	41	0.01	120	1.56
1-DrayShore-29	110	11.54	2(2)	0.03	6	1.82
1-DrayShore-30	51	3.85			1	0.13
1-DrayShore-31	8	0.65			1	0.06
1-DrayShore-32	1	0.18			1	0.02
1-DrayShore-33	41	0.27	1	0.01	1	0.01
1-DrayShore-34	110	0.54			5	0.04
1-DrayShore-35	22	0.44			6	0.03
1-DrayShore-36	27	0.54	3	0.01		
1-Cal-0.1	230(700)		64(78)		29	
1-Cal-SD1	33	5.81	255	0.38	1	0.79
1-TribDray-1	230	15.38	160	0.02	31	1.68
1-Dak-0.1	380(240)		48(79)		29	
1-DrayShore-37			25	0.01		
1-DrayShore-38			11	0.01	51	0.13
1-DrayShore-39			160(170)	0.01	10	
1-DrayShore-40			26	0.01	7	0.07
1-Dray-SD4	220	14.47	180	0.05	21	1.51
1-DrayShore-41	330	0.69	7	0.04	4	0.94
1-DrayShore-42					3	0.01
1-DrayShore-43			1	0.01	2	0.06
1-DrayShore-44					3	0.01
1-DrayShore-45			3	0.01	1	0.01
1-DrayShore-46					1	0.01
1-DrayShore-47			8	0.01	5	0.28
1-DrayShore-48			79	0.02	1	0.17
1-DrayShore-49	64	0.89	290	0.01	7	0.03
1-Cain-0.01	1650	34.14	250(350)	0.38	50	3.63
1-Cain-SD1	720	2.84	53	0.03	11	0.25

Values in parentheses are field replicate results

Continuous Hydrolab deployment results

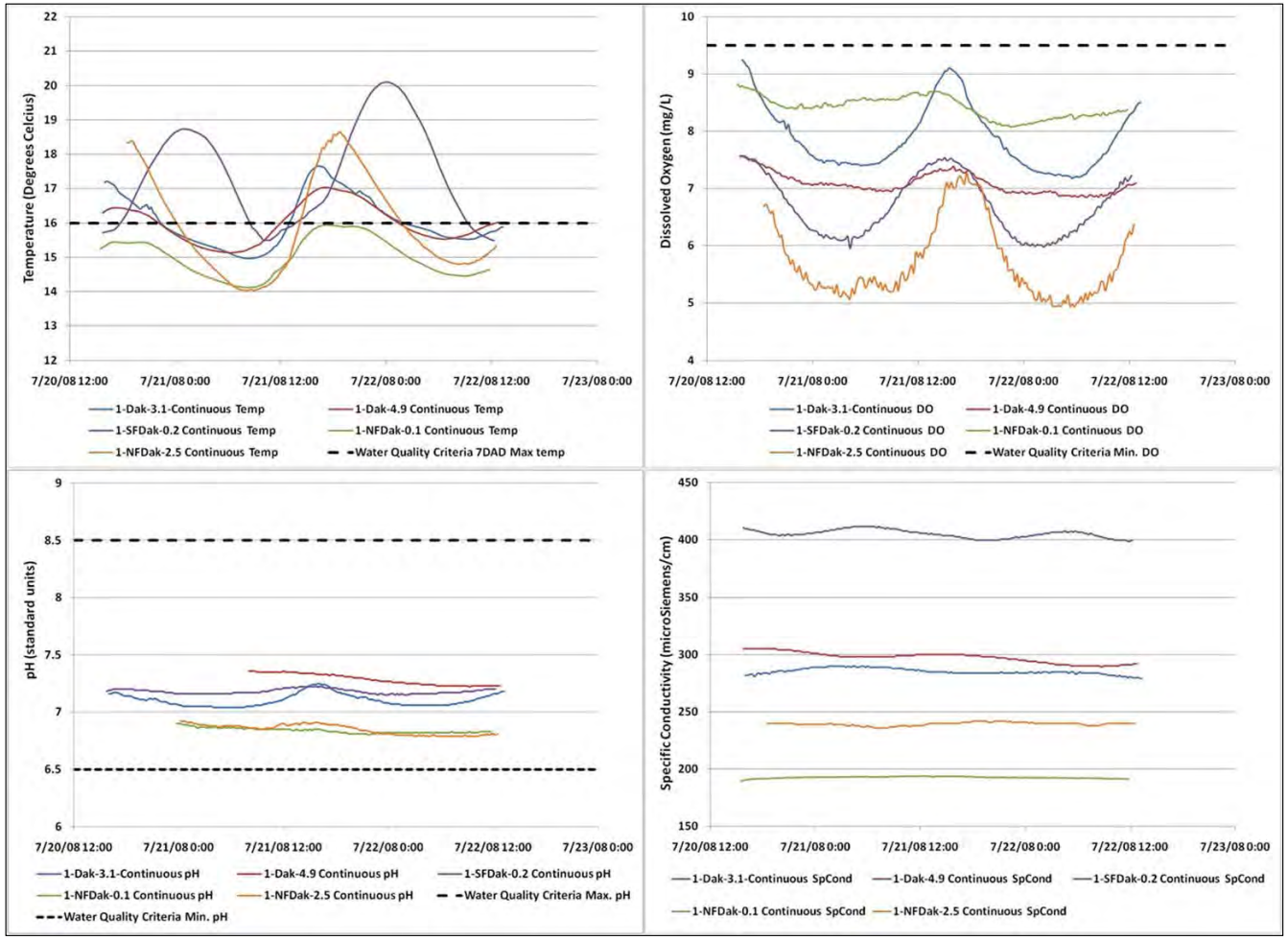

Figure E 1. Continuous data plots for the Dakota Creek basin, including applicable water quality standards.

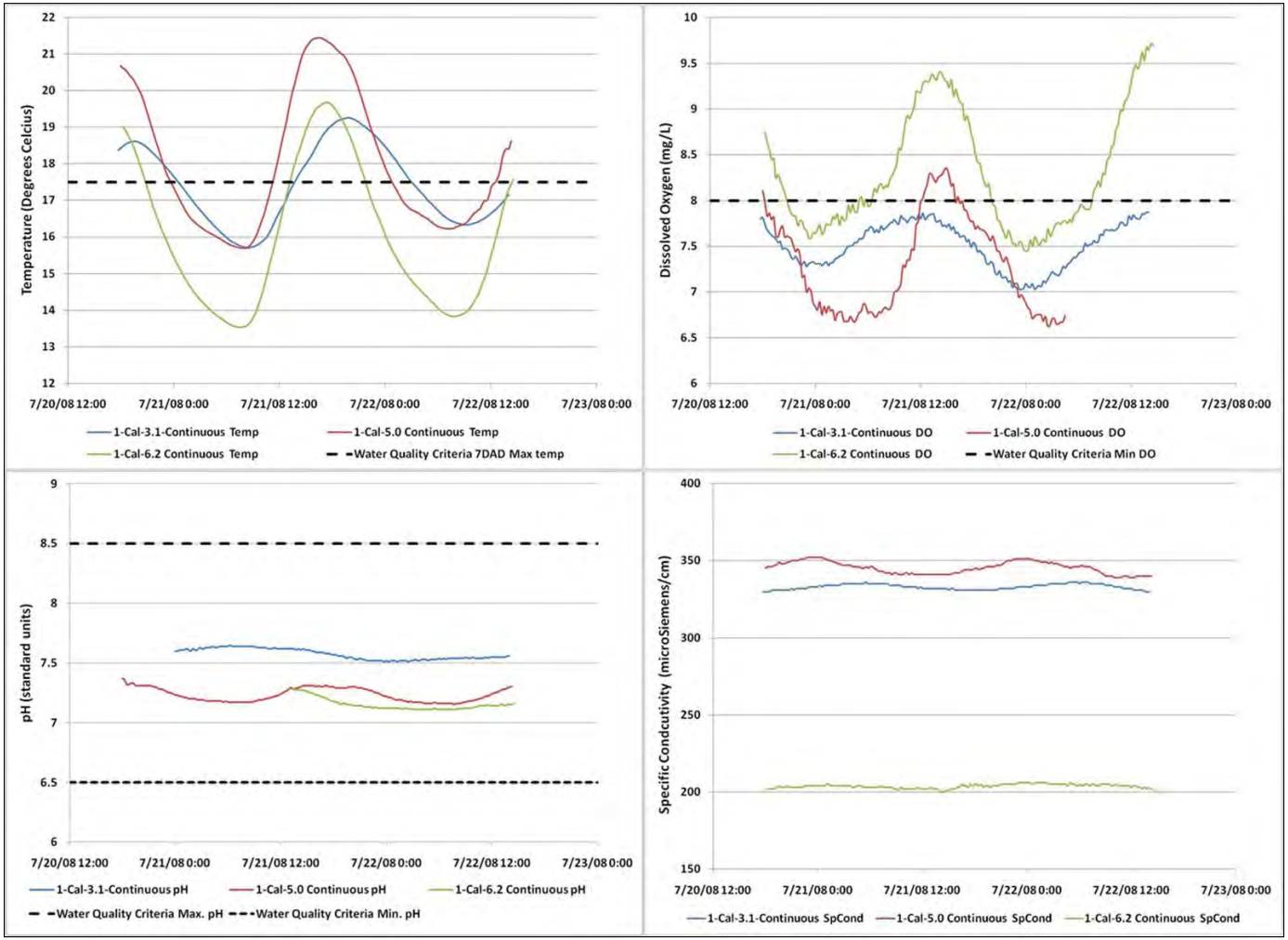

Figure E 2. Continuous data plots for the California Creek basin, including applicable water quality standards.

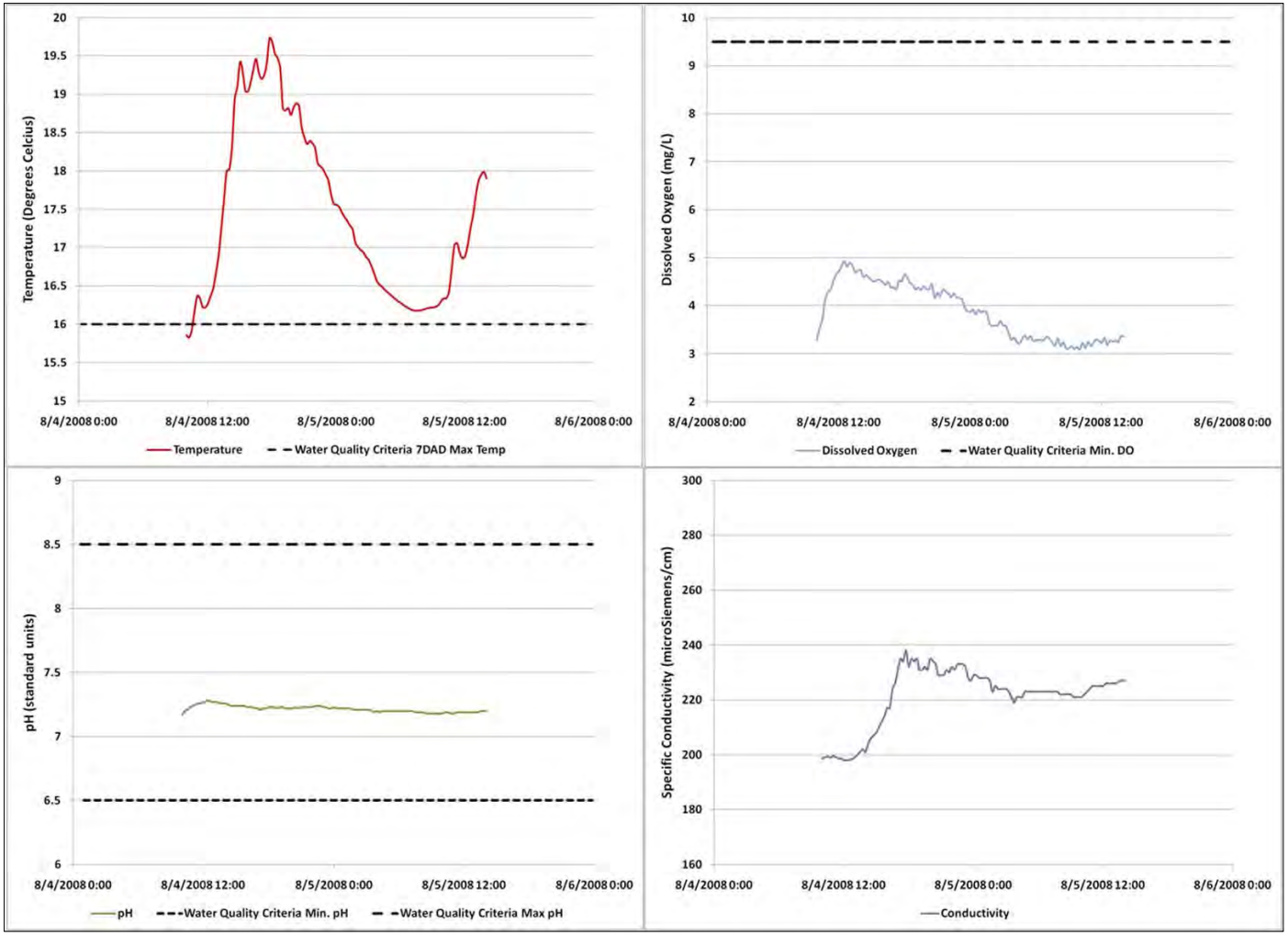

Figure E 3. Continuous data plots for the Cain Creek (1-Cain-0.4), including applicable water quality standards.

Appendix F: Statistical Rollback Procedure

The roll-back procedure is as follows:

- A check was made to make sure the FC bacteria data fit a log-normal distribution at each sampling location. WQHYDRO® (Aroner, 2007) was used to test the FC bacteria data for log-normal distribution fit.
- An Excel® (Microsoft, 2006) spreadsheet was used to calculate the geometric mean of the data.
- The 90th percentile of the data was estimated by using the following statistical equation (the 90th percentile value of samples was used in this TMDL evaluation as an estimate for the "no more than 10% samples exceeding …." criterion in the FC bacteria standard (WAC 173-201A)).

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

where: μ_{log} = mean of the log transformed data

σ_{log} = standard deviation of the log transformed data

- The target percent reduction required was set as the highest of the following two resulting values:

$$\text{Target percent reduction} = \left[\frac{observed\ 90th\ percentile - 200\ cfu/100mL}{observed\ 90th\ percentile} \right] x100$$

$$\text{Target percent reduction} = \left[\frac{observed\ geometric\ mean - 100\ cfu/100mL}{observed\ geometric\ mean} \right] x100$$

Appendix G: Microbial Source Tracking Results

Freshwater microbial source tracking (MST) results

Table G1 summarizes the results for the HSPCR MST samples collected during the TMDL. FC concentrations and loads measured for the TMDL are included for reference.

Table G 1. HSPCR microbial source tracking results in the Dakota Creek basin.

Site	Date	FC/100mL	Discharge (ft^3/sec)	FC load (billion cfu/day)	PCR Code	Bacteroides marker
1-TribDak-N2	9/2/2008	180	0.152	0.67	A	
1-NF-Dak-2.5	9/2/2008	140	0.109	0.37	GB	
1-TribDak-2	9/2/2008	2800	0.036	2.47	H	HF134
1-TribDak-S1	9/2/2008	170	0.041	0.17	A	
1-TribDak-S2	9/2/2008	31	0.047	0.04	A	
1-TribDak-S2	9/21/2008	170	0.022	0.09	H	HF183
1-TribDak-S1	9/21/2008	970	0.036	0.85	A/dupGB	
1-TribDak-N2	9/21/2008	490	0.180	2.16	GB	
1-NF-Dak-2.5	9/21/2008	210	0.056	0.29	H	HF134
1-TribDak-2	9/22/2008	280	0.027	0.19	H	HF134
1-TribDak-S2	10/13/2008	240	0.040	0.23	GB	
1-TribDak-S1	10/13/2008	23	0.060	0.03	GB	
1-TribDak-N2	10/13/2008	670	0.285	4.68	A	
1-NF-Dak-2.5	10/13/2008	3400	0.381	31.71	GB	
1-TribDak-N1	10/13/2008	980	0.019	0.46	H	HF134
1-TribDak-2	10/14/2008	1900	0.183	8.50	GB	
1-TribDak-1	10/14/2008	400	0.004	0.04	GB	
1-TribDak-S2	11/4/2008	1400	5.396	184.90	R	CF128
1-TribDak-S1	11/4/2008	390	1.077	10.28	R	CF128
1-TribDak-N2	11/4/2008	3300	5.939	479.45	R	CF128
1-NF-Dak-2.5	11/4/2008	3700	32.005	2897.09	GB	
1-TribDak-2	11/5/2008	230	0.952	5.36	A	
1-TribDak-1	11/5/2008	54	0.042	0.06	GB	
1-TribDak-S2	12/2/2008	50	4.696	5.74	GB	
1-TribDak-S1	12/2/2008	62	2.792	4.23	GB	
1-TribDak-N2	12/2/2008	67	2.635	4.32	A	
1-NF-Dak-2.5	12/2/2008	67	13.696	22.45	A/dupGB	
1-TribDak-N1	12/3/2008	170	1.074	4.46	GB	
1-TribDak-2	12/3/2008	180	2.112	9.30	GB	
1-TribDak-1	12/3/2008	84	0.273	0.56	GB	

EPA PCR Codes: A= Absent; GB= General Bacteroides; H= Human; R=Ruminant

Comment [SLH12]: A means no bacterioides present? GB means Not human or Ruminant or could be one of those subsets just doesn't have marker?

Table G2 summarizes the results for the HSPCR MST samples collected during the TMDL. FC concentrations and loads measured for the TMDL are included for reference.

Table G 2. HSPCR microbial source tracking results in the California Creek basin.

Site	Date	FC/100mL	Discharge (ft^3/sec)	FC load (billion cfu/day)	PCR Code	Bacteroides marker
1-TribCal-5	9/2/2008	400	0.070	0.68	GB	
1-TribCal-4	9/2/2008	240	0.002	0.01	GB	
1-TribCal-2	9/2/2008	120	0.026	0.08	R	
1-Cal-6.2	9/2/2008	180	0.815	3.59	GB	
1-TribCal-5	9/22/2008	770	0.031	0.59	GB	
1-TribCal-4	9/22/2008	170	0.005	0.02	GB	
1-TribCal-2	9/22/2008	790	0.015	0.29	H	HF134
1-Cal-6.2	9/22/2008	140	0.550	1.88	GB	
1-Cal-5.0	9/22/2008	220	1.800	20.45	GB	
1-TribCal-5	10/14/2008	130	0.165	0.53	A	
1-TribCal-4	10/14/2008	54	0.014	0.02	H	HF134
1-TribCal-2	10/14/2008	150	0.070	0.26	H	HF183
1-Cal-6.2	10/14/2008	1200	1.055	30.97	GB	
1-Cal-5.0	10/14/2008	830	3.900	79.19	GB	
1-TribCal-5	11/4/2008	63	1.264	1.95	A	
1-TribCal-4	11/4/2008	410	0.283	2.84	H	HF183
1-TribCal-3	11/5/2008	3	0.401	0.03	A	
1-TribCal-2	11/5/2008	220	0.454	2.44	A	
CA14	11/5/2008	700	n/a	n/a	R	CF183
1-TribCal-5	12/3/2008	26	1.150	0.73	A	
1-TribCal-4	12/3/2008	6	0.420	0.06	A	
1-TribCal-3	12/3/2008	24	3.772	2.21	GB	
1-TribCal-2	12/3/2008	57	1.780	2.48	GB	
CA14	12/3/2008	182	n/a	n/a	GB	

EPA PCR Codes: A= Absent; GB= General Bacteroides; H= Human; R=Ruminant

Table G3 summarizes the results for the HSPCR MST samples collected during the TMDL. FC concentrations and loads measured for the TMDL are included for reference.

Table G 3. HSPCR microbial source tracking results in the Cain Creek basin.

Site	Date	FC/100mL	Discharge (ft^3/sec)	FC load (billion cfu/day)	PCR Code	Bacteroides marker
1-Cain-0.01	9/2/2008	66	0.173	0.28	GB	
1-Cain-SD1	9/2/2008	76	0.049	0.09	H	HF134
1-Cain-0.01	9/22/2008	470	0.111[1]	1.276	GB	
1-Cain-SD1	9/22/2008	340	0.008	0.07	A	
1-Cain-0.01	10/14/2008	930	0.615	14.00	GB	
1-Cain-SD1	10/14/2008	200	0.009	0.05	GB	
1-Cain-0.01	11/5/2008	92	0.686[1]	1.544	GB	
1-Cain-SD1	11/5/2008	77	0.137	0.26	A	
1-Cain-0.01	12/3/2008	300	2.383	17.49	GB	
1-Cain-SD1	12/3/2008	18	0.471	0.21	GB	

[1]Flow from 1-Cain-0.4; due to tidal influence at 1-Cain-0.1

EPA PCR Codes: A= Absent; GB= General Bacteroides; H= Human; R=Ruminant

Marine microbial source tracking (MST) results

Table G4 summarizes the results for the HSPCR MST samples collected during the TMDL. FC concentrations and loads measured for the TMDL are included for reference.

Table G 4. Microbial source tracking results for FC concentrations (analyzed by WADOH) and host-specific polymerase chain reaction samples (analyzed by EPA-MEL).

Site	Date	FC MPN/100mL	PCR Code	Bacteroides marker
Marina-1	9/2/2008	33	n/a	
Marina-1	9/22/2008	33	n/a	
Marina-1	10/14/2008	49	n/a	
Marina-1	11/5/2008	170	n/a	
Marina-1	12/3/2008		n/a	
Marina-1	1/13/2009	240	n/a	
Marina-3	9/2/2008	33	n/a	
Marina-3	9/22/2008	11	n/a	
Marina-3	10/14/2008	170	n/a	
Marina-3	11/5/2008	13	n/a	
Marina-3	12/3/2008		n/a	
Marina-3	1/13/2009	920	n/a	
Marina-D	9/2/2008	11	GB	
Marina-D	9/22/2008	70	HR	HF183,CF128
Marina-D	10/14/2008	23	GB	
Marina-D	11/5/2008	130	GB	
Marina-D	12/3/2008	49	GB	
Marina-D	1/13/2009	540	n/a	
Marina-Q	9/2/2008	49	GB	
Marina-Q	9/22/2008	17	A	
Marina-Q	10/14/2008	33	GB	
Marina-Q	11/5/2008	240	A	
Marina-Q	12/3/2008	12	GB	
Marina-Q	1/13/2009	130	n/a	
Marina-R	9/2/2008	33	H	HF134
Marina-R	9/22/2008	70	A	
Marina-R	10/14/2008	920	GB	
Marina-R	11/5/2008	49	GB	
Marina-R	12/3/2008	240	GB	
Marina-R	1/13/2009	920	n/a	

EPA PCR Codes: A= Absent; GB= General Bacteroides; H= Human; R=Ruminant

A-1. Semiahmoo Bay and Semiahmoo Spit shoreline survey data.

Station Id	Date	Time	Temp °C	Discharge (ft^3/sec)	Conductance (mS/cm)	Dissolved oxygen (mg/L)	[2]	Fecal coliform/100mL (MF)	Fecal coliform load (cfu/day)	Fecal coliform/100 mL (MPN)	MST Id	Comments
CC0.01	6/4/2009	0930	15.0	0.126	0.862	7.02		50	1.54E+08			
(QA1)CC0.01	6/4/2009	0930	14.9		0.927	6.99		76				
CCSD	6/4/2009	1030	16.1	0.024	8.216	4.46		110	6.46E+07			
CCSD	6/4/2009	1030		0.02								
CAN1	6/4/2009	1115						50				
CAN2	6/4/2009	1120						32				
SD1	6/4/2009	1155	13.0	0.01	0.573	9.51	<	2	4.89E+05			
SD2	6/4/2009	1125	14.0	0.004	0.348	9.08		50	4.89E+06			
MD1	6/4/2009	1230		no flow								
MD2	6/4/2009	1245	17.2	inadequate flow to measure	2.508	6.49		66				
SS1	6/4/2009	1350		no flow								
SS2	6/4/2009	1355		no flow								
SS3	6/4/2009	1357		no flow								
SS4	6/4/2009	1430		flow inadequate to measure								
CC1.3	7/7/2009	0905		no flow								
CC0.4	7/7/2009	0930	14.5	0.157	0.328	6.16		1,480	5.68E+09		H(HF134)	
(QA1)CC0.4	7/7/2009	0930	14.9					1,760	0.00E+00			
CC0.01	7/7/2009	1005	15.1	0.12	2	7.18		980	2.88E+09	900	H(HF134,HF183)	
CCSD	7/7/2009	1025	14.8	0.036	6.438	4.56		110	9.69E+07		H(HF183)	
SD2	7/7/2009	1105		no flow								
SD1	7/7/2009	1120	14.4	0.06	0.601	10.23		18	2.64E+07		R(CF128),LD H(HF183)/R(CF128))	
SD0.5	7/7/2009	1135		no flow								
MD1	7/7/2009	1140		no flow								
MD2	7/7/2009	1150		no flow								
SS1	7/7/2009	1300		no flow								
SS2	7/7/2009	1305		no flow								
SS3	7/7/2009	1310		no flow								
SS4	7/7/2009	1225		flow inadequate to measure								
SS5	7/7/2009	1315		beach seep			<	2				
PC1	7/7/2009	1150									H(HF134)/R(CF128)	MST positive control, Blaine STP settled influent
CC1.3	9/17/2009	0945		stagnant								
CC0.4	9/17/2009	1005	13.3	0.034	0.386	4.84		2,000	1.66E+09			
CC0.2	9/17/2009	1025	13.8	0.033	0.438	4.73		2,400	1.94E+09			
CC0.01	9/17/2009	1050	14.5	tidal eddy	10.560	7.35		1800		1400		
QA1(CC0.01)	9/17/2009	1050						2000				
CCSD	9/17/2009	1100	15.9	0.037	4.298	5.58		280	2.53E+08			
SD2	9/17/2009	1140	16.1	0.02	0.741	9.27		88	4.31E+07			
QA2(SD2)	9/17/2009	1145	16.1	0.018	0.738	9.22		130	5.72E+07			
SD1	9/17/2009	1200		no flow								
MD1	9/17/2009	1220		no flow								
MD2	9/17/2009	1225		no flow								
SS1	9/17/2009	1245		no flow								
SS2	9/17/2009	1250		submerged								
SS3	9/17/2009	1255		no flow								
SS4	9/17/2009	1315		no flow								
SS5	9/17/2009	1320		trickle inadequate flow to measure								
CC1.3	10/27/2009	0915	8.2	0.091	0.358	6.83		36	8.01E+07		H(HF183)	
CC1.3A	10/27/2009	0920	7.4	0.269	0.169	6.57		48	3.16E+08		GB(BAC32)	
CC0.4	10/27/2009	1005	9.7	1.222	0.255	9.38		120	3.59E+09		R(CF128)	
QA1(CC0.4)	10/27/2009	1005						140	0.00E+00			
CC0.2	10/27/2009	1020	9.8	NM	0.356	9.45		110				
CC0.01	10/27/2009	1035	10.0	1.37	0.302	9.9		110	3.69E+09	80	GB(BAC32)	
CC0.01(QAflow	10/27/2009	1035	9.9	1.49	0.307	9.98						
CCSD	10/27/2009	1050	12.6	0.15	0.808	8.47		76	2.79E+08		H(HF183)/R(CF128)	
SD1	10/27/2009	1120	12.7	0.086	0.498	9.44		92	1.94E+08		H(HF183)/R(CF193)	

Station Id	Date	Time	Temp °C	Discharge (ft^3/sec)	Conductance (mS/cm)	Dissolved oxygen (mg/L)	2	Fecal coliform/100mL (MF)	Fecal coliform load (cfu/day)	Fecal coliform/100 mL (MPN)	MST Id	Comments
SD2	10/27/2009	1130	8.8	0.053	0.187	11		240	3.11E+08			
MD1	10/27/2009	1200		Seep, inadequate to measure								
MD2	10/27/2009	1215		No flow								
SS1	10/27/2009	1245		No flow, evidence of recent flow in sand								
SS2	10/27/2009	1250		submerged								
SS3	10/27/2009	1253		No flow								
SS6	10/27/2009	1300		No flow								
SS7	10/27/2009	1310		No flow, standing water								
SS4	10/27/2009	1320	11.3	0.202	0.334	10.22		640	3.16E+09		A (LD, H(HF183)/R(CF128)	
(QA2)SS4	10/27/2009	1320						520				
SS8	10/27/2009	1345	10.2	inadequate to measure	0.142	9.18		110			H(HF183)/R(CF128)	
CC1.3	11/11/2009	1225	8.3	0.074	0.202	7.88		4	7.24E+06		H(HF183)	
(QAfield)CC1.3	11/11/2009	1225	8.3		0.203	7.81						
CC1.3A	11/11/2009	1215	8.8	0.558	0.168	9.82		10	1.37E+08		GB(BAC32)	
(QA1)CC1.3A(flow)	11/11/2009	1215		0.556								
(QA2)CC1.3A	11/11/2009	1215						8				
CC0.4	11/11/2009	1245	9.1	1.2	0.235	10.44		230	6.75E+09		H(HF183)	
CC0.2	11/11/2009	1325	9.1	1.21	0.224	10.43		190	5.62E+09		H(HF183)/R(CF128, CF193)CF128, LD H(HF183)/R(CF128)	
CC0.01	11/11/2009	1015	7.8	0.91	34.110	9.96		220	4.90E+09	240	H(HF183)	tidal influence
CCSD	11/11/2009	1020	11.1	0.077	0.954	9.65		14	2.64E+07		H(HF183),(LD HHF183/RCF128,CF	
SD1	11/11/2009	1100	11.8	0.08	0.491	10.21		1300	2.54E+09		H(HF183)	
SD2	11/11/2009	1115	8.5	0.07	0.214	11.44		4	6.85E+06		H(HF183)/R(CF128)	
QA1SD2	11/11/2009	1115		no flow				4				
MD1	11/11/2009	1150		no flow								
MD2	11/11/2009	1200		no flow								
SS1	11/11/2009	0945		no flow								
SS2	11/11/2009	0950		no flow								
SS3	11/11/2009	0952		no flow								
SS6	11/11/2009	0930		no flow								
SS7	11/11/2009	0945		no flow								
SS4	11/11/2009	0850	10.0	0.031	0.278	7.24		230	1.74E+08		H(HF183)/R(CF128, CF193)	
SS8	11/11/2009	0915	7.9	inadequate to measure	0.385	10.88		20			H(HF183)	
PC3	11/11/2009	1250									R(CF128)	HSPCR positive control sample 3 cow feces, Lummi Island
CC1.3A	12/9/2009	0845	0.0	0.28	0.162	12.82		26	1.78E+08		R(CF193)	
(QA1) CC1.3A	12/9/2009	0845		0.279				24	1.64E+08			
CC1.3	12/9/2009	0900	0.0	0.01	0.34	10.58		68	1.66E+07		GB(BAC32)	
CC0.4	12/9/2009	0930	2.1	0.515	0.252	15.27		58	7.31E+08		H(HF134,HF183)/R(CF193)	
CC0.2	12/9/2009	1010	1.9	0.508	0.258	15.29		380	4.72E+09		GB(BAC32)	
CC0.01	12/9/2009	1030	2.3	0.239	1.298	15.18		300	1.75E+09		R(CF128),LD,H(HF183)	tidal influence flow calculated
CCSD	12/9/2009	1045	9.4	0.143	0.413	12.13		4	1.40E+07		H(HF183)	
SD1	12/9/2009	1130	9.6	0.031	0.511	12.47		2	1.52E+06		R(HF128)	
(QA2) SD1	12/9/2009	1130	9.6		0.512	12.4		16				
SD2	12/9/2009	1110	3.9	0.021	0.284	15.42		12	6.17E+06		H(HF183)/R(CF128)	
SD0.5	12/9/2009	1140		no flow								
MD1	12/9/2009	1150		no flow								

QUALITY ASSURANCE PROJECT PLAN

July 2009

PROJECT NAME: **Addendum to Drayton Harbor Watershed Fecal Coliform TMDL; Phase I, Water Quality Study Design**

Prepared by:

Hirsch Consulting Services
Lummi Island, Washington
(360)-758-4046 (HirschServ@aol.com)

Prepared for:

Nooksack Indian Tribe Natural Resources Department

Approved by:

Nooksack Indian Tribe

_____ Date _____
Llyn Doremus, hydrologist

Washington Department of Ecology

_____ Date _____
Nuri Matheiu

EPA

_____ Date _____
Gretchen Hayslip

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APPENDIX C Marine Water Sampling Procedure

APPENDIX D QAPP for Drayton Harbor Microbial Source Tracking Pilot Study

Background

The Nooksack Tribe (NIT) relies upon fish and shellfish harvested from all the tribe's usual and accustomed fishing locations: the Nooksack River Basin, Drayton Harbor, and the northern shore lands of the San Juan Islands and Puget Sound. In particular, the waters within Drayton Harbor and outside the Semiahmoo Spit are Treaty protected shellfish harvest areas of NIT. The consumption of fish and shellfish as a primary dietary constituent requires that fish are free of bio-accumulated organic compounds, pathogens and metals. Fish and shellfish must live in high quality waters to avoid prolonged exposure to, consumption and accumulation of these toxins. Restoring and maintaining high water quality conditions throughout the Nooksack basin is essential for the health of Tribal members who consume fish and shellfish. Improving water quality in these regions is fundamental to the continued and future tribal harvest of Chinook salmon and other tribal fish and subsistence seafoods.

Through the EPA funded Section 106 Program, the Nooksack Indian Tribe (NIT) is collecting data to augment the Washington Department of Ecology's (Ecology) Drayton Harbor Bacteria Total Maximum Daily Load (TMDL) evaluation. These additional data will provide information on fecal bacteria inputs from potential sources around the mouth of Drayton Harbor and along the shoreline of Semiahmoo Bay northward to the Canadian border. This Quality Assurance Project Plan (QAPP) describes three of the study components which include: a series of shoreline surveys; marine sampling adjacent to the Semiahmoo Bay shoreline from the Canadian border south to Drayton Harbor; circulation studies of the Cain Creek outflow. The framework for the Drayton Harbor TMDL, data collection already underway, and methods used for data collection, as well as a description of the Drayton Harbor watershed and its history are presented in the Drayton Harbor Watershed Fecal Coliform Total Maximum Daily Load: Phase 2, Water Quality Study Design (Quality Assurance Project Plan), (Mathieu and Sargeant, 2008).

Project Goal and Study Objectives

Project goal

The project goal is to collect information on bacteria content in fresh and marine waters that can be used to assess bacteria sources that may originate in the vicinity of the mouth of Drayton Harbor, augmenting the Washington Department of Ecology's (Ecology) Drayton Harbor Bacteria TMDL study. The project will generate data on fecal bacteria content in waters near potential sources around the mouth of Drayton Harbor and along the shoreline of Semiahmoo Bay northward to the Canadian border, and data for use in interpreting the potential transport routes of bacteria discharged in these areas.

Study objectives

Objectives of the proposed study are as follows:

- Characterize fecal coliform content in freshwater shoreline drainages discharging along the Semiahmoo Bay and Semiahmoo Spit during a dry and a wet season.
- Characterize marine near-shore fecal coliform density during flood tide along the Semiahmoo Bay shoreline to the Drayton Harbor mouth during a dry and a wet season.
- Characterize circulation of the Cain Creek outflow during ebb tide.

Study design

Three study components will be conducted near the mouth of Drayton Harbor from June 2009 through December 2009 to collect information on dry and wet season conditions. The project data collection activities include:

- freshwater shoreline surveys,
- marine near-shore water quality monitoring,
- circulation studies of the Cain Creek outflow.

The anticipated schedule for project data collection activities is shown in Table 1.

Fresh Water Shoreline Surveys

Shoreline discharges will be sampled along the Semiahmoo Bay shoreline from the Canadian border south to Blaine Harbor and along Semiahmoo Spit six times throughout the course of the project (Table 1). Approximately 20 survey locations will be sampled. Specific sample locations will be selected during the first shoreline survey based on locations of stormwater discharge pipes from the City of Blaine and other indicators of discharge along the shoreline. Fecal coliform loading will be assessed by instantaneous instream flow measurement collected using a Swoffer current meter and laboratory analysis of fecal coliform content in fresh water samples. A water quality sensor (YSI 556) will be used to measure temperature, specific conductivity, and dissolved oxygen content (DO) at the time of sample collection. Selected sample locations will be recorded during the first sampling event using a handheld Garmin Mariner eTrex GPS unit.

Locations where significant fecal bacteria discharge are identified during the dry season shoreline surveys will be selected for follow-up microbial source tracking sampling and analyses during wet season sampling events using the *Bacteroides* host specific polymerase chain reaction (HSPCR) analysis. The EPA Region 10 Laboratory (Manchester Lab) will analyze samples collected at high fecal bacteria detection survey sites to assist in identifying fecal coliform discharge sources. HSPCR analyses will be conducted according to the EPA QAPP composed for previous MST analyses completed on samples from Drayton Harbor (EPA, 2006), attached as Appendix D. These microbial source tracking (MST) analyses will constitute Phase 3 of the characterization work completed in the Drayton Harbor watershed by Ecology and Whatcom County.

Marine near shore sampling

Marine sampling adjacent to the Semiahmoo Bay shoreline will be conducted during five events over the study period. Samples will be collected from the Canadian border to the mouth of Drayton Harbor by

boat to assess fecal coliform input to Drayton Harbor that may affect DOH station 15 on incoming, flood tides. A series of (about 5-8) sampling stations will be established for fecal coliform sampling from the border monument south adjacent to the shoreline to Marine Drive, and including DOH station 15. Protocols used by the Washington Department of Health (DOH) in the Systematic Random Sampling (SRS) program (DOH, 1997) will be followed including sampling for salinity and temperature using a YSI 556 water quality sensor or a refractometer. Sampling locations will be recorded by GPS during the first sampling event.

Cain Creek Circulation

Cain Creek outflow will be monitored during five ebb tides to determine the route taken by floats/drogues during a six to eight hour period. A combination of numbered grapefruits (floats) and 1-ft deep drogues will be deployed at the mouth of Cain Creek at the beginning of the ebb tide (approximately 7-8 ft tidal elevation). The 1-ft drogue is modeled after drogues that have been used in the past by the Washington State Department of Health Shellfish Program and deployed in numerous circulation studies in Drayton Harbor. It is constructed of 12" X 16" (3/16th inch thick) aluminum crossed vanes suspended below a yellow crab-pot type float.

Drogues and floats will be released at the mouth of Cain Creek at the beginning of an ebb tide. Position of the floats and drogues will be recorded about every hour during each study event and mapped (TOPO Interactive Map) for the duration of the study to illustrate the movement of the markers over the course of the tide cycle. Drogue, float and sample locations will be determined with a handheld Garmin Mariner eTrex GPS unit. Study tidal conditions and drogue release locations may be adjusted if results indicate a need for adaptation. Tidal conditions will be documented for all study events. Approximately 5-8 fecal coliform samples will be collected at intervals along the path of float/drogue travel beginning at the mouth of Cain Creek according to DOH marine water sampling protocols (DOH, 1996) including sampling for salinity and temperature at marine sites using a YSI 556 water quality sensor or a refractometer. Samples collected at the mouth of Cain Creek will be analyzed for fecal coliform content using methods for enumeration of fresh water bacteria content (membrane filter method) and marine water bacteria content (most probable number method) to match procedures used by Ecology in their data collection at this site.

Organization and Timeline

Project Personnel

Project Manager: Julie Hirsch –
Hirsch Consulting Services,
2523 Island View Lane
Lummi Island, Washington, 98262
(360)758-4046.
hirschserv@aol.com

Preparation of QAPP:	Julie Hirsch - Hirsch Consulting Services
Field Personnel:	Julie Hirsch - Hirsch Consulting Services
	Geoff Menzies – Puget Sound Restoration Fund 988 W. Laurel Road Ferndale, Washington 98248 (360) 384-9135 geoffmenzies@comcast.net
Administrative Support:	Betsy Peabody – Puget Sound Restoration Fund, 590 Madison Ave. N. Bainbridge Island, Washington, 98110 (206) 780-6947 Betsey@restorationfund.org
Analytical Services:	Avocet Environmental Testing – 1500 North State Street, Suite 200 Bellingham, Washington 98225 (360) 734-9033
	Dr. Stephanie Harris-- DVM, Lead Microbiologist EPA Region 10 Manchester Environmental Laboratory, 7411 Beach Drive East Port Orchard, Washington 98366 (360) 871-8710 Harris.stephanie@epa.gov
Reporting:	Julie Hirsch - Hirsch Consulting Services
Quality Assurance:	Julie Hirsch - Hirsch Consulting Services
Project Lead:	Llyn Doremus-- Nooksack Indian Tribe Department of Natural Resources 5016 Deming Rd Deming, Washington, 98244 (360)-592-5176 ldoremus@nooksack-nsn.gov

Table 1. Anticipated Project Timeline

Task	Part 1				Part 2								
	Jn	Jly	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Ap	May	Jn
	2009						2010						
1. Monitoring Plan	X												
2. Shoreline Surveys	x	x	x	x	x	x	x						
3. Marine near-shore sampling	x	x	x	x	x	x	x						
4. Circulation studies	x	x	x	x									
5. Reporting				x					x	x	x	x	
6. Outreach												x	x

Data Collection Methods

Field Procedures

Water Quality Sample Collection

Samples collected during the shoreline surveys, marine near shore sampling, and Cain Creek circulation study will use the following procedures. Grab samples will be collected using either a sampling wand or hand dipping in midstream and just below the surface. At freshwater sites samples will be collected prior to measuring discharge so that the sediment matrix is not disturbed. All sample containers will be provided by Avocet Environmental Testing. Fecal coliform bacteria samples will be collected in accordance with the water sampling protocol detailed in Standard methods 9060A and 9060B (APHA, 1998) or in the Washington State Department of Health Procedure #003, Marine Water Sampling, Office of Shellfish Programs, Washington State Department of Health (DOH, 1996), attached as Appendix C. Samples will be collected in 120ml sterile plastic bottles, which will immediately be placed on ice in a cooler. Samples will be delivered to the laboratory within 8 hours of sampling. Each bottle will be labeled with a site number prior to sampling and site numbers will be recorded on write-in- the- rain field data sheets prior to sampling. Site numbers, date, and time sampled for each sample will be transcribed to the chain-of-custody sheet prior to submitting samples to the laboratory.

Water Quality Parameter Measurements

Field measurements will be taken at freshwater sampling sites and at marine sample sites using a calibrated YSI 556 multi-parameter sensor. Fresh water parameters that will be measured are: conductivity, temperature, and dissolved oxygen (DO). At marine sites temperature and salinity will be

measured. Procedures that will be used for calibration and operation of the YSI 556 MPS are described in the YSI 556 MPS operations manual (YSI Environmental, 2003), which is attached as Appendix A. Alternately salinity measurements will be taken using a portable salinity refractometer, EXTECH model RF20 following the procedure described in the instrument user's guide (EXTECH, 2003). Methods, precision and quantitation limits, and sample handling requirements are presented in Table 2.

Stream Flow Measurements

Instantaneous stream flows will be measured in wadeable streams using the USGS procedure for measurement of discharge by conventional current meter method (Rantz and others, 1982) and a Swoffer current meter according to the Swoffer operations manual (Swoffer Instruments, Inc. , 2008). Cross-sectional area of stream units (cells) are multiplied by measured flow velocity to obtain discharge volume estimates.

Measurement of discharge issuing through pipes or culverts may be done using timed flow volumes accumulation into a calibrated container (catchment).

Analytical Methods

Laboratory analyses of fecal coliform content in freshwater samples will be conducted by Avocet Environmental Testing using the membrane filter method (MF), Standard Methods 9222D (APHA, 1998). Marine samples will be analyzed by the most probable number (MPN), multiple tube fermentation method (Standard Methods 9221 E). Avocet Environmental Testing is accredited by Ecology for fecal coliform bacteria analysis. The Avocet Environmental Testing Quality Assurance Manual is included as Appendix B. The Analytical methods are summarized in Table 2.

Bacteroides host specific polymerase chain reaction analysis (HSPCR) will be conducted at the EPA Region 10 Office of Environmental Assessment Laboratory according to procedures defined in the Quality Assurance Project Plan for Drayton Harbor Microbial Source Tracking Pilot Study (EPA, 2006). Samples will be shipped via FEDEX overnight service to arrive within 30 hours of sampling.

Table 2. Summary of methods and sample handling,

Parameter	Description	Method	Sample Container	Preser-vation	Holding Time
Water Temperature	YSI 556	YSI 556	None	None	none
Specific Conductivity	YSI 556	YSI 556	None	None	none
pH	YSI 556	YSI 556	None	None	none
Dissolved Oxygen	YSI 556	YSI 556	None	None	none

Parameter	Description	Method	Sample Container	Preser-vation	Holding Time
Salinity	Portable refractometer	ExTech RF20	None	None	none
Fecal coliform bacteria	Membrane filtration	APHA 9222D	PE, 125 mL, sterile	4 °C, dark	(max) 24-hours
Fecal coliform bacteria	Multiple tube fermentation	APHA 9221E	PE, 125 mL, sterile	4 °C, dark	(max) 24-hours
HSPCR	PCR-2marker	EPA Region 10 Lab Procedures	PE, 250 mL, sterile	10 °C, dark	(max) 24-hours

Data Quality Objectives and Quality Control Procedures

Data Quality Objectives

The standards used for deriving the project data quality objectives are intended to generate data of a comparable level of quality to that collected from ongoing sampling programs, to allow comparison with previously collected data in the Drayton Harbor watershed. In particular, data collected for this project should be comparable to Ecology's TMDL evaluation data (Mathieu and Sargeant, 2008) and Washington Department of Health's data collected for the Systematic Random Sampling Program (DOH, 1997). As such, the data quality objectives (DQOs) listed in the TMDL QAPP are adopted herein by reference. The DQOs listed in the EPA QAPP for Drayton Harbor microbial source tracking (EPA, 2006) are adopted by reference for the MST portion of the project. The TMDL also defines it's DQOs in terms of method quality objectives, reporting limits and resolution. Those are described in the section that follows, and presented in Table 3.

Representativeness

To address the natural spatial and temporal variability encountered in characterizing fecal bacteria distribution in the natural environment, the project design incorporates data collection data over a wide range of conditions that are likely to affect bacteria content in the near shore Drayton Harbor environment. Samples and measurements will be collected at about 20 shoreline locations, five to eight marine locations, and continuously monitor flow progression at 30-minute intervals over a tidal phase (approximately 6 hours) in the Cain Creek Circulation characterization. This large number of data points will be collected from varied environment types including a large shoreline area (approximately four miles in length) with a sandy spit (Semiahmoo Spit) and an area with urban stormwater discharges (Blaine city shoreline), a marina environment (Blaine Harbor) and a marine estuarine environment (Cain Creek estuary). Data will also be collected over a range of environmental conditions (summer, fall and winter months).

Comparability

In order to facilitate comparable data collected for this project with Ecology collected data and Dept of Health collected data, the procedures for data collection used by those agencies are incorporated into this document. Procedures documented herein are reviewed and approved by Ecology for further assurance that they will provide data comparable to that collected during the TMDL study.

Completeness

DOE has determined that five samples are required from each sampled site in order for the sample record to provide a complete range of site characterization data for Drayton Harbor TMDL waste allocation. This project will conduct a minimum of five sample events for the Shoreline Surveys and the Marine near Shore Sampling components of the study in order to collect the minimum number of 5 samples from each site being characterized. When field (dry) conditions preclude collection of five samples at a site, data from that site will be used for alternative analyses, source location identification, or recommendations.

Quality Control

Measurement quality objectives state the level of acceptable error in the measurement process. Precision is a measure of the variability in the results of replicate measurements due to random error which are inherently associated with field sampling and laboratory analysis. Accuracy is the resolution at which the method can detect the desired constituent. Table 3 presents the method quality objectives for each measurement and analyses to be conducted.

Avocet Environmental Testing will perform replicate laboratory analysis on 10% of samples submitted. Precision for the bacteria replicates is expressed as the relative standard deviation (RSD) and replicates should not exceed an RSD of 20%. Sample temperature for each cooler containing project samples will be measured upon submission to the laboratory and sample data will be flagged as estimates will if the temperature measured is above 4°C.

The EPA Region 10 Laboratory will follow quality control procedures defined in the Quality Assurance Project Plan for Drayton Harbor Microbial Source Tracking Pilot Study (EPA, 2006). Replicate laboratory analysis for HSPCR will be performed on 10% of samples submitted. The results for these identical replicates should be in agreement. If they are not in agreement, the overall results for that batch of samples will be evaluated for validity in discussions between the EPA Region 10 Laboratory Technical Director for Microbiology and the Project Officer.

Hirsch Consulting Services or its designees will submit three water samples containing ruminant or human fecal material (on a rotating or intermittent schedule) for a 'blind' PCR analysis by the Region 10 Laboratory. The blind sample will be clearly identified as such (without identifying the source of the fecal material) and will be submitted with each sample event batch or intermittently. The blind sample will be submitted for PCR analysis only. The results of these blind samples will be used to establish a base line expectation for the Laboratory. Currently, there is no established guideline for method accuracy using blind samples. If the method fails to correctly identify the type of fecal material in a blind

sample, the overall results for that batch of samples will be evaluated for validity in discussions between the EPA Region 10 Laboratory Technical Director for Microbiology and Project Officer.

Field and laboratory errors are minimized by adhering to the procedures described herein for sampling and water quality measurements. Field personnel have been trained in Ecology and DOH sampling protocols that will be followed during this project. Field replicates will be collected with each fecal coliform sample set submitted for laboratory analysis, (20% replication). Ten percent of samples collected for additional field water quality analysis will be replicated in the field (field replicates). If the results for any analyses are beyond limits of acceptability, corrective action will be taken and the associated data documented as qualified.

Measurement error with respect to equipment detection accuracy will be minimized by performing calibrations for all meters immediately prior to sampling as recommended by the manufacturer. Vessels used for manual flow estimation will be graduated to 500 mL or quart increments.

Table 3. Method quality objectives for field and laboratory analyses

Parameter	Method	Range	Precision	Accuracy	Quantitation Limits
Water Temperature	YSI 556	-5 to 45 C	0.01°C	± 0.15 °C	NA
Specific Conductivity	YSI 556	0 – 200 mS/cm	± 0.001 mS/cm, to 0.1 mS/cm (range dependent)	± 0.5% of reading OR ± 0.001mS/cm, whichever is greater	10% RSD*/0.1 mS/cm, 0.01 units
Dissolved Oxygen	YSI 556	0 to 50 mg/L	0.01 mg/L	±0.2 mg/L or ± 2% of the reading, whichever is greater	10% RSD*, 0-50mg/L/0.01mg/L
Salinity	ExTech RF20	0 to 100 ppt	±1ppt	±1ppt	0 to 100 ppt
Fecal coliform bacteria	Membrane filter APHA 9222D	< 2 to 1,600 cfu/100 mL	20% RSD*	20% RSD*	2 cfu/100 mL
Fecal coliform bacteria	Most probable number APHA 9221E	< 2 to 60,000 cfu/100 mL	20% RSD*	20% RSD*	2.0 cfu/100 mL
HSPCR	EPA Region 10 Lab Procedures				10-100 DNA strand

* RSD-Relative standard deviation, standard deviation divided by the mean, 50% of (field) replicate pairs < 20% RSD, 90% of (field) replicate pairs <50% RSD′ and 20% for laboratory replicates (Avocet).

Sample Handling

Sample Custody and Documentation

All samples will be placed into ice chests packed tightly with ice or synthetic ice packs upon collection. Fecal coliform samples will be hand delivered to Avocet Environmental Testing in Bellingham within 8 hours of collection. MST samples will be shipped to the EPA Region 10 laboratory via UPS overnight delivery and received by the laboratory within 30 hours of sample collection. A chain-of-custody form will accompany each cooler of samples to the laboratory. All sample containers will be labeled with a self adhesive label including sample identifiers. Sample collection, processing, and analysis techniques are standard and widely accepted.

Data Assessment, Reporting, and Audits

Analytical data received from the laboratory will be transcribed into an Excel computer database. Copies of field sheets will be transmitted to NIT and to Ecology along with fecal coliform data compiled in a draft Excel spreadsheet within two weeks of receipt from the laboratory. Each data point will be checked to ensure accuracy in data entry and incorrect entries will be corrected when found.

A progress report will summarize sampling events and conditions including activities conducted during part 1 of the project through September 2009. A final report will be prepared to summarize the results for all sampling events and to compare data with Washington State Surface Water Quality Standards and including fecal coliform load estimates.

Data reporting will be in the form of tables, graphs, maps, and analyses in a final report. Reporting will include field data sheets, chain of custody documentation, laboratory analytical reports and an Excel database. All QA/QC data and data qualifiers will be reported. Any deviations from methods or procedures stated in the QAPP will be reported. All data generated by this project will be reviewed by the NIT project lead. Problems identified with any data or reported information will be discussed with field data team, and Department of Ecology, to determine appropriate measures for correction in future data collection activities, qualifying of data, or removal of project data from further analyses.

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Appendix A

YSI 556 Multi Parameter Sensor Operations Manual

Appendix B

Avocet Environmental Testing

Quality Assurance Manual

Appendix C

Marine Water Sampling Procedure

Washington Department of Health (1997)

Appendix D

Quality Assurance Project Plan for

Drayton Harbor

Microbial Source Tracking Pilot Study

Environmental Protection Agency (2006)

Cain Creek Water Quality and Microbial Source Tracking

December 2013

Prepared by:

Hirsch Consulting Services
Lummi Island, Washington
(360)-758-4046 (hirschserv@gmail.com)

Prepared for:

Puget Sound Restoration Fund

Funded by:

Whatcom Community Foundation, Sustainable Whatcom Fund

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Abstract

Cain Creek is an urban watershed that drains a large portion of the city of Blaine, Washington to Semiahmoo Bay which is contiguous with Drayton Harbor and Boundary Bay. Cain Creek's water quality designation is *extraordinary* to support primary contact recreation and shellfish harvest as a tributary to Semiahmoo Bay. Drayton Harbor has historically been a productive commercial, tribal and recreational shellfish growing area. However, pollution from fecal coliform bacteria has disrupted a safe shellfish harvest back to the 1950s. Efforts have been ongoing to control fecal bacteria sources. In 2004 the Puget Sound Restoration Fund's Drayton Harbor Community Oyster Farm was able to begin harvesting oysters as a result of improved water quality, though fecal bacteria discharges still cause seasonal closures. *Total Maximum Daily Load* allocations call for bacteria reductions throughout the Drayton Harbor watershed with up to a 95% target reduction at Cain Creek. This project built upon work done by Ecology and others to identify sources of fecal bacteria contamination in the Cain Creek drainage. Through grant funding by the Whatcom Community Foundation and partnerships with the City of Blaine and EPA Region 10 Laboratory, the Puget Sound Restoration Fund and Hirsch Consulting Services conducted monitoring in 2012 to assist in prioritizing locations for corrective action. The study indicates a prevalence of human fecal markers throughout the lower drainage detected by DNA analysis using the host specific polymerase chain reaction method. Sauer et.al, (2010) found that indicators (*E. coli* and enterococci) at high densities (> 10,000 CFU/100mL) were not correlated to human *Bacteroides* markers and would have failed to flag sites that showed evidence of sewage contamination. Results of this study will be used by Blaine Public Works to target corrective actions by identifying potential breaches of sewer and stormwater systems as part of a Centennial grant project funded by the Washington State Department of Ecology.

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Figure 3. Cain Creek sample sites 2012 (red squares). Gray circles represent sites sampled in 2009. 6

Figure 4. Cain Creek 2012 fecal coliform bacteria compared to surface water standards and MST identifications. (NM = not measured, H = human, R = ruminant) 15

Figure 5. Cain Creek sample sites 2012 (red squares) and gray circles represent sites sampled in 2009. Label key: site ID, FC geometric mean, %>100FC/100ml, MSTid,H/R,(#occurrence) 16

Background and Problem Statement

Cain Creek is an urban watershed that drains a large portion of the city of Blaine to Semiahmoo Bay. Since 1999, data have shown that fecal bacteria levels exceed water quality standards and may impact shellfish harvest along Semiahmoo Bay shorelines in the US and Canada and inside Drayton Harbor (Hirsch Consulting Services, H.C.S. and Doremus, 2010). Cain Creek's water quality designation is *extraordinary* to support primary contact recreation as tributary to Semiahmoo Bay. The Washington State fecal coliform bacteria standard for Cain Creek is 50 CFU/mL. Impaired water quality affects tribal, commercial and recreational shellfish harvest in Drayton Harbor and in Semiahmoo and Boundary bays.

The Federal Clean Water Act requires that a Total Maximum Daily Load (TMDL) is developed for impaired water bodies and calculates the amount of a pollutant that a waterbody can receive and still safely meet water quality standards. In 2008, the Washington State Department of Ecology began the bacteria TMDL of the Drayton Harbor watershed (including Cain Creek) to improve water quality in support of safe primary contact recreation and shellfish harvest.

Trend analysis conducted by Ecology prior to the TMDL study indicated that water quality standards were violated at the mouth of Cain Creek. During the TMDL study Ecology sampled four stations from the headwaters to the mouth of Cain Creek. They found that all of the sites with the exception of the location at the headwaters exceeded both the geometric mean and 90th percentile standards. This site met the geometric mean standard but exceeded the 90th percentile standard (Mathieu and Sargeant, 2008). The TMDL Cain Creek sample sites are shown in Figure 1. Three of four stations sampled by Ecology during the TMDL evaluation required from 58% to 95% fecal coliform bacteria reductions during both wet and dry seasons (Ecology, 2010). The site at the headwaters required no reduction during the wet season. Data collected by Ecology and by H.C.S indicated that bacteria levels were relatively low at the headwaters of Cain Creek but increased sharply downstream at the subsequent sampling station. Downstream geometric mean and 90th% fecal coliform thresholds were exceeded with geometric means up to 15 times the allowable level of 50 CFU/100 mL (599 – 762 CFU/100 mL). Human DNA biomarkers were identified repeatedly at five of six Cain Creek sample sites.

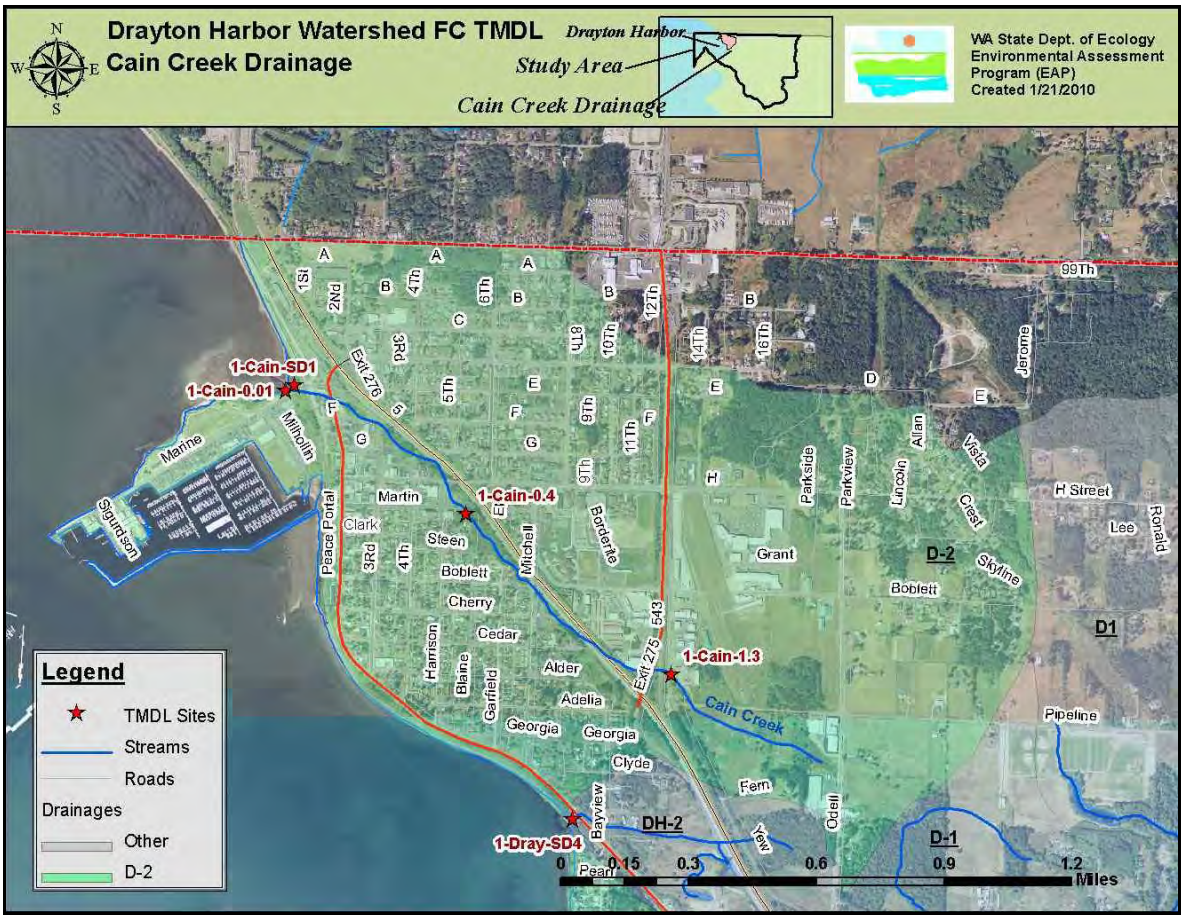

Figure 1. Cain Creek sample sites samples during Ecology's Drayton Harbor TMDL evaluation (2008).

A study completed for the Nooksack Indian Tribe in 2010 augmented the TMDL and assessed the potential contribution of Cain Creek to fecal coliform densities in Drayton Harbor and Semiahmoo Bay using loading data collected at five locations upstream of the stream mouth. Ebb tide circulation (drogue) studies indicated that high bacteria loading from Cain Creek is likely to impact water quality in the eastern near-shore of Semiahmoo Bay and DOH Station 15 at the Drayton Harbor mouth (H.C.S. 2010). This study identified human and ruminant DNA markers in samples collected at the mouth of Cain Creek, Semiahmoo Bay and DOH station 15 on more than one occasion during the summer of 2009 (Figure 2). The consistent presence of human source markers in fresh and marine waters highlights a source of sanitary significance for contact and shellfish harvest as stated by the World Health Organization that human sources pose a significantly higher health risk than non-human sources (World Health Organization, 2003).

Through funding by the Whatcom Community Foundation, data were collected to assist the City of Blaine in reducing fecal bacteria discharged to Cain Creek. Microbial source tracking analysis using *Bacteroides* DNA markers was donated by the EPA Region 10 Laboratory. This study established

additional sampling sites below the headwaters of Cain Creek to further characterize water quality, identify fecal bacteria source(s) and facilitate corrective action.

<u>Figure 2. Mapped data for ebb tide sampling, on August 11, 2009</u> shows results for fecal coliform bacteria and MST identifications near the Cain Creek outflow in Semiahmoo Bay and DOH station 15, the Drayton Harbor mouth. (H = human, R = ruminant.)

Fecal Coliform Water Quality Standard

Semiahmoo Bay and its tributaries (Cain Creek) carry Washington State's most stringent water quality designations to support safe shellfish harvest and primary contact recreation. Fecal coliform bacteria are indicators of the presence of enteric waterborne pathogens such as *Norovirus, Cryptosporidium spp., Giardia lamblia, Campylobacter jejuni, Salmonella enterica and E. coli O157:H7* (Soller et. al, 2010). Fecal coliform bacteria water quality criteria are listed in Table 1.

Table 1. Washington State Water Quality Standards for fecal coliform bacteria designated for Semiahmoo Bay and its tributaries.

MARINE WATER QUALITY STANDARD

water use designation: shellfish harvest[1]

The geometric mean shall not exceed fecal coliform content of 14 CFU/100 ml; and less than 10% exceed 43 CFU/100 ml.

FRESH WATER QUALITY STANDARD

water use designation: extraordinary primary contact recreation

The geometric mean shall not exceed fecal coliform content of 50 CFU/100 ml; and less than 10% exceed 100 FCU/100 ml

[1]National shellfish sanitation program (NSSP, 1997) administered by Washington Department of Health uses the estimate 90% and requires at least 30 data points for shellfish growing area classification.

Cain Creek

The Cain Creek headwaters begin in a minimally developed wetland area just south of the Blaine Airport and drain into the main channel which parallels the I-5 freeway through Blaine. The creek discharges to an estuary of Semiahmoo Bay on the eastern fringe of Marine Park, due west of the intersection of Peace Portal and Marine Drive, approximately ⅓ of a mile south of the international border with Canada. Historically Cain Creek discharged to shoreline that is now occupied by Blaine Harbor marina however in the 1800's it was rerouted to Semiahmoo Bay. The creek has been heavily impacted by the development of Blaine and the construction of the I-5 freeway and serves as receiving waters to a number of storm drainages (City of Blaine, 1995). The creek corridor encompasses category two wetlands. Cain Creek water quality influences Semiahmoo Bay and under certain tidal conditions, affects the mouth of Drayton Harbor (H.C.S and Doremus, 2010). The mouth of Cain Creek has violated water quality standards consistently back to 1995 as it discharges to Semiahmoo Bay (Eissinger, 2002).

Project Goal and Study Objective

The goal of this project was to collect data on bacteria content of Cain Creek at sites that have not been monitored in the past. The project was conducted in partnership with Blaine Public Works to provide information for use in reducing fecal coliform input to Cain Creek, Semiahmoo Bay and Drayton Harbor. Blaine Public Works staff advised site selection to locate stations in the proximity of sewage collection lines to facilitate detection of potential leaks. This effort generated high quality data, comparable to those collected for the Drayton Harbor Total Daily Maximum Load study.

The study objective was to fill information gaps in Cain Creek monitoring data by characterizing fecal coliform content and sources in the central portion of the drainage.

Study design

Sample stations in the mid portion of Cain Creek and at points near sewage collection lines were selected in consultation with Blaine Public Works staff to provide information that may indicate sewage collection leaks or other sources of fecal contamination. Sewer and stormwater conveyances in the vicinity of sample sites are shown in Appendix A. Sample sites shown in Figure 2 and described in Table 2 were selected as long-term reference points for subsequent monitoring by the Blaine Public Works. Samples were collected at four stations during five sampling events from January through May 2012 on a monthly schedule based upon Blaine Lighthouse Point Laboratory availability. An effort was made to target base flow conditions. Fecal coliform loading was estimated by instantaneous in-stream flow measurement collected using a Flowatch current meter and laboratory analysis of fecal coliform content in fresh water samples. Field measurements were taken for temperature, dissolved oxygen, pH and conductivity at the time of sample collection using a Hanna Instruments HI9828 water quality meter with GPS. Sample locations were recorded using the HI9828 unit.

Locations where significant fecal bacteria concentrations were identified during the first two sampling events were targeted for follow-up microbial source tracking sampling and analyses during the remaining three sampling events using the *Bacteroides* host specific polymerase chain reaction (HSPCR) analysis. The EPA Region 10 Laboratory (Manchester Lab) donated DNA analysis of samples collected at high fecal bacteria detection sites to assist in identifying fecal coliform discharge sources. The analysis identified human and ruminant bacteria sources. The HSPCR analysis was conducted according to the EPA QAPP composed for previous MST analyses completed on samples from Drayton Harbor (EPA, 2006).

Table 2. Cain Creek sample sites 2012.

Site ID	Description	Latitude (˚N)	Longitude (˚W)
CC1.2	Fir Ave Behind Propack brushy	48.98797	122.73564
CC0.8	End of Boblett and Mitchel, across walking bridge from Blaine High	48.99072	122.74214
CC 0.6	End Blaine Ave. & Steen Rd, sewer line nearby	48.99259	122.74459
CC0.15	Peace Portal culvert near Physical Therapy Office	48.99576	122.74952

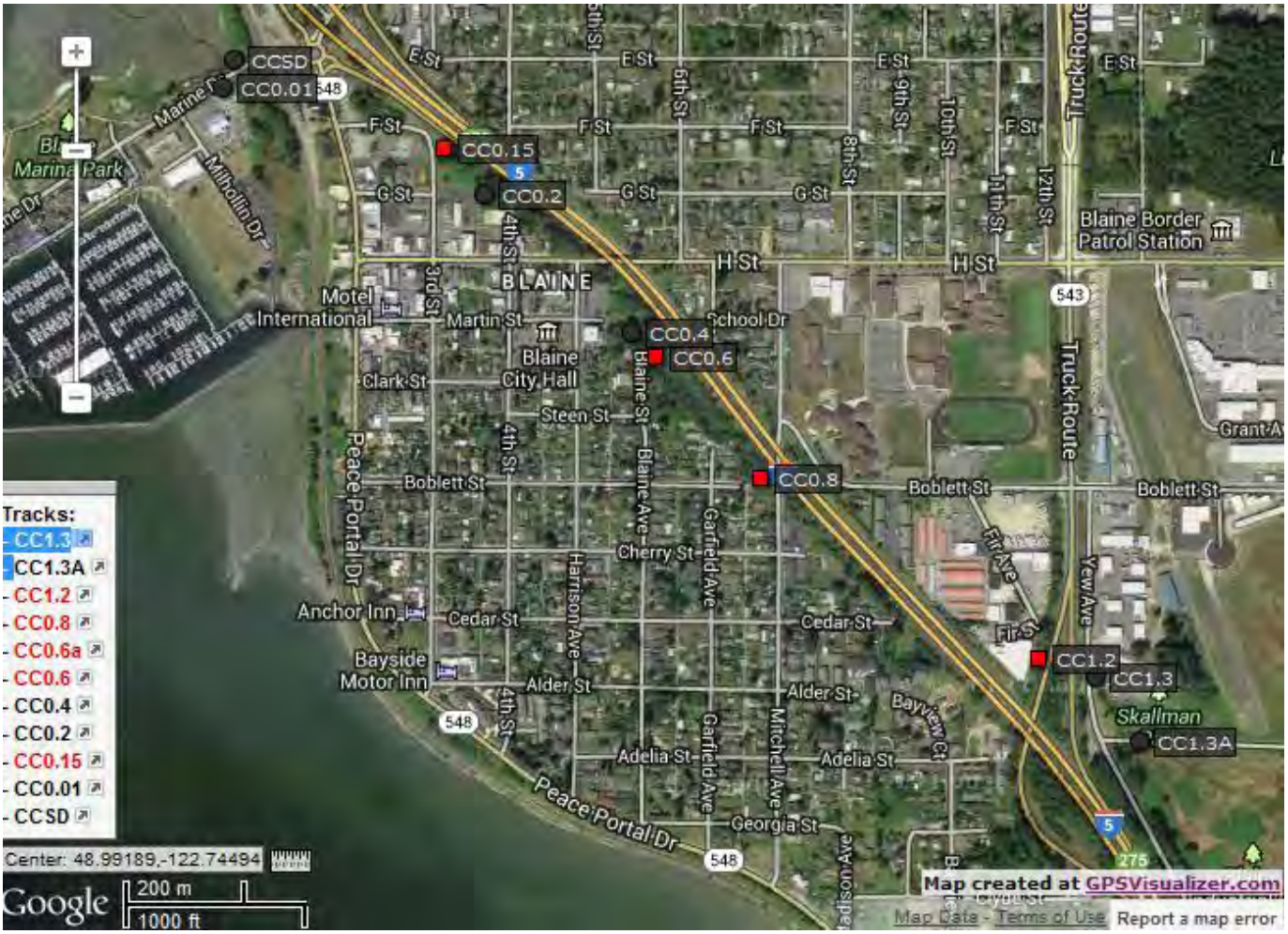

Figure 3. Cain Creek sample sites 2012 (red squares). Gray circles represent sites sampled in 2009.

Data Collection Methods

Field Procedures

Water Quality Sample Collection

Grab samples were collected using either a sampling wand or hand dipping in midstream and just below the surface prior to measuring discharge leaving the sediment matrix undisturbed. All sample containers were provided by Lighthouse Point Water Reclaimation Laboratory. Fecal coliform bacteria samples were collected in accordance with the water sampling protocol detailed in Standard methods

9060A and 9060B (APHA, 2006) or in the Washington State Department of Health Procedure #003, Marine Water Sampling, Office of Shellfish Programs, Washington State Department of Health (DOH, 1996). Samples were collected in 250mL sterile plastic bottles, which were immediately placed on ice in a cooler. Samples were delivered to the laboratory within 8 hours of collection. Each bottle was labeled with a site number prior to sampling and site numbers were recorded on write-in- the- rain field data sheets prior to sampling. Site numbers, date, and time sampled for each sample were transcribed to the chain-of-custody log prior to submitting samples to the laboratory. Samples for analysis at the EPA Region 10 Laboratory were labeled with sample identification, project code and account code, pre-assigned by the EPA Regional Sample Control Coordinator (RSCC).

Water Quality Parameter Measurements

Field measurements were taken using a calibrated HI9828 multi-parameter sensor. Fresh water parameters collected were: temperature, dissolved oxygen (DO), pH and conductivity. Procedures used for calibration and operation of the HI9828 are described in the HI9828 operations manual (Hannah Instruments 2011). Sample handling requirements are described in Table 2. Methods, precision and quantitation limits, and sample handling requirements are presented in Table 3.

Stream Flow Measurements

Instantaneous stream flows were measured in wadeable streams using the USGS procedure for measurement of discharge by conventional current meter method (Rantz and others, 1982) and a Flowatch current meter according to the Flowatch operations manual (JDC Electronics, 2011). Cross-sectional area of stream units (cells) are multiplied by measured flow velocity to obtain discharge volume estimates.

Analytical Methods

Laboratory analysis of fecal coliform content in freshwater samples was conducted by the City of Blaine's Lighthouse Point laboratory using the membrane filter method (MF), Standard Methods 9222D (APHA, 2006). The Lighthouse Point laboratory is accredited by Ecology for fecal coliform bacteria analysis. The Analytical methods are summarized in Table 2.

Bacteroides host specific polymerase chain reaction analysis (HSPCR) was conducted by the EPA Region 10 Office of Environmental Assessment Laboratory according to procedures defined in the Quality Assurance Project Plan for Drayton Harbor Microbial Source Tracking Pilot Study (EPA, 2006). Samples were shipped via FEDEX overnight service and arrived at the laboratory within 30 hours of sampling.

Table 3. Summary of methods and sample handling.

Parameter	Description	Method	Sample Container	Preser-vation	Holding Time, field/lab analysis
Water Temperature	HI 9828	HI 9828	None	None	None, field
Specific Conductivity	HI 9828	HI 9828	None	None	None, field
pH	HI 9828	HI 9828	None	None	None, field
Dissolved Oxygen	HI 9828	HI 9828	None	None	None, field
Fecal coliform bacteria	Membrane filtration	APHA 9222D	PE, 125 mL, sterile	10 °C, dark	(max) 24-hours, lab
DNA markers	HSPCR	EPA Region 10 Lab Procedures	PE, 250 mL, sterile	10 °C, dark	(max) 24-hours, lab

Results and Discussion

Data Quality

Measurement quality objectives state the level of acceptable error in the measurement process. The standards used for deriving the project data quality objectives (DQOs) are intended to generate data of a comparable level of quality to allow comparison with previously collected data in the Drayton Harbor watershed. Data collected for this project are comparable to Ecology's TMDL evaluation data (Mathieu and Sargeant, 2008) and Washington Department of Health's data collected for the Systematic Random Sampling Program (DOH, 1997). Precision is a measure of the variability in the results of replicate measurements due to random error which is inherently associated with field sampling and laboratory analysis. Accuracy is the resolution at which the method can detect the desired constituent. The DQOs listed in the EPA quality assurance project plan (QAPP) for Drayton Harbor microbial source tracking (EPA, 2006) are adopted by reference for the MST portion of this project. Data quality objectives are method quality objectives, reporting limits and resolution presented in Table 4.

Field and laboratory errors were minimized by adhering to the procedures described herein for sampling and water quality measurements. Field personnel were trained in Ecology and DOH sampling protocols that were followed during this project. All fecal coliform bacteria samples were submitted to the

laboratory within 6 hours of collection. Measurement error with respect to equipment detection accuracy was minimized by performing calibrations for all meters immediately prior to sampling as recommended by the manufacturer.

Fecal Coliform Bacteria

Quality control procedures were the measures taken in the field and in the laboratory to ensure that data quality objectives were met. Sample temperature for each cooler containing samples was measured upon submission to the laboratory and sample data were flagged as estimates if the temperature measured was above 10°C. A field replicate was collected with each fecal coliform sample set submitted for laboratory analysis (25% replication). Precision for the bacteria field replicates is expressed as the relative standard deviation (RSD) where the median of replicate samples does not exceed an RSD of 20%. Replicate fecal coliform bacteria samples met the RSD criteria. The Lighthouse Point laboratory followed their quality assurance manual (Blaine Wastewater Laboratory, 2010).

Microbial Source Tracking

The EPA Region 10 Laboratory followed quality control procedures defined in the Quality Assurance Project Plan for Drayton Harbor Microbial Source Tracking Pilot Study (EPA, 2006). Positive DNA Controls (consisting of plasmid DNA containing the target sequence): A positive control was analyzed in conjunction with each set of amplifications and always provided an appropriate response for the data. Replicate laboratory analysis for HSPCR was performed on 10% of samples submitted. In cases where the duplicate analyses were not the same there are two potential explanations for this discrepancy as explained in the project laboratory report: (Harris, 2012):

1) The level of extracted DNA present in the sample was below the detection limit for the sample that was negative. This phenomenon is commonly seen in microbiological analyses when the sample contains the target at very low levels.

2) The level of background contaminants are high enough to interfere with the detection of DNA in one sample but not in the other.

Three water samples containing fecal material for a 'blind' PCR analysis were submitted to the Region 10 Laboratory as positive controls. The blind samples were clearly identified (without identifying the source of the fecal material) and submitted with sample event batches. Currently, there is no established guideline for method accuracy using blind samples. If the method failed to correctly identify the type of fecal material in a blind sample it may have been due to levels of DNA below detection limits or interference from background contaminants. Failure to detect a source type in a blind positive control sample does not indicate the absence of source DNA. This occurred in two of three blind control samples (Table 6).

Water Quality Meter Parameters

Twenty percent of samples collected for additional field water quality analysis (discharge and pH, dissolved oxygen, temperature and conductivity) were replicated in the field. If the results for any analyses were beyond limits of acceptability, corrective action was taken and documented. Calibrations were performed for all parameters immediately prior to sampling as recommended by the manufacturer. The Flowatch current meter was factory calibrated and certified and impeller checks and zero flow checks were conducted in the field prior to each sampling event. Specifications are shown in Table 5. All replicate field measurements met the criteria for accuracy provided in the manufacturer's instruction manual (Hannah Instruments 2011, JDC, 2011).

Table 4. Method quality objectives for field and laboratory analyses.

Parameter	Method	Range	Precision	Accuracy	Quantitation Limits
Water Temperature	HI9828	-5 to 55 C	0.01°C	± 0.15 °C	NA
Conductivity	HI9828	0 – 200 mS/cm	± 0.001 mS/cm, to 0.1 mS/cm (range dependent)	± 0.1% of reading OR ± 0.001mS/cm, whichever is greater	10% RSD*/0.1 mS/cm, 0.01 units
Dissolved Oxygen	HI9828	0 to 50 mg/L	0.01 mg/L	±0.2 mg/L or ± 2% of the reading, whichever is greater	10% RSD*, 0-50mg/L/0.01mg/L
Fecal coliform bacteria	Membrane filter APHA 9222D	< 2 to 1,600 cfu/100 mL	20% RSD*	20% RSD*	2 cfu/100 mL
HSPCR	EPA Region 10 Lab Procedures				10-100 DNA strand

* RSD-Relative standard deviation, standard deviation divided by the mean, 50% of (field) replicate pairs < 20% RSD, 90% of (field) replicate pairs <50% RSD′ and 20% for laboratory replicates.

Table 5. Specifications for Flowatch Current Meter

Features:	Flow rate/Windspeed
Units:	km/h *(kilometers per hour)* m/s*(meters per second)* knots mph *(miles per hour)* fps *(feet per second)*
Range:	0.2 to 32+ mph; 0.3 to 51+ km/h
Resolution:	0.1 unit
Accuracy:	+/- 2%

Table 6. HSPCR blind positive control sample results.

Blind positive control	Source	ID[1]
PC1	Human feces, 2 individuals	GB
PC2	Raw sewage, Lighthouse Pt STP	H(HF183)
PC3	4 cows, Lummi Island	GB

ID = DNA sequence identified, GB = general *Bacteriodes,* HF183 = human.

Representation, Completeness, Sample Handling & Data Management

This project plan was developed to provide representative, complete, and comparable data. The sampling methods and the equipment used to collect samples, as outlined, ensured that samples are representative.

Fecal coliform bacteria sample bottles were packed tightly with ice in the cooler immediately upon collection and hand delivered to the Lighthouse Point laboratory within 6 hours of collection. All sample containers were labeled with a self adhesive label including sample identifiers. Chain of custody documentation was submitted to the laboratory with each sample batch. These sample handling techniques resulted in 100% completeness.

Microbial source tracking sample shipments were coordinated with the EPA Region 10 laboratory and shipped via UPS overnight delivery and received by the laboratory within 30 hours of sample collection. Shipments to the EPA Region 10 Laboratory were confirmed with Stephanie Harris prior to sampling and the EPA RSCC was notified of shipments and sample identifiers. A chain-of-custody log accompanied each cooler of samples to the laboratory. All sample containers were labeled with a self adhesive label with sample identifiers.

Sample collection, processing, and analysis techniques are standard and widely accepted. Use of these standard methods resulted in data that is comparable to most other surface water monitoring studies including the Drayton Harbor TMDL evaluation.

Data reporting assessment and audit procedures ensured that data can be compared to other surface water studies. Analytical data received from the laboratory was transcribed into an Excel computer database. Each data point was checked to insure accuracy in data entry. Field data was transcribed from field data sheets into the computer database and each entry was checked for accuracy and incorrect entries were corrected.

A report is prepared to summarize results for all sampling events including a compilation of field and laboratory data in an Excel database. Data are presented in the form of tables, graphs, maps, and analyses in this final report. Field data sheets, chain of custody documentation, laboratory analytical reports will be produced upon request. All QA/QC data and data qualifiers are reported. Any deviations from methods or procedures stated in the QAPP are reported.

Cain Creek

Data were collected to identify fecal coliform bacteria sources and to assist the City of Blaine in prioritizing locations and corrective actions based upon fecal coliform loading at Cain Creek. Corrective actions should be taken to bring Cain Creek into compliance with water quality standards and to reduce bacteria discharges influencing Drayton Harbor and Semiahmoo Bay. Rainfall conditions at the time of sampling are shown in table 7 and project data are summarized in Table 8 and Figure 2. Data are compared with the results of a study conducted by H.C.S. at Cain Creek in 2009 (Table 9). Table 10 summarizes data collected by the Northwest Indian College at the Cain Creek mouth and the storm drain at the mouth (NWIC, 2013). Data collected for temperature, pH, dissolved oxygen and conductivity are summarized in Table 13.

Table 7. Rainfall conditions.

Date	Time	[1]24-hour rainfall (in.)	[1]72 hour rainfall (in.)
1/26/2012	915	0.14	0.41
2/16/2012	0842	0	0.12
3/14/2012	0915	0.15	0.35
4/11/2012	1000	0	0
5/23/2012	0900	0	0.86

[1.] Rainfall from Weather Underground, http://www.wunderground.com/weatherstation/WXDailyHistory.asp?ID=KWABLAIN13

Fecal Coliform Bacteria and Microbial Source Tracking

Table 8. Cain Creek Fecal coliform bacteria data collected from January through May, 2012.

Station	N	Geomean	%>100	Min (FC/100mL)	Max (FC/100mL)	Mean discharge (ft^3/sec)	Mean Load (billion FC/day)	Mean Load (billion FC/day)[1]
WQ Standard		**50**	**<10%**					
CC1.2 (Fir Ave. behind Propack Bldg.)	6	**58**	**17**	17	511	0.54	7.7E+08	0.77
CC0.8 (End of Boblett and Mitchell.)	6	**67**	**50**	10	176	0.90	1.8E+09	1.8
CC0.6(End Blaine Ave. & Steen Rd.)	6	49	**50**	0	567	1.27	5.8E+09	5.8
CC0.15 (At Peace Portal culvert.)	7	**57**	**50**	12	410	0.90	2.5E+09	2.5

[1] Mean fecal coliform bacteria load calculated using the arithmetic mean bacteria concentration/100mL.

Fecal coliform bacteria geometric means ranged from a concentration of 49 – 67 FC/100mL. The 2009 study found geometric means in the lower portion of the drainage ranging from 149-762 FC/100mL. Data collected by NWIC during 2012 at the mouth of Cain Creek shows geometric means of 90-138 FC/100mL. While concentrations appeared lower during the period sampled in this study both of the other studies include wet season data and likely reflect the influence of increased storm water runoff. Fecal coliform bacteria loads were also lower when compared to data collected in 2009.

Table 9. Cain Creek Fecal coliform bacteria data collected from June through December 2009.

Station	n	Geometric mean[1]	%>100[1]	Min (FC/100mL)	Max (FC/100mL)	Mean discharge (ft^3/sec)	Mean Load (billion FC/day)[2]
CC1.3 Cain Creek @ Pipeline Rd	3	26	0	7	68	0.209	0.19
CC1.3A, Cain Creek @ Pipeline Rd,concrete culvert	3	23	0	10	48	0.172	1.36
CC0.4,downstream of beaver dam behind Blaine Trade Cer	9	**762**	**100**	58	6300	0.380	25.1
CC.0.2, behind library	6	**571**	**100**	110	5700	1.685	62.5
CC0.01,Mouth of Cain Creek; 60" culvert off of Marine Dr.	9	**647**	**89**	63	4600	6.420	222
CCSD, storm drain @mouth	9	**148**	**78**	4	2100	0.269	3.84

[1] Bold indicates violation of Washington fecal coliform primary contact standard a) geometric mean of 50 FC/100mL and no more than 10% exceeding 100 FC/100mL.
[2] Mean fecal coliform bacteria load calculated using the arithmetic mean bacteria concentration/100mL.

The geometric mean for site CC0.6 fell just below the standard at 49 FC/100mL while the other three sites violated the geometric mean threshold. All four sites violated the 90th percentile standard. The Drayton Harbor TMDL identified storm water runoff as a significant FC loading source during both the wet and dry seasons in Cain Creek.

Table 10. Cain Creek data collected by Northwest Indian College, January through December 2012.

Station	N	Geomean	%>100	Min (FC/100mL)	Max (FC/100mL)
CC mouth	11	**90**	**41**	12	570
CCO (outfall storm drain)	11	**138**	**58**	20	560

Table 11. Microbial source tracking results for 2012 study by host specific polymerase chain reaction (HSPCR)

Sites	n	Biomarkers [1]			
		Human	Ruminant	[2] GB	Absent
CC0.8	3	1	1	1	
CC 0.6	3	2		1	
CC0.15	3	2		1	

Table 12. Microbial source tracking HSPCR results for 2009 study.

Sites	N*	Biomarkers				
		Human	Ruminant	H/R***	GB**	Absent
CC0.01	6	5/6	2/6	1/6	1/6	
CC0.2	3	2/3	2/3	2/3	1/3	
CC0.4	6	5/6	3/6	2/6		
CC1.3	3	2/3			1/3	
CC1.3A	3		1/3		1/3	1/3
CCSD	6	5/6	4/6	3/6		

* N = number of samples, **GB=general *Bacteroides*

***H/R=human and ruminant markers identified in the same sample.

Human DNA markers were observed in 2/3 samples at sites CC0.15, near Peace Portal culvert and CC0.6 at the end of Blaine Street. These sites also exhibited the highest fecal coliform bacteria loads. Site CC0.6 is close to site CC0.4 that was sampled in 2009. When MST data are pooled for these two sites, human DNA markers were identified in 7/9 samples. Site CC0.15 is just downstream from site CC0.2 that was sampled in 2009. When MST data are pooled for these two sites, human DNA markers were identified in 4/6 samples. Human and ruminant DNA markers occurred at site CC0.8 near Boblett Street and Mitchell Avenue in 1/3 samples collected. Ruminant markers could originate from cow or deer feces. Soller (et.al, 2010) found higher probability of disease incidence in recreational waters with exposure to fecal bacteria of human and cattle origin when compared to other animal sources. Sauer et.al, (2010) found that *E. coli* and enterococci at high densities (> 10,000 CFU/100mL) were not correlated to human *Bacteroides* markers and would have failed to flag sites that showed evidence of sewage contamination. The prevalence of human fecal biomarkers identified in time and space, combined with a high health risk justifies identification and correction of these source(s).

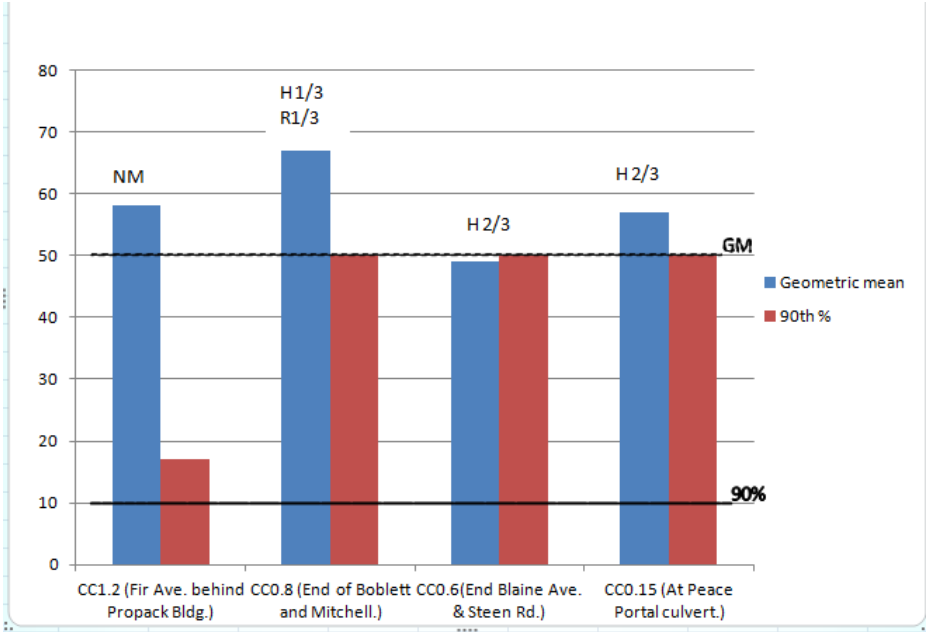

Figure 4. Cain Creek 2012 fecal coliform bacteria compared to surface water standards and MST identifications. (NM = not measured, H = human, R = ruminant)

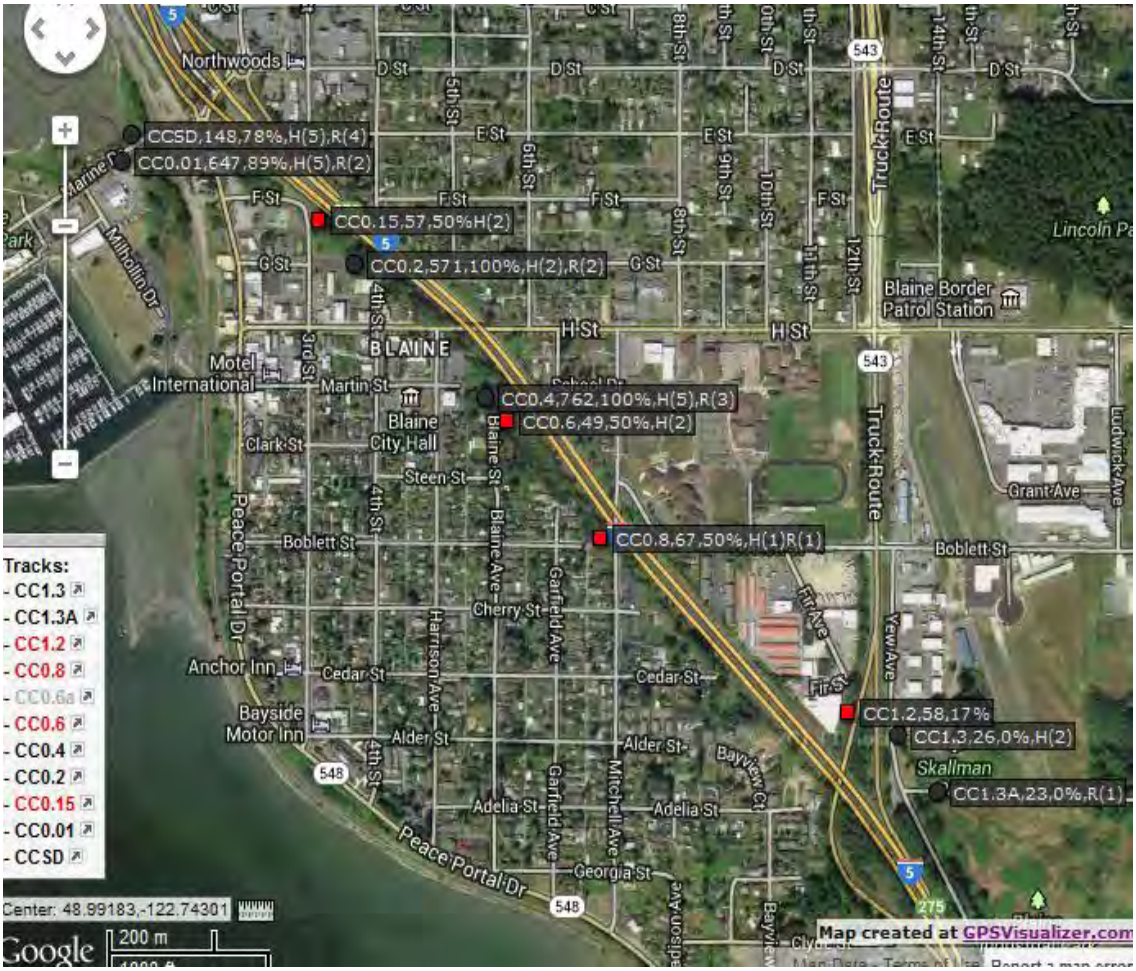

Figure 5. Cain Creek sample sites 2012 (red squares) and gray circles represent sites sampled in 2009. Label key: site ID, FC geometric mean, %>100FC/100ml, MSTid,H/R, (#occurrence)

Temperature, pH, Dissolved Oxygen and Conductivity

Data were collected for physical water quality parameters to characterize the general health of the creek and to assess suitability for potential restoration of fish habitat in the future. Results are summarized in Table 13.

Maximum temperatures ranged from 11.63 to 12.86 ° C and met Washington State water quality freshwater temperature standard for salmon and trout spawning of 13 ° C (WAC – 173-201A). This result is not surprising since data were collected from January through May and did not span the warm summer months. Data for pH were well within freshwater pH criteria which brackets a range of 6.5 to 8.5 pH units. The minimum pH measured was 7.10 and the maximum was a pH of 7.96. Dissolved oxygen minima ranged from 5.07 mg/L at site CC1.2 to 8.17 mg/L at CC0.15 with levels at the remaining two sites at 7.96 (CC0.8) and 7.36 (CC0.6). The lowest 1-day minimum criteria for salmonid rearing,

spawning and migration is 8.0 mg/L and if that condition is due to natural conditions, then human actions considered cumulatively may not cause the D.O. of to decrease more than 0.2 mg/L. Three of four sites fell below the freshwater criteria with dissolved oxygen levels depressed to 5.07 mg/L at CC1.2, as the creek discharges from passage under I-5. This dataset is inadequate to determine whether these conditions are due to human activity, however one would expect dissolved oxygen levels to trend higher during the cooler months and lower in the summer based upon the decrease in oxygen solubility with increased temperature. Dissolved oxygen data collected in 2009 during summer months reflect levels below 5.0 mg/L at CC0.4 and CC0.2 when temperatures ranged from 13 to 17 °C, (H.C.S. and Doremus, 2010). These results indicate that Cain Creek is often depleted with respect to dissolved oxygen. Conductivity values ranged from 0.04 – 0.73 mS/cm which indicates a level of dissolved solids that is within a normal range for freshwater streams (EPA, 2013)

Table 13. Cain Creek results for temperature, pH, dissolved oxygen and conductivity, January through May 2012.

Sites	CC0.15	CC0.6	CC 0.8	CC01.2
Temp (° C) N = 5				
Mean	7.52	7.50	7.22	6.49
Min	4.57	4.48	4.76	3.68
Max	12.66	12.82	12.56	11.63
pH N = 5				
Mean	7.46	7.52	7.49	7.23
Min	7.10	7.42	7.33	7.13
Max	7.83	7.80	7.96	7.42
Dissolved Oxygen (mg/L) N = 5				
Mean	10.31	9.71	9.52	7.96
Min	8.17	7.36	7.96	5.07
Max	11.50	11.00	11.24	9.31
Conductivity (mS/cm) N = 5				
Mean	0.21	0.19	0.22	0.29
Min	0.12	0.04	0.20	0.10
Max	0.28	0.26	0.32	0.73

Conclusions

Corrective action in the Cain Creek drainage should be prioritized at CC0.8 and downstream in proximity to sewer lines and structures to address human fecal sources that have been identified. Sewer lines are shown near the Cain Creek at sites CC0.8 and CC0.6 (Appendix A). Leaks can be identified by sewer camera and dye testing of homes near the creek corridor. Collaboration with Whatcom County Health should ensure there are no remnant septic systems in the vicinity of Cain Creek. Collaboration with the Department of Transportation should address stormwater discharges from I-5. The creek corridor should be monitored for the possibility of human source(s) originating from homeless encampment(s) or diaper waste runoff from garbage receptacles which could be present in storm water.

Dissolved oxygen data collected for this study and in 2009 indicate that Cain Creek is often depleted with respect to dissolved oxygen. In respect to future restoration efforts, the reasons for observed dissolved oxygen depletion should be investigated and evaluated for correction if it is due to human activity such as land clearing or dumping of organics such as yard waste.

As a result of a concerted effort to restore safe surface water for recreation and shellfish harvest, the City of Blaine has been awarded a Centennial grant to address fecal sources identified in Cain Creek. Repeated occurrence of human fecal markers is a compelling case for expending the resources needed to correct these sources of fecal pollution in and bring Cain Creek into compliance with water quality standards and TMDL allocations. This effort will initiate restoration of the Cain Creek corridor for recreational uses and wildlife habitat as identified in Blaine's Comprehensive Parks and Recreation Plan (2004) and Wildlife Protection Plan (2002). This water quality study and successful Centennial grant application were accomplished through a public, non-profit partnership of the Whatcom Community Foundation, Puget Sound Restoration Fund and Blaine Public Works Department.

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Figure 1. Study area map.

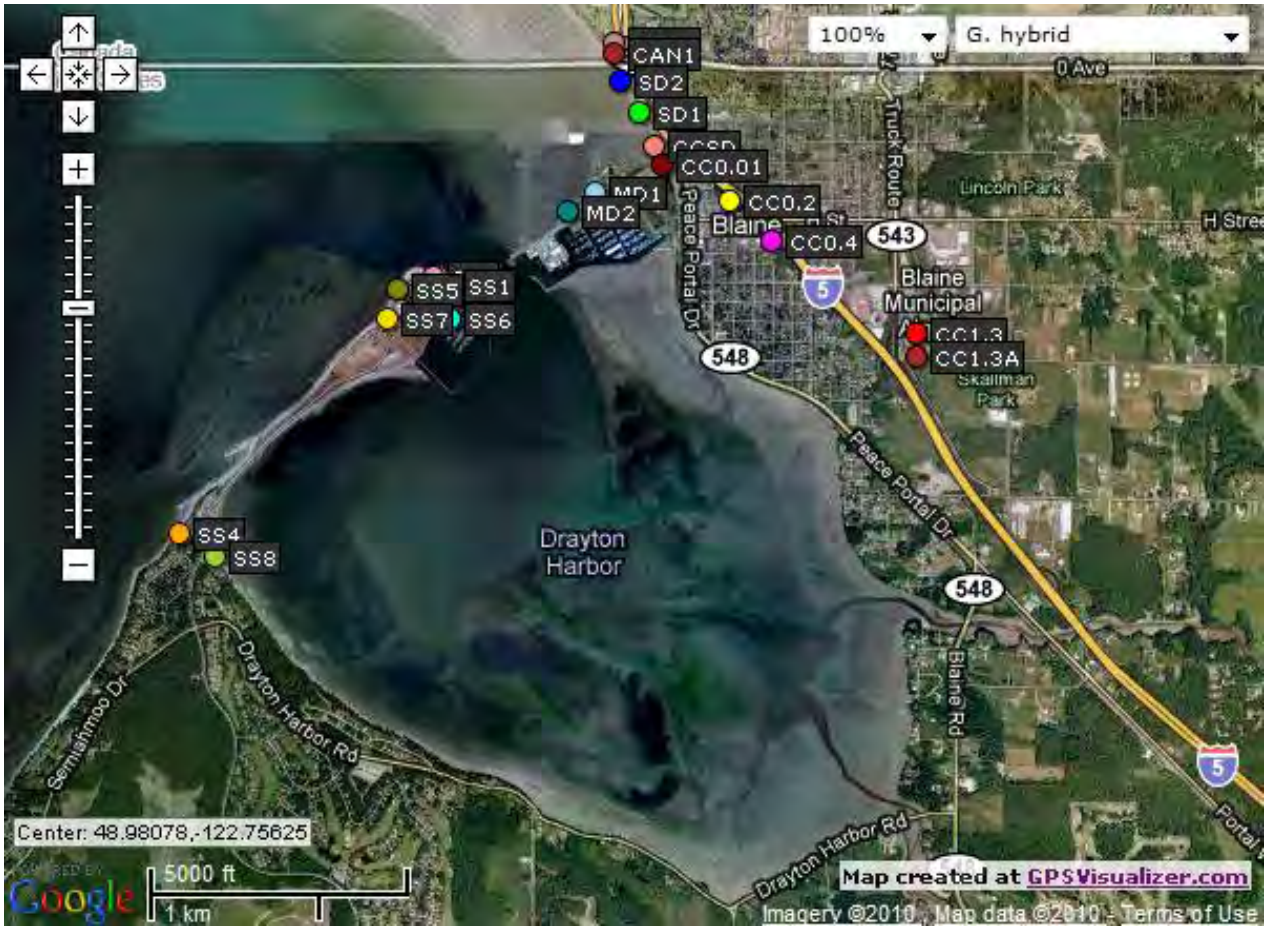

Figure 2. Shoreline survey sample sites.

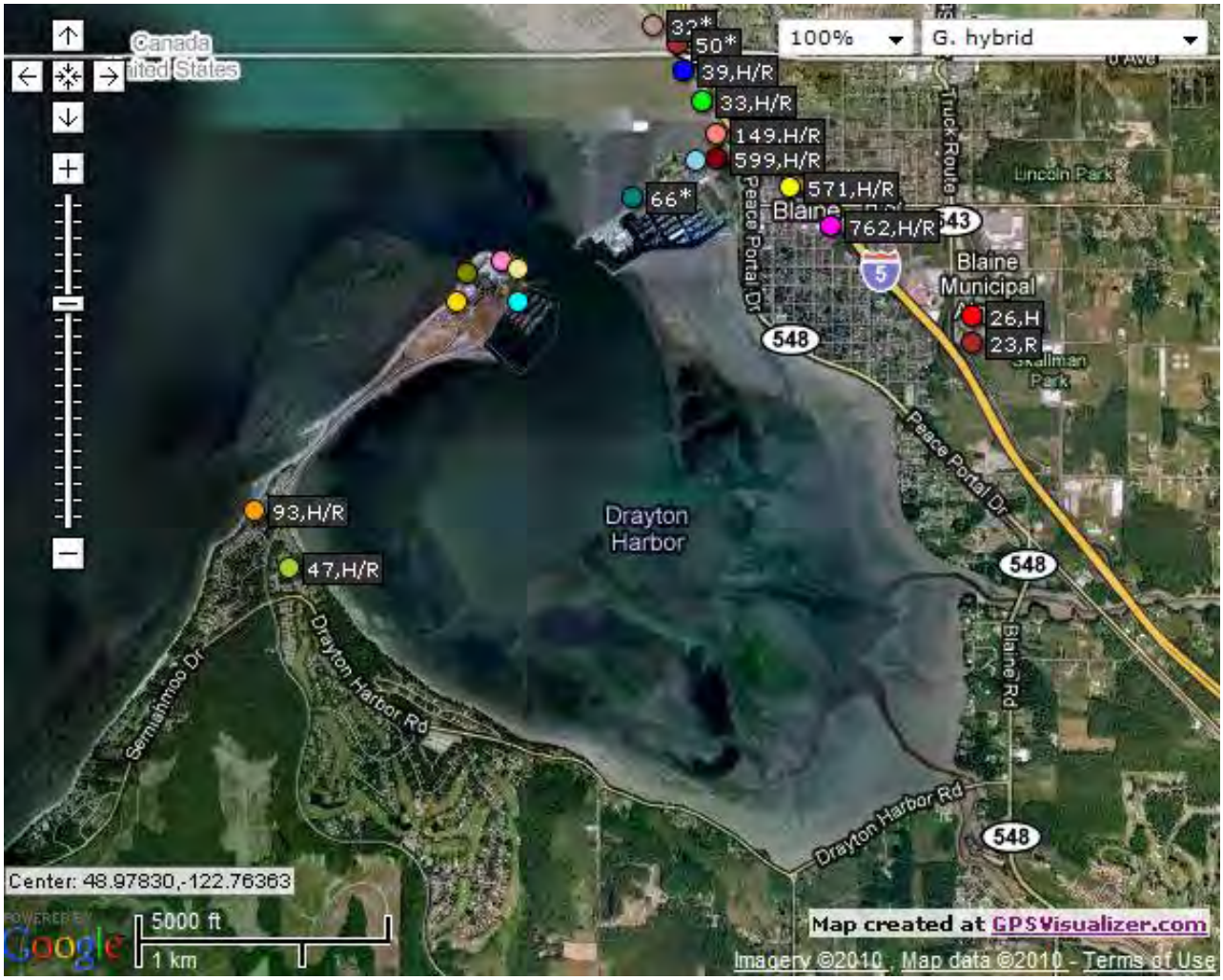

Figure 3. Cain Creek and shoreline survey sample sites with fecal coliform geometric mean and MST biomarkers. Asterisk signifies single sample result.

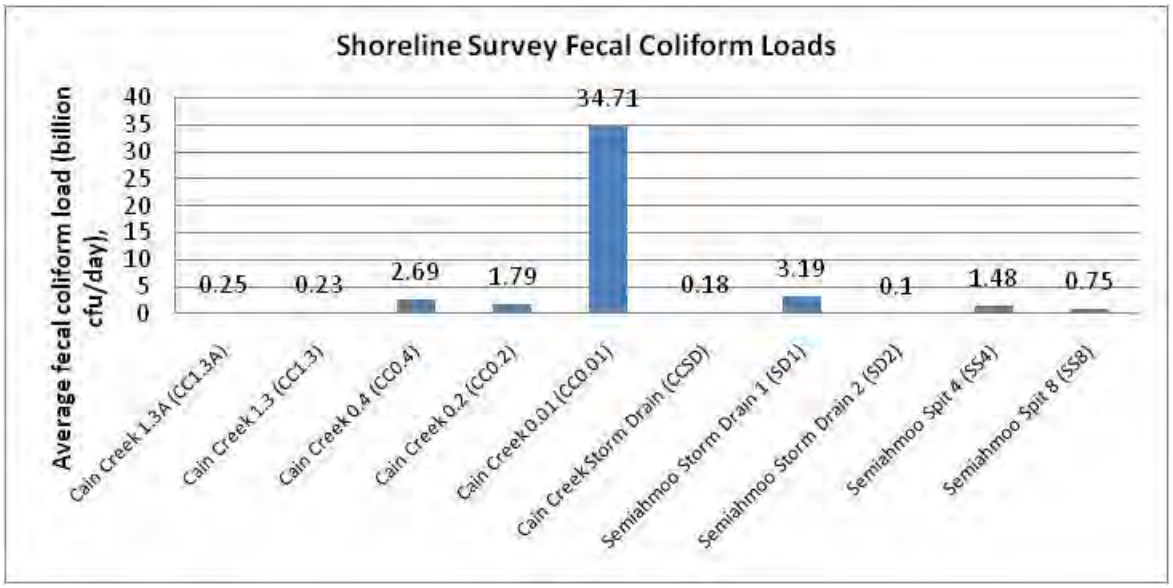

Figure 4. Average fecal coliform loading for Cain Creek and shoreline survey sample sites, billion cfu/day.

Figure 5. Mapped data for ebb tide sampling, June 10,2009.

Previous 24-hour rainfall: 0.00 inches
Tidal conditions: High 05:37, 7.92 ft, Low 13:40, -1.56 ft, difference 9.48 ft. ,high tidal exchange
Wind Speed/direction: 6 mph/S
Predominant drogue/float direction: NW

Legend for mapped marine data

- Green triangle = drogue/float deployment
- Red circle= drogue/float end point
- D1 and D2=drogue 1ft. depth
- D3 and D4=drogue 8 in. depth
- O=Surface float, orange
- Colored square=sample point independent of drogue/float.
- Gray box=Fecal coliform bacteria (FC)/100mL, H/R=human/ruminant biomarker

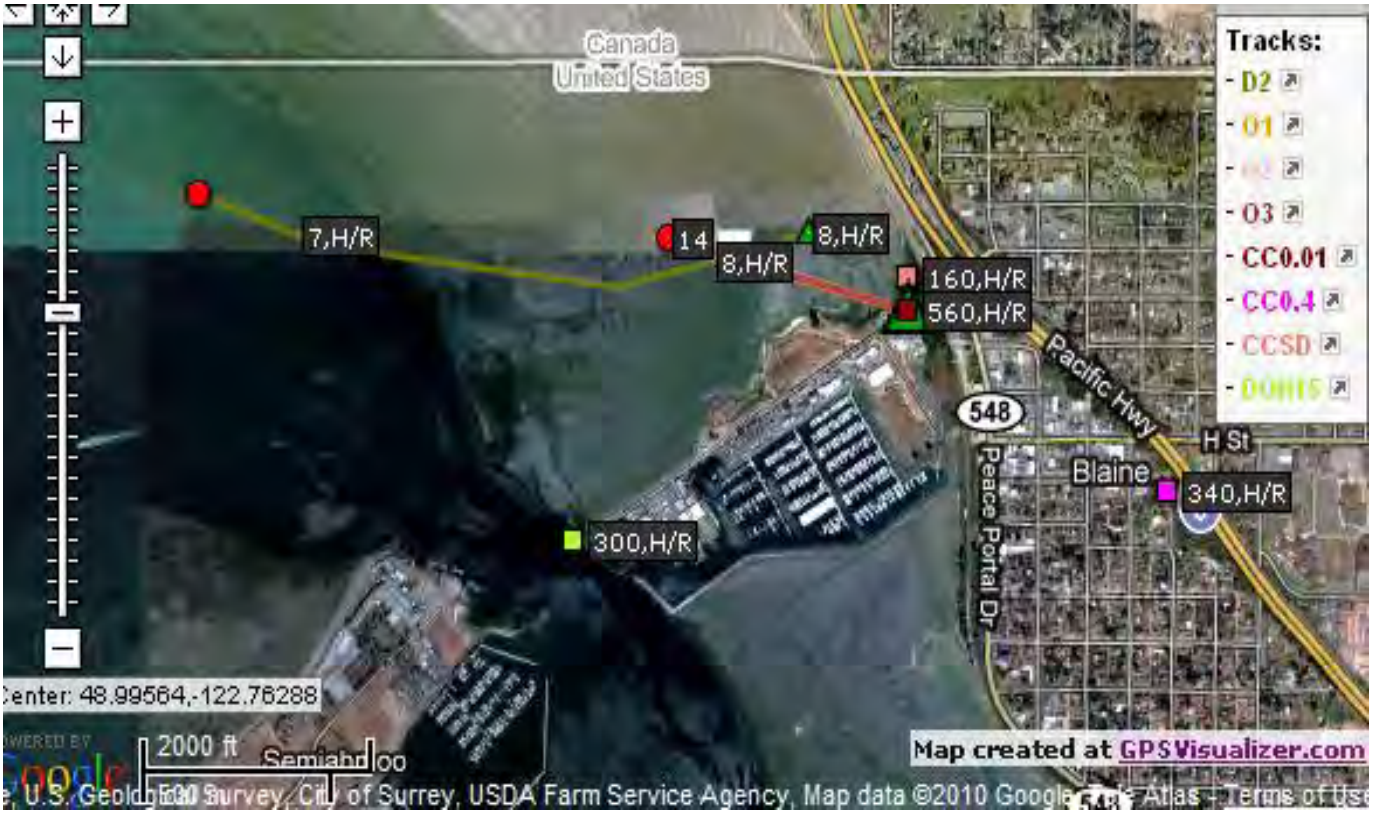

Figure 6. Mapped data for ebb tide sampling, June 24, 2009.

Previous 24-hour rainfall: 0.02 inches
Tidal conditions: High 05:07, 9.36 ft., Low 13:07 -3.75 ft., difference 13.11 ft., high tidal exchange
Wind Speed/direction: 0- 8 mph/NNE
Predominant drogue/float direction: NW

Legend for mapped marine data

- Green triangle = drogue/float deployment
- Red circle= drogue/float end point
- D1 and D2=drogue 1ft. depth
- D3 and D4=drogue 8 in. depth
- O=Surface float, orange
- Colored square=sample point independent of drogue/float.
- Gray box=FC/100mL, H/R=human/ruminant biomarker

Figure 7. Mapped data for ebb tide sampling, August 10, 2009.

Previous 24-hour rainfall: 0.57 inches
Tidal conditions: High 08:30,6.80 ft., Low 14:34, 2.41 ft. , difference 4.39 ft., low tidal exchange
Wind Speed/direction: 2.5-4.5mph/SSE
Predominant drogue/float direction: NW

Legend for mapped marine data

- Green triangle = drogue/float deployment
- Red circle= drogue/float end point
- D1 and D2=drogue 1ft. depth
- D3 and D4=drogue 8 in. depth
- O=Surface float, orange
- Colored square=sample point independent of drogue/float.
- Gray box=FC/100mL, H/R=human/ruminant biomarker

Figure 8. Mapped data for ebb tide sampling, August 11, 2009.

Previous 24-hour rainfall: 0.53 inches
Tidal conditions: High 09:36, 6.57 ft. Low 15:08, 3.63 ft., difference 2.94 ft., low tidal exchange
Wind Speed/direction: 3-5mph/SSW
Predominant drogue/float direction: NW

Legend for mapped marine data

- Green triangle = drogue/float deployment
- Red circle= drogue/float end point
- D1 and D2=drogue 1ft. depth
- D3 and D4=drogue 8 in. depth
- O=Surface float, orange
- Colored square=sample point independent of drogue/float.
- Gray box=FC/100mL, H/R=human/ruminant biomarker

Figure 9. Mapped data for ebb tide sampling, September 22, 2009.

Previous 24-hour rainfall: 0.53 inches
Tidal conditions: High: 09:14, 8.72 ft. Low 14:26, 5.48 ft., difference 3.24 ft.low tidal exchange
Wind Speed/direction: 1-4mph/WSW.
Predominant drogue/float direction: SW

Legend for mapped marine data

- Green triangle = drogue/float deployment
- Red circle= drogue/float end point
- D1 and D2=drogue 1ft. depth
- D3 and D4=drogue 8 in. depth
- O=Surface float, orange
- Colored square=sample point independent of drogue/float.
- Gray box=FC/100mL, H/R=human/ruminant biomarker

Figure 10. Mapped data for flood tide sampling, June 17, 2009 with flood tide geometric mean for Port of Bellingham sample site.

Previous 24-hour rainfall: 0.00 inches
Tidal conditions: Low 08:05, 1.49 ft, High 14:57 5.79 ft., difference 4.30 ft., low tidal exchange
Wind Speed/direction: 12 mph/S
Predominant drogue/float direction: NE

Legend for mapped marine data

- Green triangle = drogue/float deployment
- Red circle= drogue/float end point
- D1 and D2=drogue 1ft. depth
- D3 and D4=drogue 8 in. depth
- O=Surface float, orange
- Colored square=sample point independent of drogue/float.
- Gray box=FC/100mL, H/R=human/ruminant biomarker

Figure 11. Mapped data for flood tide sampling, September 16, 2009.

Previous 24-hour rainfall: 0.00 inches
Tidal conditions: Low 09:52 ,-.52 ft,High 17:02,9.3 ft., difference 9.82 ft., high tidal exchange
Wind Speed/direction: 5-15 mph/W
Predominant drogue/float direction: NE

Legend for mapped marine data

- Green triangle = drogue/float deployment
- Red circle= drogue/float end point
- D1 and D2=drogue 1ft. depth
- D3 and D4=drogue 8 in. depth
- O=Surface float, orange
- Colored square=sample point independent of drogue/float.
- Gray box=FC/100mL, H/R=human/ruminant biomarker

Figure 12. Mapped data for flood tide sampling, October 28, 2009.

Previous 24-hour rainfall: 0.00 inches, day 3, shellfish growing area closure, 1.13 in. October 25.
Tidal conditions: Low 07:41,2.57 ft, high 14:46,8.97 ft., difference 6.40 ft., medium tidal exchange
Wind Speed/direction: 2-5mph/N
Predominant drogue/float direction: NE

Legend for mapped marine data

- Green triangle = drogue/float deployment, Red circle= drogue/float end point
- D1 and D2=drogue 1ft. depth, D3 and D4=drogue 8 in. depth, O=Surface float, orangeColored square=sample point independent of drogue/float.
- Gray box=FC/100mL, H/R=human/ruminant biomarker

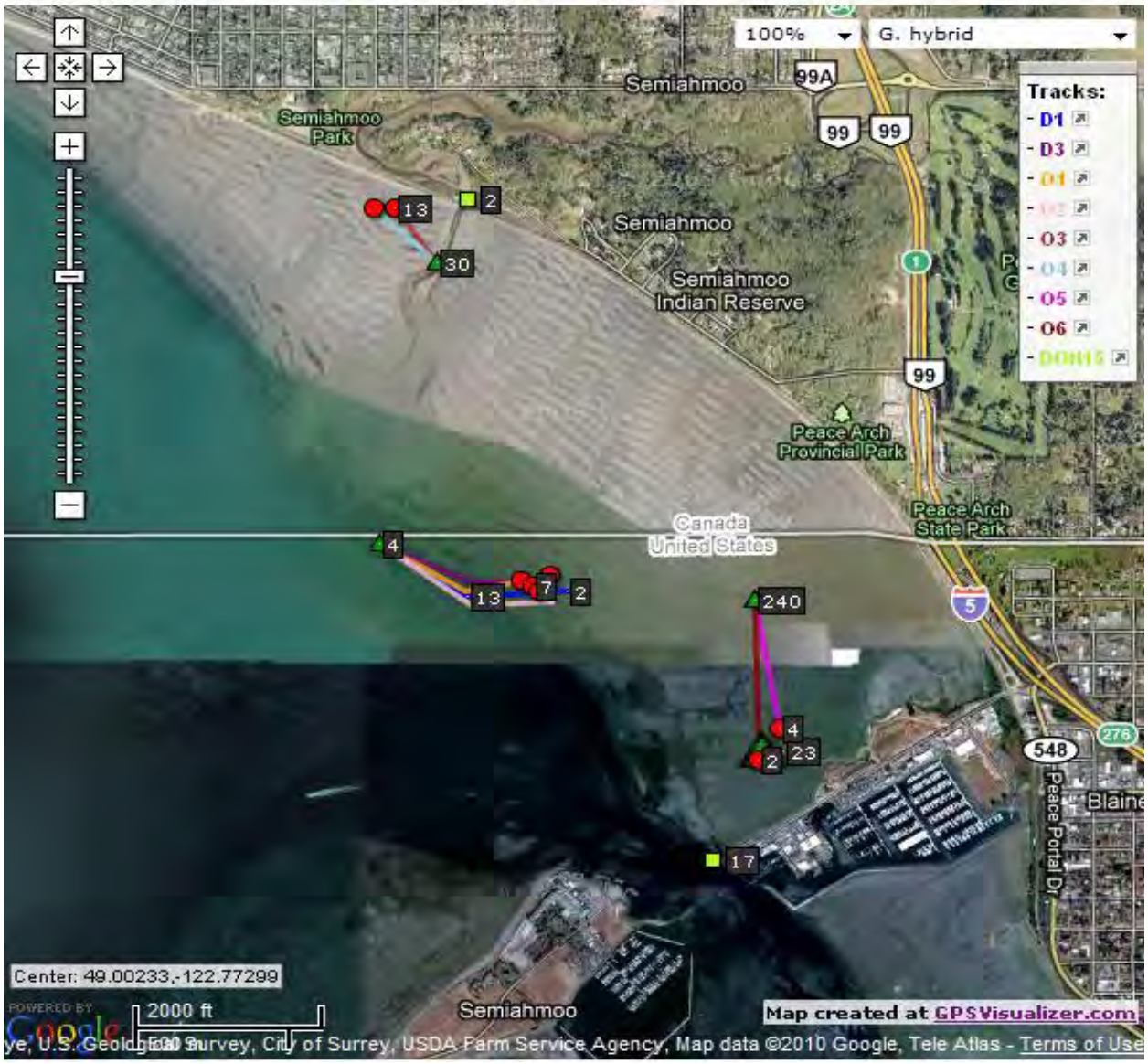

Figure 13. Mapped data for flood tide sampling, November 12, 2009.

Previous 24-hour rainfall: 0.00 inches, Tidal conditions: Low 06:50, 3.25 ft, High 13:30, 9.95 ft., difference 6.70 ft., medium tidal exchange. Wind Speed/direction: 3-6 mph/N/NE, Predominant drogue/float direction: S/SE

Legend for mapped marine data

- Green triangle = drogue/float deployment, Red circle= drogue/float end point
- D1 and D2=drogue 1ft. depth, D3 and D4=drogue 8 in. depth, O=Surface float, orange.
- Colored square=sample point independent of drogue/float.
- Gray box=FC/100mL, H/R=human/ruminant biomarker

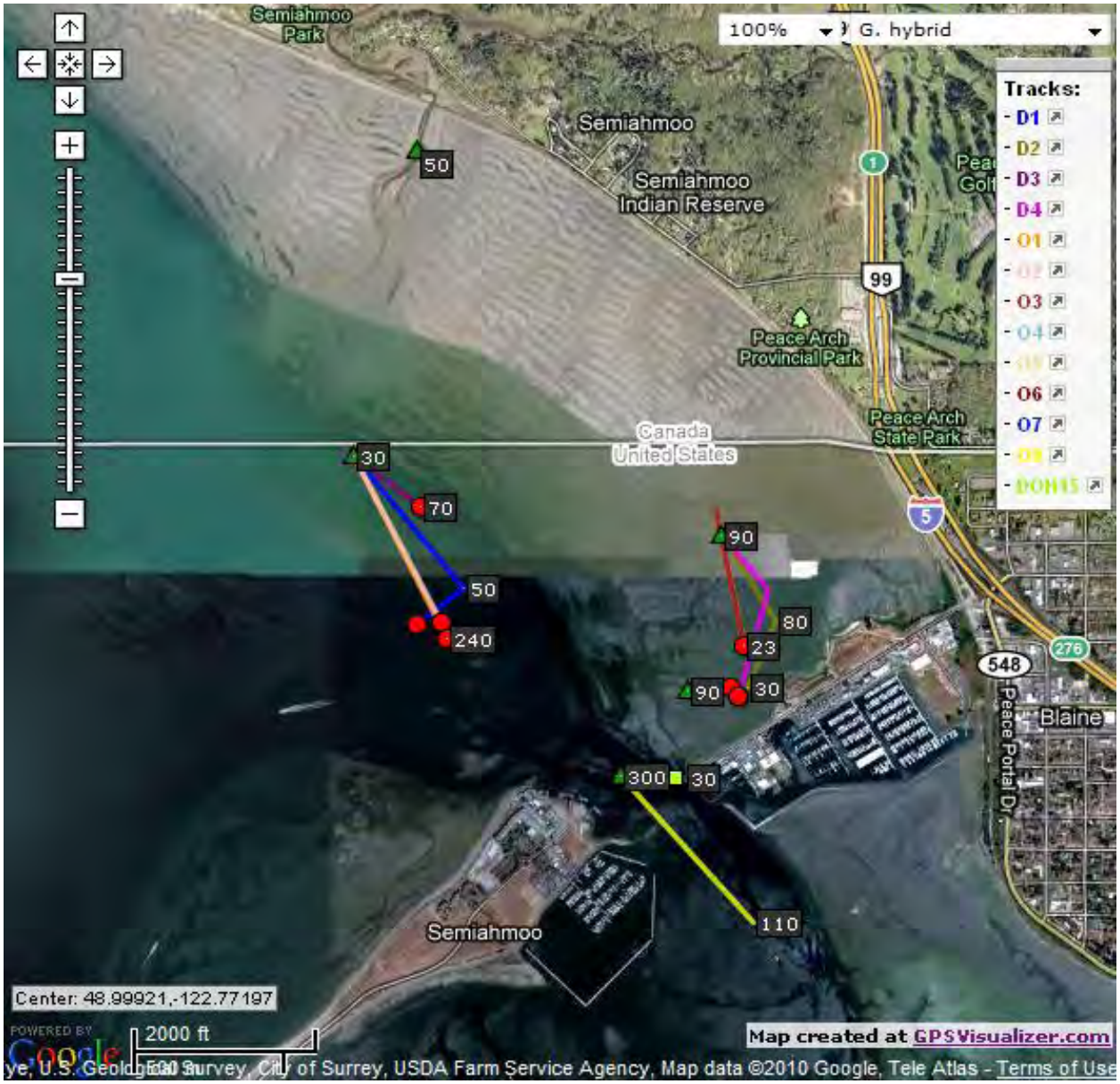

Figure 14. Mapped data for flood tide sampling, December 10, 2009.

Previous 24-hour rainfall: 0.00 inches. Tidal conditions: Low 05:04, 3.54 ft, High 11:46, 10.35 ft., difference 6.81 ft., medium tidal exchange. Wind Speed/direction: 1-3 mph/N. Predominant drogue/float direction: S/SE

Legend for mapped marine data

- Green triangle = drogue/float deployment, Red circle= drogue/float end point
- D1 and D2=drogue 1ft. depth, D3 and D4=drogue 8 in. depth, O=Surface float, orange.
- Colored square=sample point independent of drogue/float.
- Gray box=FC/100mL, H/R=human/ruminant biomarker

Addendum to Drayton Harbor Watershed Fecal Coliform TMDL and Phase 3 Microbial Source Tracking; Semiahmoo Bay

July 2010

Prepared for:

Nooksack Indian Tribe Department of Natural Resources
Deming Washington

Prepared by:

Hirsch Consulting Services
Lummi Island, Washington
(360)-758-4046 (hirschserv@aol.com)

Llyn Doremus
Nooksack Indian Tribe, Department of Natural Resources
Deming, Washington
(360)-592-5176 (ldoremus@nooksack-nsn.gov)

Geoff Menzies
Puget Sound Restoration Fund
Ferndale Washington
(360)-384-9135 (geoffmenzies@comcast.net)

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Acknowledgements

This project would not have been possible without EPA funds and the commitment of the Nooksack Tribe to restoring water quality to Puget Sound and to shellfish growing areas. Special thanks goes to the EPA Region 10 Laboratory for donating MST analysis for Drayton Harbor water quality studies and to Ecology for incorporating this work into their Drayton Harbor bacteria TMDL. We acknowledge our Canadian counterparts for their participation and all of the partnerships that contribute to restoring water quality to our shared waters.

Abstract

To augment the Washington Department of Ecology's Drayton Harbor Total Maximum Daily Load study, the Nooksack Indian Tribe funded the collection of additional data from the waters around the mouth of Drayton Harbor between June and December 2009. Potential bacteria sources were evaluated using data collected in the vicinity of the mouth of the Drayton Harbor and along the shoreline of Semiahmoo Bay northward to the Canadian border. The study was conducted in three components:

1) Six shoreline surveys along the Semiahmoo Bay shoreline from the Canadian border South to Blaine Harbor and along Semiahmoo Spit. Freshwater inputs were sampled including Cain Creek, storm drains and other small freshwater discharges.

2) Near shore marine sampling was conducted during five flood tides starting at the border monument to the mouth of Drayton Harbor. Samples were collected for analyses intermittently along the drogue paths.

3) Marine sampling was conducted during five ebb tides and followed drogues deployed at the mouth of Cain Creek . All samples were analyzed for fecal coliform bacteria content.

A subset of samples was analyzed for *Bacteroides* biomarkers using host specific polymerase chain reaction (HSPCR) analysis by the EPA Region 10 (Manchester) Laboratory. Presence of human and ruminant markers was widespread in fresh and marine waters and marked by significantly higher occurrence than observed in phase 1 and 2 of MST study completed in the Drayton Harbor and the upper watershed in 2006 and 2008. From a total of 12 sites shown in Figure 1, human biomarkers were identified at 11 locations with multiple detections at 10 sites. Ruminant biomarkers were found at 11 sites with multiple detections at 9 locations. Fecal sources present were correctly identified in 3 blind positive control samples by the EPA laboratory. Maps showing site locations and illustrating drogue tracks, fecal coliform bacteria densities and *Bacteriodes* identifications are shown. Ebb tide drogue studies indicated that high bacteria loading from Cain Creek is likely to impact water quality in the eastern near-shore of Semiahmoo Bay and that DOH Station 15 could be negatively impacted by the Cain Creek outflow. Flood tide results, demonstrated movement of drogues and floats south and east from the border monument toward the mouth of Drayton Harbor. Although drogues and floats did not enter Drayton Harbor, under certain wind and high tidal exchanges, high loads from the Little Campbell River are likely to impact Drayton Harbor consistent with Hay Study findings.

Project results were presented to a technical work group of agencies, including representatives from Canada, as a focal point to generate ideas for corrective actions to improve water quality in shared waters. These recommendations are presented in Appendix C that includes a prioritization based upon study results to assist in guiding corrective actions. Study data are used in the TMDL and recommendations will be reviewed by the Drayton Harbor Shellfish Protection District (DHSPD) advisory committee for incorporation into their Drayton Harbor Status Report and Water Recovery Plan.

Background

The Nooksack Tribe (NIT) relies upon fish and shellfish harvested from the Tribe's usual and accustomed fishing locations, which include waters in Drayton Harbor and outside along Semiahmoo Spit. The consumption of fish and shellfish as a primary dietary constituent requires that fish are free of bio-accumulated organic compounds, pathogens and metals. Restoring and maintaining high water quality throughout the Nooksack basin and its marine receiving waters is essential for the health of Tribal members who consume fish and shellfish. Improving water quality in these regions is fundamental to the continued and future Tribal harvest of fish and shellfish.

Drayton Harbor and Semiahmoo Bay are designated for water quality purposes by the Washington Department of Ecology (WAC-201-612) for shellfish harvest. Tributaries to Drayton Harbor and Semiahmoo Bay are assigned use designations of extraordinary contact recreation. These uses carry the most stringent criteria for fecal bacteria (WAC13-201A, Ecology, 2006). High fecal bacteria concentrations in Drayton Harbor have resulted in the Washington Department of Health classification of the waters as unsafe for shellfish harvest, and violation of those stringent water quality standards, generating a 303(d) listing. To address the water quality violations and improve water quality in Drayton Harbor in 2007 the Washington Department of Ecology (Ecology) initiated work on the Drayton Harbor Bacteria Total Maximum Daily Load (TMDL) study. The TMDL focused on characterizing sources of bacteria discharging to Drayton Harbor from California and Dakota Creeks, watersheds influenced by agricultural production and runoff. To augment Ecology's TMDL this project collected data for use in characterizing fecal bacteria inputs from potential sources around the mouth of Drayton Harbor and along the shoreline of Semiahmoo Bay northward to the Canadian border (shown in Figure 1). The framework for the Drayton Harbor TMDL, methods used for data collection, as well as a description of the Drayton Harbor watershed and its history are presented in the draft *Drayton Harbor Watershed Fecal Coliform Total Maximum Daily Load: Water Quality Improvement Report* (Hood and Mathieu, in publication).

Distinction of agricultural versus human sources of bacteria loading to Drayton Harbor has been the subject of two studies using Microbial Source Tracking (MST). *Bacteroides* host specific polymerase chain reaction (HSPCR) and ribotyping methods were used assess whether human and ruminant sources (H.C.S. 2008) were impacting the California and Dakota Creek tributaries to Drayton Harbor for the first study. The results identified cow/ruminant biomarkers at all eight tributary sites tested with multiple occurrences at four sites. Human sources were found at two of six tributary sites. Horse biomarkers were found at both sites tested with multiple occurrences.

At the four marine Drayton Harbor shellfish growing area stations tested there were widespread detections of human biomarkers, with repeated occurrences at three sites. Cow/ruminant biomarkers were detected at six of ten marine sites with multiple occurrences at five locations. Horse biomarkers

were found at two of four marine stations tested by the ribotyping method and avian fecal sources were the most frequently biomarker detected (by ribotyping) in marine waters.

In 2008, Whatcom County funded follow up MST analyses in tandem with the Drayton Harbor TMDL data collection at selected sites in the California Creek, Dakota Creek, and Cain Creek sub-basins. Of a total of sixteen sites, human biomarkers were identified at seven locations and ruminant biomarkers were found at five sites. Of the sixty-four total samples analyzed, human biomarkers were found in 16%, ruminant in 8%, general *Bacteroides* in 77%. MST biomarkers were absent in 23% of the samples tested. Analyses of samples collected from the Blaine Harbor marina by Ecology yielded human and ruminant biomarkers.

For this study, the third phase of MST study expands on phase 2 findings by conducting additional analyses in Cain Creek and its impacts of its discharge to marine waters of Semiahmoo Bay and Drayton Harbor. Sample analysis for *Bacteroides* DNA biomarkers by host specific polymerase chain reaction was provided by the Region 10 EPA (Manchester) Laboratory.

Bacteriodes is an anaerobic bacterium found in the gut of warm-blooded animals, where bacterial strains are specific to the host animal. The method can identify the general *Bacteroides* biomarker and it detects the presence of 2 ruminant specific biomarkers (CF 128 and CF 193) and 2 human specific biomarkers (HF 134 and HF183). This method is qualitative and it can detect the presence or absence of these biomarkers. Because *Bacteriodes* is an anaerobic bacterium, it dies off fairly rapidly when exposed to the environment and therefore the method is most effective in identifying the presence of ruminant or human sources in close proximity to a discharge. Detection limits vary somewhat among markers and inhibiting substances can sometimes limit detection (Harris 2009). The sensitivity of the ruminant marker CF 193 is 10 cps (copies of template required for detection) where 100 cps are required for detection of the other three biomarkers; ruminant CF 128 and human HF134, and HF183 (Shanks *et. al*, 2006). Therefore detection of human fecal sources may be less successful when sample sites are not in close proximity to the source of fecal contamination. Ruminant species include cattle, sheep, goats, deer, giraffes, antelopes, and camels. Detection of only the general *Bacteroides* biomarker (GB) indicates the likelihood that contaminants from sources other than humans or ruminants are present.

Each phase of the MST analyses guided a technical work group to inform agency staff of results and to generate recommendations and commitments for follow-up actions that focused on correcting pollution sources. The Drayton Harbor and Semiahmoo Bay study area is shown in Figure 1.

Goal and Objectives

Project Goal

The justification for the work reported herein was based on an assumption that ongoing bacteria loading to the waters of Drayton Harbor cause the high bacteria concentrations detected in the sampled locations around the mouth of Drayton Harbor. Reduction of bacteria content in the waters in and around Drayton Harbor will require elimination or decreasing the bacteria sources that discharge to that

vicinity. Although ongoing and intensive efforts have been devoted to that effort, most of the waters in Drayton Harbor continue to violate the water quality conditions needed for safe shellfish harvest and consumption. In order to develop and implement methods by which bacteria loading is eliminated or reduced, a better understanding of the sources of bacteria discharging to Drayton Harbor is needed.

This project collected information on bacteria content in fresh and marine waters used to assess the origin of bacteria in the vicinity of the mouth of Drayton Harbor, augmenting the Washington Department of Ecology's (Ecology) Drayton Harbor Watershed Fecal Coliform TMDL study. Locations selected for potential source characterization are near the mouth of Drayton Harbor, along the shoreline of Semiahmoo Bay northward to the Canadian border and along Semiahmoo Spit. Bacteria content and origins was evaluated in samples collected from these locations, and discharge rates measured in order to estimate loading rates. Transport routes of bacteria discharged in these areas and the likelihood of eventual migration into Drayton Harbor was studied to better assess the influence of sources on the high fecal bacteria content measured inside the mouth of Drayton Harbor.

Objectives

Objectives of the study are as follows:

- Identify sources and processes contributing to high bacteria concentrations measured at the Washington State Department of Health's (DOH) Systematic Random Sampling site located just outside the mouth of Drayton Harbor, DOH15.
- Characterize fecal coliform content and loading rates from freshwater shoreline drainages discharging along the Semiahmoo Bay and Semiahmoo Spit during a dry and a wet season.
- Characterize circulation of the Cain Creek outflow during ebb tides from wet and dry season conditions and marine near-shore fecal coliform density and circulation during ebb tide conditions for dry and wet seasons.
- Characterize marine near-shore fecal coliform density and circulation during flood tide conditions for dry and wet seasons.

Study Design

The project was structured to collect information with which to better understand the sources and transport mechanisms contributing to the high fecal coliform levels measured near the mouth of Drayton Harbor. Specifically DOH15 and DOH5 (inside Drayton Harbor south of Semiahmoo Spit and) monitored by DOH) receive discharges from areas included in the study area that may impact water quality in Drayton Harbor. Fresh water discharging to the water surrounding the Drayton Harbor mouth

was characterized, with concurrent sampling and characterization of the marine waters in the area and transport pathways for bacteria discharged to Drayton Harbor were evaluated. Fresh water data were collected from Cain Creek, the northern-most fresh water stream that discharges to Semiahmoo Bay in the U.S., to estimate bacteria loading rates from the Creek. Bacteria content in storm drains and seeps on both sides of the Drayton Harbor mouth was measured. To better delineate potential sources of bacteria in these fresh water discharges, selected samples were analyzed using MST. Several fresh water drainages discharge to Semiahmoo Bay north of the Canadian border where high fecal bacteria concentrations have been detected; the Serpentine River and the Little Campbell River (Hay & Com., 2003; Fleming and Quilty, 2006). Although, it is likely that contributions of fecal bacteria from these rivers impact the marine waters sampled for this project, they were not characterized in the analyses presented herein.

Analyses of receiving water bacteria content and circulation were used to determine the fate and transport of bacteria received from fresh water discharges. Drogue tracking and sampling during ebb and flood tides was used to define the direction and rate of shallow surface marine water transport in the vicinity of the Cain Creek estuary and the Drayton Harbor mouth.

Data were collected in three sub-components: 1) bacteria content in fresh water from potential source areas discharging in the vicinity of the mouth of Drayton Harbor; 2) characterization of transport pathways and bacteria concentrations during an ebb tide cycle; and 3) flood tide transport pathways and bacteria concentrations. Data were collected from the waters near the mouth of Drayton Harbor from June 2009 through December 2009 to characterize dry and wet season conditions. Sampling dates are listed in Table 5. The *Addendum to Drayton Harbor Watershed Fecal Coliform TMDL; Phase I, Water Quality Study Design quality assurance project plan* (Hirsch, 2009) provides a detailed description of the study design and methods (Appendix D).

Fresh Water Shoreline Surveys

Fresh water sources of fecal bacteria discharging from stormwater outfalls and seeps along the shoreline of Semiahmoo Bay from the Canadian border south to Blaine Harbor and along Semiahmoo Spit were assessed by collecting samples at ten stormwater outfalls (three located between the U.S.- Canadian border and the mouth of Cain Creek, two located between the Cain Creek mouth and the mouth of Drayton Harbor, and six on Semiahmoo Spit) and two seeps along Semiahmoo Spit. Six shoreline surveys were conducted between June and December 2009. Sample collection locations are listed in Table 1 and shown in Figure 2.

The potential contribution of Cain Creek to fecal coliform in Drayton Harbor was assessed using data collected at five locations upstream of the mouth of Cain Creek. Fecal coliform loading was assessed by instantaneous instream flow measurement collected using a Swoffer current meter at the time of sample collection at Cain Creek sample locations.

Locations where samples collected during the dry season shoreline surveys evidenced significant fecal bacteria content were selected for follow-up microbial source tracking sampling and analyses during wet season sampling events. Microbial source tracking using the *Bacteroides* host specific polymerase chain reaction analysis was done by the EPA Region 10 Laboratory (Manchester Lab) using methods described

in the EPA QAPP composed for previous MST analyses completed on samples from Drayton Harbor (EPA, 2006). This set of MST analyses constituted Phase 3 of the MST characterization work completed previously in the Drayton Harbor watershed by Ecology and Whatcom County.

Ebb Tide Flows from Cain Creek

To evaluate the flow direction of waters issuing from Cain Creek into the marine waters of Semiahmoo Bay during an ebb tide drogues and floats were released at the mouth of Cain Creek and tracked over a four hour period. The locations of the drogues and floats were recorded periodically over the duration of the tracking period, and samples collected at the recorded locations and ancillary points in the vicinity. The configuration of drogues and floats was selected to reproduce methods used by the DOH for previous circulation studies conducted in the Drayton Harbor vicinity. Fresh water samples were also collected from selected points in Cain Creek at the initiation of the ebb tide marine measurements in order to evaluate the potential for Cain Creek source contributions to measured marine water fecal bacteria concentrations.

Cain Creek outflow was monitored during five different ebb tides to determine the route taken by the floats and drogues. Approximately 10-12 fecal coliform samples were collected at intervals along the path of float/drogue travel beginning at the mouth of Cain Creek.

Table 1. Shoreline Survey Data Collection Sites.

Site ID	TMDL site ID	Description	Latitude (˚N)	Longitude (˚W)
CC1.3	1-Cain-1.3	Cain Creek @ Pipeline Rd south of airport,plastic culvert	48.98674	122.73325
CC1.3A		Cain Creek @ Pipeline Rd S. of airport, damaged concrete culvert enters channel from S.	48.98674	122.73328
CC0.4	1-Cain-0.4	Cain Creek behind Blaine Trade Center	48.99295	122.74513
CC0.2		Cain Creek behind library	48.99507	122.74857
CC0.01	1-Cain-0.01	Cain Creek mouth; 60" culvert off of Marine Dr, just north of boatyard	48.99689	122.75465
CCSD	1-Cain-SD1	Channel from storm drainage outfall to Semiahmoo Bay, north of the mouth of Cain Creek about 50ft downstream of outfall	48.99711	122.75465
SD1		Storm drainage outfall to Semiahmoo Bay, north of CCSD	48.99985	122.75595
SD2		Storm drainage outfall to Semiahmoo Bay, about 20'S of Canada Border	49.00216	122.75779
CAN1		Small stream drainage to Semiahmoo Bay over beach just N.of Canada border	49.00216	122.75779
CAN2		Small stream drainage to Semiahmoo Bay over beach just N.of Canada border	49.00232	122.75794
MD1		Storm drainage outfall to Semiahmoo Bay from Marine Dr.	48.99654	122.75643
MD2		Storm drainage outfall to Semiahmoo Bay from Marine Dr. midway out to end of dock, 8" white PVC mostly submerged in gravel.	48.99455	122.76179
SS1		Storm drainage outfall to Semiahmoo Bay at end of Semiahmoo Spit, 36" concrete culvert	48.99056	122.77135
SS2		Storm drainage outfall to Semiahmoo Bay at end of Semiahmoo Spit, 8 " gray plastic submerged in saltwater	48.99099	122.77232
SS3		Storm drainage outfall to Semiahmoo Bay at end of Semiahmoo Spit , 6" PVC pipe	48.99099	122.77268
SS4		Storm drainage outfall to Semiahmoo Bay on N side of Semiahmoo Spit behind Blaine STP, 30" concrete culvert	48.97729	122.79345
SS5		Beach seep N. of Semiahmoo Inn	48.99035	122.77563
SS6		Concrete culvert (10'') from old Semiahmoo boatyard near marina	48.9888	122.77139
SS7		Beach Walker Condo storm drain w engineered grate	48.98878	122.7765
SS8	DS-1	Beach seep S. side Semiahmoo Spit below houses	48.9761	122.7906

Flood Tide circulation characterization

Sources contributing to the high fecal coliform concentrations potentially deriving from waters north of the Drayton Harbor mouth were assessed by drogue tracking and sample collection during incoming flood tides. To evaluate flood tide circulation patterns drogues and floats were released at two locations and monitored over the course of four hours. Five flood tide tracking and sampling events were conducted between June and December 2009. Drogue tracking procedures are described in the Field Procedures section under Data Collection and Analysis Methods. Marine water samples for fecal bacteria analysis were collected concurrently during each event, including DOH Station 15.

Data Collection and Analyses Methods

Field and analytical methods are summarized in Table 2 and described in greater detail in the Quality Assurance Project Plan for the Addendum to Drayton Harbor Watershed Fecal Coliform TMDL; Phase I, Water Quality Study Design (Appendix D).

Field Procedures and Sample Handling

Water Quality Sample Collection

Samples from fresh water, during the shoreline surveys, and from marine water during ebb tide and flood tide characterizations, were collected using DOH sample collection and transport procedures as described in the Systematic Random Sampling (SRS) program and Standard methods 9060A and 9060B (DOH, 1996; APHA, 1998). All samples were collected and stored in containers provided by Avocet Environmental Testing (fecal coliform analyses) or the EPA Region 10 Laboratory (microbial source tracking analyses). Fecal coliform samples were collected in 120mL sterile plastic bottles and MST samples were collected in 250mL sterile plastic bottles. Samples were immediately placed on ice in a cooler upon collection. Each bottle was labeled with a site number prior to sampling and site numbers were recorded on write-in- the- rain field data sheets prior to sampling. Site numbers, date, and time sampled for each sample was transcribed to the chain-of-custody sheet prior to submitting samples to the laboratory. Fecal coliform samples were delivered to the laboratory within 8 hours of sampling. MST samples were shipped to the EPA Region 10 Laboratory via Fedex Express priority overnight shipping and arrived within 30 hours of sampling.

Samples for fecal bacteria and MST analyses were collected using either a sampling wand or hand dipping in midstream and just below the surface. Sample locations were recorded using a handheld Garmin Mariner eTrex GPS unit. At freshwater sites samples were collected prior to measuring discharge so that the sediment matrix was not disturbed.

Water Quality Parameter Measurements

Field measurements for temperature, dissolved oxygen and specific conductance were taken at freshwater sampling sites and (temperature) at marine sample sites using a calibrated YSI 556 multi-parameter sensor. Salinity measurements at marine sites were taken using a portable salinity refractometer EXTECH model RF20 following the procedure described in the instrument user's guide (EXTECH, 2003). Procedures used for calibration and operation of the YSI 556 MPS are described in the YSI 556 MPS operations manual (YSI Environmental, 2003).

Stream Flow Measurements

Instantaneous stream flows were measured in wadeable streams using the USGS procedure for measurement of discharge by conventional current meter method (Rantz et al. , 1982) and a Swoffer current meter according to the Swoffer operations manual (Swoffer Instruments, Inc. , 2008). Cross-sectional area of stream units (cells) were multiplied by measured flow velocity to obtain discharge

volume estimates. Measurement of discharge issuing through pipes or culverts was done using timed flow volumes accumulation into a calibrated container (catchment).

Drogue tracking for Tidal Circulation Characterization

A combination of numbered floats (oranges), 1-foot deep drogues and 8-inch deep drogues were used to monitor tidal current directions during ebb tide and flood tide cycles. The drogues were constructed of 12" X 16" (3/16th inch thick) aluminum crossed vanes suspended below a yellow crab-pot type float used in previous studies (Menzies, 2003).

Cain Creek outflow was monitored during five different ebb tides to determine the route taken by the floats and drogues. Two to 4 drogues and 6-10 floats were released at the mouth of Cain Creek at the beginning of an ebb tide. It was necessary to adapt the number of floats and drogues based upon tidal level at the Cain Creek outflow to ensure that an adequate number exited to deeper water without being hung- up on the mudflats. There were occasions where it was necessary to retrieve and redeploy drogues and floats that became hung-up. Float and drogue locations were recorded with a handheld Garmin Mariner eTrex GPS unit periodically during each circulation monitoring event and mapped using GPS Visualizer website (GPS Visualizer, 2010). Tidal conditions were derived from the NOAA tide and current website (NOAA, 2010).

Flood tide current flow direction was monitored by releasing 2-4 drogues and 6-10 floats over five tracking events that were conducted during wet and dry season conditions. Drogues were deployed at the concrete border monument at the Canadian border and further south along the near-shore in the vicinity of the Cain Creek outflow. Locations were monitored using the same methods as those described for the ebb tide characterization above. Floats were added to flood tide tracking after the 2nd sampling event.

Analytical Methods

Samples were analyzed by Avocet Environmental Testing for fecal coliform content by membrane filtration (SM9222D) for fresh water samples and multiple tube fermentation (SM9221E) for samples collected from marine waters. Avocet Environmental Testing is accredited by Ecology for fecal coliform bacteria analysis following their QAPP (Avocet Environmental Testing 2009). The analytical methods are summarized in Table 2.

Microbial Source Tracking analysis using the *Bacteroides* host specific polymerase chain reaction analysis method was conducted at the EPA Region 10 Laboratory (Manchester) according to procedures defined in the Quality Assurance Project Plan for Drayton Harbor Microbial Source Tracking Pilot Study (EPA, 2006).

Table 2. Summary of water quality analyses methods and sample handling.

Parameter	Description	Method	Sample Container	Preser-vation	Holding Time
Water Temperature	YSI 556	YSI 556	None	None	none
Specific Conductivity	YSI 556	YSI 556	None	None	none
pH	YSI 556	YSI 556	None	None	none
Dissolved Oxygen	YSI 556	YSI 556	None	None	none
Salinity	Portable refractometer	ExTech RF20	None	None	none
Fecal coliform bacteria	Membrane filtration	APHA 9222D	PE, 125 mL, sterile	4 °C, dark	(max) 24-hours
Fecal coliform bacteria	Multiple tube fermentation	APHA 9221E	PE, 125 mL, sterile	4 °C, dark	(max) 24-hours
HSPCR	PCR-2marker	EPA Region 10 Lab Procedures	PE, 250 mL, sterile	10 °C, dark	(max) 24-hours

Data Quality

Method Quality Objectives

Data quality objectives (DQOs) are summarized below and described in the QAPP in greater detail (Hirsch, 2009). The standards used for deriving the project data quality objectives were intended to generate data comparable to that collected for the Drayton Harbor Watershed Fecal Coliform TMDL Phase I Water Quality Study Plan (Mathieu and Sargeant, 2008) and by Washington Department of Health for the Systematic Random Sampling Program (DOH, 1997). As such, the method quality objectives (MQOs) listed in the Drayton Harbor TMDL QAPP and the Drayton Harbor Watershed Fecal Coliform TMDL Water Quality Improvement Report (Hood and Mathiue, in publication) were adopted herein by reference. The MQOs listed in the EPA QAPP for Drayton Harbor microbial source tracking (EPA, 2006) were adopted by reference for the MST portion of the project. The TMDL defines DQOs in terms of method quality objectives (MQOs), reporting limits and resolution. Data quality objectives are presented in the QAPP. All data collected are presented in Appendix A. Laboratory sheets and chain of custody sheets will be provided upon request. Field personnel were trained by Ecology staff and

comprised one of the TMDL data collection teams in the upper Drayton Harbor watershed in 2008. All parameters measured met applicable MQOs shown in Table 3 and quality assurance results are compared to MQOs in Table 4.

Table 3. Method quality objectives for field and laboratory analyses

Parameter	Method	Range	Precision	Accuracy	Quantitation Limits
Water Temperature	YSI 556	-5 to 45 C	0.01°C	± 0.15 °C	NA
Specific Conductivity	YSI 556	0 – 200 mS/cm	± 0.001 mS/cm, to 0.1 mS/cm (range dependent)	± 0.5% of reading OR ± 0.001mS/cm, whichever is greater	10% RSD*/0.1 mS/cm, 0.01 units
Dissolved Oxygen	YSI 556	0 to 50 mg/L	0.01 mg/L	±0.2 mg/L or ± 2% of the reading, whichever is greater	10% RSD*, 0-50mg/L/0.01mg/L
Salinity	ExTech RF20	0 to 100 ppt	±1ppt	±1ppt	0 to 100 ppt
Fecal coliform bacteria	Membrane filter APHA 9222D	< 2 to 1,600 cfu/100 mL	20% RSD*	20% RSD*	2 cfu/100 mL
Fecal coliform bacteria	Most probable number APHA 9221E	< 2 to 60,000 cfu/100 mL	20% RSD*	20% RSD*	2.0 cfu/100 mL
HSPCR	EPA Region 10 Lab Procedures				10-100 DNA strand

* RSD-Relative standard deviation, standard deviation of replicate pairs divided by the mean.

Table 4. Precision results for sample replicates compared with method quality objectives.

Parameter	[1]N	Percent replication	Median RSD criteria	Median RSD	90th percentile RSD criteria	90th percentile RSD	Pass
FC membrane filter (MF)	12	20%	<20%	16%	<50%	35%	yes
FC most probable number (MPN),mean >20cfu	6	[2] 15%	<50%	33%	<100%	NA	yes
FC most probable number (MPN),mean <20cfu	9	[2] 15%	<50%	39%	<100%	NA	yes
Temperature	15	17	0.1°C	0.0°C	NA	NA	yes
Discharge	6	16	<10%	6%	NA	NA	yes
Conductivity	6	14	<10%	1%	NA	NA	yes
Salinity (refractometer)	8	10	±1ppt	0 ppt	NA	NA	yes
Dissolved Oxygen	6	14	<10%	1%	NA	NA	yes

[1] N=Number of replicate pairs.

[2]= Overall replication for MPN samples was 15%

Data quality objectives were met by employing the following procedures.

Sample collection:

- Fecal coliform field replicates were collected for 20% of samples analyzed by membrane filtration (freshwater samples) and for 15% of samples analyzed by MPN (marine samples). Replicates met applicable to MQOs.
- Temperature control samples were submitted to the laboratory with each batch of fecal coliform samples along with chain of custody forms. All samples met temperature control limits.
- Chain of custody forms were submitted to the laboratory with each batch of samples.

Field data collection:

- The YSI 556 multi-parameter sensor was calibrated immediately prior to each sampling event according to manufacturer's instructions (YSI Environmental, 2003).
- Field measurements were replicated for 10-17% of YSI 556 measurements, Swoffer current meter measurements and refractometer measurements. Field replicate measurements met MQOs.

Laboratory Analytical data:

- Thirteen percent of the 179 fecal coliform samples analyzed by Avocet Environmental Testing were qualified as estimates due to sample dilution. If the number of fecal coliform colonies counted was outside the desired yield of 20-60 per plate or the MPN index reached its maximum the analyses conformed to the laboratory's data quality objectives. During the study period the laboratory successfully analyzed performance evaluation samples for certification purposes. Laboratory duplicates were not analyzed for project samples. Blanks were analyzed for 10% of all membrane filtration samples analyzed.

- Three blind positive control samples were submitted to the EPA Region 10 laboratory for HSPCR analysis and identified correctly. Laboratory duplicates were analyzed for 14% of the (50) samples submitted. Of the 7 laboratory duplicate pairs, five returned results with differences in biomarkers identified between the replicates, considered acceptable due to the heterogeneity of *Bacteroides* in water samples and biomarker detection limits (Harris, 2010).

Representativeness

To address the natural spatial and temporal variability encountered in characterizing fecal bacteria distribution in the natural environment and its sources, data was collected over a wide range of conditions likely to affect bacteria content in the near shore Drayton Harbor environment. Eighteen shoreline discharge sites were identified for potential sample collection and measurement, however only ten of these contained adequate flow to sample during the study period . Field observations indicated that some of these sites are likely to contain small intermittent flow during storm events. Sample collection and measurements were repeated for up to six events.

During each of ten marine collection events (five ebb and five flood) an average of 15 marine locations was monitored for water quality and samples collected for water quality analyses. Tidal movement was monitored with an average of 30 GPS readings of drogue locations per event progressing over a tidal phase (approximately four hours).

Forty seven samples from a subset of freshwater and marine locations were analyzed by HSPCR to determine human and ruminant sources of fecal content (microbial source tracking analyses). This large number of data points collected from varied environment types and over a range of environmental conditions characterized the general origin (human or ruminant) and associated fecal coliform content.

Comparability

In order to facilitate comparable data collected for this project with data collected by Ecology and DOH, the procedures for data collection used by those agencies were employed. The project QAPP was reviewed and approved by Ecology for comparability between data generated by this study and that collected during the TMDL study.

Completeness

Ecology has determined that five samples are required from each sampled site in order for the sample record to provide a complete range of site characteristics for use in the Drayton Harbor TMDL waste allocation. A minimum of five sample events for each project component; Shoreline Surveys and Marine near Shore Sampling both ebb and flood tide in order to collect an adequate number of samples for characterization. At four freshwater sample locations dry conditions precluded collection of five samples (out of ten fresh water sample sites). Sixty-two sampling opportunities were missed due to dry conditions. Data from sites with less than five data points can be used for alternative analyses, source location identification, or recommendations. Because marine sampling locations were not fixed, results were pooled for data analysis by sampling event. Four data collection opportunities were missed out of a total of 867 collected, and including three bacteria quality assurance samples for the MPN method. The overall completeness percentage was greater than 99%.

Data Assessment, Reporting, and Audits

Analytical data received from the laboratory was transcribed into an Excel computer database. Copies of field sheets were transmitted to NIT and to Ecology along with fecal coliform data compiled in a draft Excel spreadsheet within two weeks of receipt from the laboratory. Each data point entered into the datasheets was checked to ensure accuracy in data entry and incorrect entries were corrected when found. A set of data sheets was generated in comma separated delimited format (Appendix E) for entry into GPS Visualizer, a web based mapping program, and plotted over a Google Maps layer to illustrate the movement of drogues and the spatial distribution of bacteria and bacterial source identifiers in relation to potential pollution sources and to determine drogue/float speed. In some instances it was necessary to adjust site identifiers for drogue mapping in order to reformat the data for mapping. All datasheets were compiled into master spreadsheets by project component and rechecked for errors in compilation prior to data quality assessment, data analysis and reporting.

Results and Discussion

Water Quality Standards

Data were collected for use in assessing whether freshwater discharges to Semiahmoo Bay near the Drayton Harbor mouth and the eastern and southern near-shore marine waters of Semiahmoo Bay south of the Canadian border impact water quality in Drayton Harbor. The results should be used to assess potential corrective actions to reduce bacteria discharges influencing Drayton Harbor water quality and to implement measures that will bring the waters in and around Drayton Harbor into compliance with water quality standards. Project results are compared to water quality criteria listed in Table 5.

Table 5. Washington State Water Quality Standards for fecal coliform bacteria designated for Semiahmoo Bay and its tributaries.

MARINE WATER QUALITY STANDARD

water use designation: shellfish harvest[1]

The geometric mean shall not exceed fecal coliform content of 14 CFU/100 ml; and less than 10% exceed 43 CFU/100 ml.

FRESH WATER QUALITY STANDARD

water use designation: extraordinary primary contact recreation

The geometric mean shall not exceed fecal coliform content of 50 CFU/100 ml; and less than 10% exceed 100 FCU/100 ml

[1]National shellfish sanitation program (NSSP, 1997) administered by Washington Department of Health uses the estimate 90% and requires at least 30 data points for shellfish growing area classification.

Field Conditions

Rainfall, tide and wind conditions are environmental factors that may have influenced fecal coliform organism densities and distribution measured during sampling event s; conditions are summarized in Table 6. For the Ecology TMDL study, the wet season was defined as November through March. Data were collected for this study from June through early December 2009 and did not span a full wet season. This may be the cause for insufficient flows from which to collect measurements and samples at most of the sites located along Semiahmoo Spit and along Marine Drive. The amount of data available for wet season conditions is less than dry season, making the wet season analyses more provisional. The reduced sample number and restricted sampling period may have contributed to underestimation of average loading from the sources characterized.

Table 6. Environmental conditions for sampling events.

Date	Corres-ponding figure	[1]Previous 24-hour rainfall (inches)	[3] Tide	Tidal Exchange	[4] Wind speed/direction
Shoreline Survey/Tributaries			NA	NA	NA
6/4/2009		0.00	NA	NA	NA
7/7/2009		0.13	NA	NA	NA
9/17/2009		0.10	NA	NA	NA
10/27/2009		0.05	NA	NA	NA
11/11/2009		0.05	NA	NA	NA
12/9/2009		0.05	NA		NA
Ebb/Marine,Tributaries					
6/10/2009	4	0.0	High 05:37, 7.92 ft, Low 13:40, -1.56 ft, Difference 9.48 ft.	High	6 mph/S
6/24/2009	5	0.02	High 05:07,9.36 ft., Low 13:07 -3.75 ft., Difference 13.11	High	0- 8 mph/NNE
8/10/2009	6	0.57	High 08:30,6.80 ft., Low 14:34, 2.41 ft. , Difference 4.39 ft.	Low	2.5-4.5mph/SSE
8/11/2009	7	0.53	High 09:36, 6.57 ft. Low 15:08, 3.63 ft., Difference 2.94 ft.	Low	3-5mph/SSW
9/22/2009	8	0.00	High: 09:14, 8.72 ft. Low 14:26, 5.48 ft., Difference 3.24 ft.	Low	1-4mph/WSW.
Flood/Marine					
6/17/2009	9	0.00	Low 08:05, 1.49 ft, High 14:57 5.79 ft., Difference 4.30 ft.	Low	12 mph/S
9/16/2009	10	0.00	Low 09:52 ,-.52 ft,High 17:02,9.3 ft., Difference 9.82 ft.	High	5-15 mph/W
10/28/2009	11	[2] 0.00	Low 07:41,2.57 ft, high 14:46, 8.97 ft., Difference 6.40 ft.	Medium	2-5mph/N
11/12/2009	12	0.00	Low 06:50,3.25 ft, High 13:30, 9.95 ft., Difference 6.70 ft.	Medium	3-6 mph/N/NE.
12/10/2009	13	0.00	Low 05:04,3.54 ft, High 11:46, 10.35 ft., Difference 6.81 ft	Medium	1-3 mph/N.

[1] Rainfall data from Blaine sewage treatment plant (2009).

[2] Day 3 of shellfish growing area closure, 1.13 in. October 25.

[3] From http://tidesandcurrents.noaa.gov/

[4] Wind data from Wunderground,(S. Surrey/White Rock,BC (www.wunderground.com/global/stations/71785.html)

Freshwater: Shoreline Surveys and Tributaries

A summary of the analyses results for fecal coliform bacteria content for the freshwater discharges is presented in Table 7. The MST results are summarized in Tables 12 and 13 and discussed in further detail in the MST section. Sample site locations are shown in Figure 2, the geometric means and MST biomarker results for sample sites are shown in Figure 3. Fecal coliform bacteria loading is shown in Figure 4.

Table 7. Fecal coliform bacteria summary for freshwater discharges.

Station	n	Geometric mean[1]	%>100[1]	%>43[2]	Min (FC/100mL)	Max (FC/100mL)	[4] Average load billion cfu/day	# Samples exceeding 1000FC/ 100mL	Mean discharge (cubic ft./second)
CC1.3	3	26	0	33	7	68	0.23	0	0.211
CC1.3A	3	23	0	33	10	48	0.25	0	0.200
CC0.4	9	**762**	**89**	100	58	6300	2.69	5	0.380
CC.0.2	6	**571**	**100**	100	110	5700	1.79	2	0.172
CC0.01	10	**599**	**90**	100	63	4600	34.71	3	6.200
CCSD	10	**149**	**80**	0	4	2100	0.18	2	0.269
SD1	5	33	**20**	40	2	1300	3.19	1	0.232
SD2	5	39	**40**	60	6	240	0.10	0	0.115
SS4	3	**93**	**67**	67	6	580	1.48	0	0.215
SS8	2	47	50	50	20	110	0.75	0	0.385 [3]
CAN1	1	N/A	N/A	N/A	50	50	N/A	N/A	N/A
CAN2	1	N/A	N/A	N/A	32	32	N/A	N/A	N/A
MD2	1	N/A	N/A	N/A	66	66	N/A	N/A	N/A

[1] Bold indicates violation of Washington fecal coliform primary contact standard a) geometric mean of 50 FC/100mL and b) no more than 10% of samples exceeding 100 FC/100mL.

[2] Project indicator ; Washington marine fecal coliform standard no more than 10% of samples exceed 43 FC/100mL.

[3] Based upon single measurement

[4] The number of values used for loading may vary from n because some sites were sampled during marine (ebb) sampling when flow was not measured.

Cain Creek and Cain Creek Storm Drain

High fecal bacteria concentrations, exceeding the 90% water quality standard of 100 CFU/100 ml were measured on multiple occasions at the five fresh water sites sampled in Cain Creek (results are shown in Table 6). Sites CC 1.3 and 1.3A near the head waters of the sub-basin were the only freshwater locations that met applicable water quality standards. MST analyses indicated repeated occurrence of human biomarkers at CC 1.3. At CC 1.3A there was one occurrence of ruminant biomarker presence. A marked deterioration in water quality occurred between CC1.3 and the downstream site CC0.4 where the geometric mean for fecal coliform concentrations was more than 15 times the applicable standard of 50 cfu/100mL and human biomarkers were identified in 5 of 6 samples that suggests the presence of a human sewage source. Downstream the Cain Creek storm drain, (site CCSD)and the mouth of Cain Creek failed to meet FC standards and human biomarkers were detected in 5 of 6 MST samples.

Stream flow rates measured at the Cain Creek mouth varied between 0.12 and 1.21 cubic feet per second (cfs). The higher flows were measured during November and December, which coincided with somewhat lower fecal coliform concentrations. The maximum fecal coliform loading rates were relatively constant throughout the study period and ranged from 1.94E+08 cfu/day on June 4,to 1.84E+11cfu/day on November 11. The loading pattern could suggest a source of fecal coliform to Cain

Creek that is relatively constant. The rate of water flow transporting a constant fecal coliform source changes from dry to wet season and can dilute the source during higher flows resulting in lower measured fecal coliform concentrations.

For the most part fecal coliform concentrations and fecal load rates in storm drains were high, but still lower by an order of magnitude than in Cain Creek. The discharge measured in Cain Creek storm drain (CCSD) failed to meet water quality standards, although fecal coliform content in individual samples collected in November and December were below the 14 CFU/100 ml standard for shellfish harvest.

Semiahmoo Bay East Shore Storm Drains

Two storm drains (SD1 and SD2) were sampled that serve Peace Arch Park and nearby mixed residential and commercial area that discharge below the railroad tracks to the beach. Construction of freeway ramps and the customs station took place over much of the study period. These sites met the applicable geometric mean standard but failed the 90th% criteria and they both exhibited multiple occurrences of human markers. Storm Drain 1 (SD1) measured in November was exceptionally high, at 1,200 CFU/100 mL. Two small flowing discharges within a few feet of each other and 20 feet north of the Canada border and SD2 were sampled during the initial sampling event on June 4 for screening purposes. Because the samples met the water quality standard further sampling was not pursued at the time with Canadian counterparts. However the occurrence of human biomarkers at SD2 may warrant follow-up investigation to determine whether the discharges originate from a common source.

Semiahmoo Spit

There was adequate flow at 2 of 8 potential discharges identified at Semiahmoo Spit, during the study period however there was visual evidence of intermittent flow at some of the sites. Site SS4 is a culvert discharging to Tongue Shoal in Semiahmoo Bay, north of the Blaine sewage treatment plant. It had adequate flow to sample during 3 sampling events, October through December and it violated the geometric mean and 90th percentile criteria. Human fecal source(s) were identified by HSPCR in 3 of 4 samples. This site may be of particular interest to the Nooksack Tribe and should be considered for addition to the monitoring regime. The remaining site SS8 represents a beach seep near TMDL shoreline survey site DS-1 that drains a slope below residences where human biomarkers were detected by MST in 1 of 2 samples.

Many of the Semiahmoo Spit monitored storm drains discharged little to no flow during the duration of this study. This is likely a result of the small contributing area that discharges through the storm drains on Semiahmoo Spit. Drainage located where the Spit joins the mainland (SS4 and SS8) are more likely to transmit stormwater draining from a larger area. Fecal coliform concentrations exceeding the water quality standards were measured at both sites during wet months.

Fecal Coliform Loads

Fecal coliform loads were determined for shoreline survey sites when adequate flow allowed following calculations used by Ecology for the TMDL evaluation and fecal coliform sample results were averaged with results for quality assurance samples to coliform loads (Mathieu, 2010).

Average loads are shown in Table 7, load rankings are shown in Table 8 and illustrated in Figure 4. Instantaneous loads are included in the project database, Appendix A.

In general, loading resembled the dry season loads observed by Ecology during the TMDL evaluation. The site at the mouth of Cain Creek (CC0.01) exhibited the highest loads discharging 35 billion CFU/day followed by SD1 on the eastern shoreline of Semiahmoo Bay and then the two Cain Creek sites upstream from CC0.01, CC 0.2 and CC0.4 which were a magnitude lower than CC0.01. The Semiahmoo Bay storm drain (SD1) ranked second in loading due to a sample result of 1300 cfu/100mL following a first flush storm on August 11. The Semiahmoo Spit storm drain (SS4) that discharges to Tongue Shoal behind the Blaine sewage treatment plant ranked 5th in loading after the lower Cain Creek sites. The remainder of the sites exhibited a magnitude of loading lower, from the upper Cain Creek sites (CC1.3 and 1.3A) to the Cain Creek storm drain (CCSD) and Semiahmoo Storm Drain 2.

Table 8. Shoreline survey sites ranked by average loading

Shoreline Survey Sample Sites	Average fecal coliform load (billion cfu/day)
Cain Creek 0.01 (CC0.01)	34.71
Semiahmoo Storm Drain 1 (SD1)	3.19
Cain Creek 0.4 (CC0.4)	2.69
Cain Creek 0.2 (CC0.2)	1.79
Semiahmoo Spit 4 (SS4)	1.48
Semiahmoo Spit 8 (SS8)	0.75 [1]
Cain Creek 1.3A (CC1.3A)	0.25
Cain Creek 1.3 (CC1.3)	0.23
Cain Creek Storm Drain (CCSD)	0.18
Semiahmoo Storm Drain 2 (SD2)	0.10

[1] Single measurement

Temperature, Dissolved Oxygen and Conductivity

Temperature, dissolved oxygen and specific conductance were measured at fresh water sample sites when fecal bacteria samples were collected (Cain Creek and storm drain discharges). Salinity and temperature were measured at marine sample locations during drogue tracking for the ebb and flood

tide characterization. Measured values are summarized in Table 9 and presented in complete format in Appendix A.

Fresh water specific conductance measured in Cain Creek and two storm drains (SD1 and SD2) ranged from 0.14 to 34.1 millisemens per centimeter (mS/cm). Specific conductance values above 1mS/cm are representative of water with very high dissolved solids content Freeze and Cherry (1979), in this case likely due to mixing with adjacent salt water. Values above 1 mS/cm were detected in storm drain flows (CCSD and MD2) and at the mouth of Cain Creek (CC0.01). Salinities ranging between 20 and 33 were measured at sample locations during drogue tracking. These relatively low values in comparison to the average sea water salinity of 35 suggest a high proportion of freshwater mixing with marine waters. The confined configuration of the Semiahmoo Bay and the fresh water discharge of Cain Creek, Little Campbell River, Nickomekl River and Serpentine River to Semiahmoo Bay likely influence the higher proportion of fresh water represented in these salinity measurements. Hay and Co. (2003) simulations showed eddy formation in the waters south of the Little Campbell River discharge, and around the Cain Creek mouth during high tide conditions, which would further limit inflow of marine water and mixing with lower fecal coliform containing waters external to the influence of the contaminated fresh water discharges.

Dissolved oxygen content in fresh water was measured at values ranging from 4.7 to 12.8 milligrams per liter (mg/L). Saturated dissolved oxygen concentrations for the water temperatures measured (4.7 to 17.2 C) range from 9.4 to 12.4mg/l, with higher concentrations resulting from colder water temperatures (Drever, 1988). Fresh flowing water is normally saturated with dissolved oxygen due to the active atmospheric mixing associated with a flowing water surface. Water temperatures measured during summer months (June through August) ranged from 13 to 17 °C, when the lowest dissolved oxygen concentrations (4.7 to 9 mg/l) were measured. Saturated dissolved oxygen concentrations of 9 – 10.2 mg/l are associated with the recorded temperatures, and indicate that Cain Creek is often depleted with respect to dissolved oxygen. The water quality standard applicable to Cain Creek for temperature for is 6.5 mg/l, because Cain Creek is not recognized as critical habitat for ESA listed fish species (Ch 173-201A WAC). Dissolved oxygen measured in June and July at CC0.4 and CC0.2 reflect low enough dissolved oxygen to be out of compliance with the 6.5 mg/l standard.

Table 9. Shoreline survey results summary for temperature, dissolved oxygen and conductivity.

Site	n	Mean temp °C	Min	Max
CC1.3	3	5.5	0.0	8.3
CC1.3A	3	5.4	0.0	8.8
CC0.01	6	10.8	2.3	15.1
CC0.2	4	8.6	2.3	13.8
CC0.4	5	9.7	2.1	14.5
CCSD	6	13.3	9.4	16.1
SD1	5	12.3	9.6	14.4
SD2	5	10.3	3.9	16.1
SS4	3	9.7	7.8	11.3
SS8	2	9.1	7.9	10.2
	n	Dissolved oxygen (mg/L)	Min	Max
CC1.3	3	9.7	6.8	10.6
CC1.3A	3	9.7	6.6	12.8
CC0.01	6	9.4	7.0	15.2
CC0.2	4	10.0	4.7	15.2
CC0.4	5	9.2	4.8	15.3
CCSD	6	7.5	4.5	8.5
SD1	5	10.4	9.4	10.2
SD2	5	11.2	9.1	15.4
SS4	3	10.4	7.2	13.9
SS8	2	10.0	9.2	10.9
	n	Mean conductivity(mS/cm)	Min	Max
CC1.3	3	0.300	0.202	0.358
CC1.3A	3	0.166	0.162	0.169
CC0.01	6	8.113	0.302	34.110
CC0.2	4	0.319	0.224	0.438
CC0.4	5	0.291	0.235	0.386
CCSD	6	3.521	0.413	8.216
SD1	6	0.535	0.491	0.601
SD2	5	0.355	0.187	0.740
SS4	3	0.259	0.164	0.334
SS8	2	0.264	0.142	0.385

Marine: Ebb and Flood Tide Fecal Coliform Bacteria and Flow Characterization

Drogues and floats were used to track circulation patterns for over approximately four hours of an ebb or flood tide. Samples for fecal coliform analyses, temperature and salinity were measured following the drogue paths or tracks to characterize movement of fecal coliform with the currents being tracked. Because sample sites were not fixed, results were pooled by tracked tidal cycle for data presentation in Table 9. Drogue paths recorded during each of five ebb tides and flood tides (June 10, June 24, August 10, August 11 and September 22) are illustrated in Figures 5-14, and estimated drogue/float tracking speeds and direction of movement are shown in Table 10. Drogue and float tracking data for the figures were entered into the GPS Visualizer map program and list the sequence of drogues and floats used to track flow (Appendix E).

Fecal coliform geometric means exceeded the Washington State marine standard (14 cfu/100mL) for 7 of 10 sampling events and the 90th percentile criteria was exceeded for 9 of 10 events. During ebb tide sampling events geometric means exceed the standard on June 24 at 23 cfu/100mL, August 10, at 81 cfu/100mL, August 11, at 62 cfu/100mL, and September 22, at 22 cfu/100mL. Samples exceeded the 90th percentile criteria for all ebb tide sampling events. During flood tide sampling events geometric means exceeded the water quality standard on September 16 at 28 cfu/100mL, October 28, at 28 cfu/100mL, and December 10, at 67cfu/100mL. Samples exceeded the 90th percentile criteria for flood tide sampling events on June 17 and November 11.

A comparison of fecal coliform results between ebb and flood tide fecal coliform bacteria densities was conducted to further characterize bacteria levels in the eastern near-shore of Semiahmoo Bay and in the vicinity of the Drayton Harbor mouth. The geometric mean of the pooled ebb tide data was 41 cfu/100mL and it was 18 cfu/100mL for flood tide. Using a Student's T-test to compare fecal coliform densities (using the log ^{10} of the fecal coliform densities) a significant difference was found between tidal phases (α 0.05 p=0.05). However there was not a significant difference found between tidal cycles for samples collected only at DOH station 15 (α 0.05 p=0.10). There were 8 marine samples collected during ebb tide events with densities 500 cfu/100mL or greater and most of these were collected at the Cain Creek outflow and influenced the ebb tide geometric mean. Results during ebb and flood tide sampling events show high variability between Semiahmoo Bay fecal coliform bacteria samples and indicate there may be localized contamination in the southeast near-shore of Semiahmoo Bay.

Ebb tide drogue tracking and coordinated sample collection was done during ebb tides on: June 10 (6:08 – 13:30), June 24 (11:15-13:38), August 10 (8:30 – 12:45), August 11 (9:00 – 13:15), September 22 (10:15 – 13:55),and essentially represented ebb tide current patterns during dry months. During all five tracking events drogues released near the mouth of Cain Creek migrated westward over the tracking period. The movement direction varied between west-northwest (June 10, June 24, August 10 and 11), and west-south west (September 22). Light winds ranged from calm to 8 miles per hour (mph) with winds from each direction being present during sample tracking events. Only on August 10, did the wind direction correlate with the direction of float and drogue migration with wind speeds of 3-5 mph. Circulation patterns simulated by Hay & Co (2003) suggest that ebb tide flows predominantly move from

southeast to northwest, similar to the general direction of the drogue movement s recorded on June 10, June 24, August 10 and 11. Tidal exchanges for the ebb cycles were high on June 10 with a difference of 9.48 ft. between the high and low, high on June 24 with a difference of 13.11 ft., low on August 10 with a difference of 4.39 ft., low on August 11 with a difference of 2.94 ft., and low on September 22 with a difference of 3.24 ft. Ebb tide drogue paths suggest that on most occasions Cain Creek discharge is likely to impact water quality in the eastern near-shore of Semiahmoo Bay. However on September 22 drogues tracked W/SW in the direction of the Drayton Harbor mouth indicating that Cain Creek could impact Drayton Harbor and DOH Station 15 under similar wet season conditions when Cain Creek flows are higher.

Drogues released during flood tides were transported eastward. During tracking events on June 17, June 24 and October 28 drogues moved in a east-northeast direction. Drogue movement tracked on November 12 and December 10 was to the south and southeast. In some cases surface floats landed on the beach adjacent to the Canadian – U.S. border and to the north (on the Semiahmoo First Nation reserve).

Flood tide results for November 12 and December 10, when the wind direction was from the north, directed movement of drogues and floats south and east from the border monument toward the Drayton Harbor mouth. Although drogues and floats did not enter Drayton Harbor during any of the flood tide monitoring events, drogue movement from the Canadian – U.S. border towards the mouth of Drayton Harbor during two of the tracked flood tide events suggests that water flow may enter Drayton Harbor from the area monitored. There is a potential for waters from Cain Creek, Little Campbell River and other surface water discharges north of the Canadian border to carry fecal coliform bacteria into Drayton Harbor. Simulations showed fecal bacteria in the Little Campbell River entering Drayton Harbor in December and January (high bacteria loading months) and to a lesser extent during moderate November, February, March and April (Hay & Co. 2003). The model simulations underestimated the extent of fecal coliform contamination due to poor delineation of fresh water surface layer movement and limited data available for model input. The model did not include Cain Creek and it often predicted fecal coliform content lower than observed concentrations. The Hay Study concluded that use of an adjustable-layer model would better predict higher fecal coliform impacts by concentrating fecal coliform bacteria impacts in more confined surface layers.

Data collected at Tongue Shoal by the Port of Bellingham since 2000 indicates that water quality during flood tide meets the water quality standard with a geometric mean at 2 FC/100mL (Farallon and H.C.S., 2009). The site sampled is shown in Figure 9, denoted with the GM label for geometric mean. Influx of uncontaminated water from Georgia Strait (around Birch Point) during flood tides may play an important role in maintaining water quality in Drayton Harbor from further degradation. Near-shore fecal coliform measurements collected by the Nooksack Indian Tribe at three sites along the north shore of Semiahmoo Spit suggest that one of the sites exceeds the 90th percentile marine water quality criteria.

Table 10. Eastern near-shore Semiahmoo Bay fecal coliform measured during drogue and float tracking for ebb tide and flood tide flow characterization.

Date	n	Tide	24-hr rain (in.)	Geometric mean[1]	%>43[1]	Est. 90%[2]	Min	Max
6/10/2009	9	E	0.00	6	**11**	**57**	2	500
6/24/2009	7	E	0.24	**23**	**29**	**201**	7	300
8/10/2009	6	E	0.57	**81**	**67**	**266**	23	240
8/11/2009	6	E	0.53	**62**	**29**	**814**	8.0	1600.0
9/22/2009	7	E	0.00	**22**	**43**	**112**	2	80
6/17/2009	7	F	0.00	2	0	4	2	6
9/16/2009	7	F	0.05	**28**	**57**	**165**	2	110
10/28/2009	7	F	0.00	**28**	**14**	**62**	17	110
11/12/2009	11	F	0.00	11	9	**61**	2	240
12/10/2009	12	F	0.00	**67**	**50**	**67**	23	370

[1]Bold represents exceedence of Washington marine fecal coliform standard; geometric mean shall not exceed 14FC/100mL and no more than 10% of samples shall exceed 43 FC/100mL.

[2]Estimated 90th percentile shall not exceed 43 FC/100mL, National Shellfish Sanitation Program criteria for approved shellfish growing waters estimated 90th percentile calculation (NSSP, 1997).

Table 11. Estimated drogue and float tracking speed (mph) and direction by event.

Date	Corres-ponding figure	Mean	Min	Max	Predominant direction
Ebb					
6/10/2009	4	0.21	0.09	0.36	W/NW
6/24/2009	5	0.18	0.15	0.24	W/NW
8/10/2009	6	0.28	0.21	0.38	W/NW
8/11/2009	7	0.22	0.03	0.49	W/NW
9/22/2009	8	0.37	0.14	0.74	W/SW
Flood					
6/17/2009	9	0.06	0.06	0.06	E/NE
6/24/2009	10	0.2	0.18	0.20	E/NE
10/28/2009	11	0.15	0.13	0.18	E/NE
11/12/2009	12	0.14	0.08	0.35	S/SE
12/10/2009	13	0.18	0.07	0.36	S/SE

Microbial Source Tracking Analyses

The MST results are summarized in Table 12 by frequency of occurrence and in Table 13 by sample date, location and biomarker.

Table 12. MST results summary by frequency of occurrence.

Sites	n	Biomarkers [1]				
		Human	Ruminant	[2] H/R	[3] GB	Absent
Freshwater						
CC0.01	6	5	2	1	1	
CC0.2	3	2	2	2	1	
CC0.4	6	5	3	2		
CC1.3	3	2			1	
CC1.3A	3		1		1	1
CCSD	6	5	4	3		
SD1	4	3	3	2		
SD2	2	2	2	2		
SS4	3	3	2			1
SS8	2	1	1	1		
Marine						
DOH15	2	2	2	2		
Semiahmoo Bay	7	7	6	6		

[1] Biomarkers that were identified in laboratory duplicates are included.

[2] H/R=human and ruminant markers that were identified in the same sample.

[3] GB=general *Bacteroides* only

This study analyzed forty seven samples for MST. The majority of these samples were collected from fresh water, at Cain Creek sites (21 samples) and stormwater drains discharging from the Cain Creek watershed (6 samples),storm drains discharging to the eastern shoreline of Semiahmoo Bay (6 samples) or Semiahmoo Spit (5 samples). Nine marine samples were analyzed for MST including (2)samples collected at the DOH site 15 and (7) samples collected in the eastern near-shore portion of Semiahmoo Bay south of the Canada border.

From a total of 12 sites, human and ruminant biomarkers were identified at 11 locations. Of forty seven total samples analyzed, human biomarkers were found in 79%, ruminant in 60%, and MST biomarkers were absent in 4% of the samples tested.

Results were reported for human and ruminant biomarkers, with ruminants grouped together.
Both ruminant and human biomarker detection was widespread throughout the study area and human sources were identified consistently for most of the sample dates. Ruminant biomarkers were also detected repeatedly at most sites tested however in the urban setting where agriculture is not a

predominant land use, as it is in the upper Drayton Harbor watershed, there is a higher likelihood that the ruminant detections were due to wildlife (deer).

At all of the Cain Creek sites with the exception of CC1.3A, human biomarkers were observed consistently over the study period and throughout the drainage. On August 11 samples showed a predominance of human biomarkers to be present and on November 11 human sources were detected in all samples analyzed. At the Cain Creek Storm Drain the presence of human biomarkers also predominated with their detection in 5 of 6 samples collected. The high frequency of biomarker detection (2 to 6) for human or ruminant biomarkers suggests chronic sources of contamination and indicates that they are impacting water quality. In Blaine's urban setting the high frequency of human biomarkers is of concern because Blaine is a sewered community with no known septic systems (Dodd 2010). These results bring into question the integrity of parts of the sewage collection system, and the possibility of illicit discharges especially in the lower Cain Creek drainage (CC0.4 and below.)

Ruminant markers were commonly found in the study area; they were present at all of the Cain Creek sample sites and multiple identifications were made at 4 of 6 sites (including the Cain Creek Storm Drain site CCSD). Cows were observed pasturing in the upper Cain Creek watershed upstream of CC 1.3 .

The storm drains located along the south eastern shoreline of Semiahmoo Bay (SD1 and SD2) also showed repeated human and ruminant contamination. At SD1 ruminant sources predominated with 4 detections out of 4 samples analyzed.

Human biomarkers were consistently detected (in 3 out of 3 samples collected) at the Semiahmoo Spit storm drain (SS4) that discharges to Tongue Shoal behind the Blaine sewer treatment plant. This result may be of particular interest to the Nooksack Tribe as it discharges to a Tribal shellfish harvest area. Site SS8, a beach seep located on the south side of Semiahmoo Spit below a housing development, was sampled twice for MST with detection of human biomarkers on both occasions.

Human biomarkers were detected in all seven of the marine water samples analyzed, with concurrent human and ruminant detections at six of them. Marine water samples for MST analysis were collected exclusively during ebb tide conditions, at locations north of the mouth of Drayton Harbor and at DOH15 in Semiahmoo Bay on the east side of the Drayton Harbor entrance. These results differ from the data collected in 2006-2007(H.C.S., 2008) when no human biomarker detections were made in marine waters using the HSPCR method but human sources were detected using a ribotyping method. The ability of the *Bacteroides* HSPCR method to detect human biomarkers in the south eastern Semiahmoo Bay and at DOH 15 during this study may be due to human pollution source(s) that are relatively close to the sample sites. Only ruminant biomarkers were detected however at DOH 15 in the earlier Drayton Harbor study while in this study human sources were identified in both samples tested there.

Table 13. MST results summary by sampling date and location.

sample site	date	result
CAIN CREEK		
CC0.01	24-Jun	H/R
CC0.01	7-Jul	H
CC0.01	11-Aug	H
CC0.01	27-Oct	GB
CC0.01	11-Nov	H
CC0.01	9-Dec	H/R
CC0.2	11-Aug	H/R
CC0.2	11-Nov	H/R
CC0.2	9-Dec	GB
CC0.4	7-Jul	H
CC0.4	11-Aug	H
CCO.4	27-Oct	R
CCO.4	11-Nov	H
CCO.4	9-Dec	H/R
CC1.3	24-Jun	H/R
CC1.3	27-Oct	H
CC1.3	11-Nov	H
CC1.3	9-Dec	GB
CC1.3A	27-Oct	GB
CC1.3A	11-Nov	GB
CC1.3A	9-Dec	R

sample site	date	result
SEMIAHMOO BAY STORMWATER DRAINS		
CCSD	24-Jun	H/R
CCSD	7-Jul	H
CCSD	11-Aug	R
CCSD	27-Oct	H/R
CCSD	11-Nov	H/R
CCSD	9-Dec	H
SD1	7-Jul	R
SD1	27-Oct	H/R
SD1	11-Nov	H
SD1	9-Dec	R
SD2	11-Nov	H/R
SD2	9-Dec	H/R
SEMIAHMOO SPIT		
SS4	27-Oct	H/R
SS4	27-Oct	H/R
SS4	9-Dec	H
SS8	27-Oct	H/R
SS8	11-Nov	H
MARINE SITES		
DOH-15	24-Jun	H/R
DOH-15	11-Aug	H/R
D2	24-Jun	H/R
D2A	24-Jun	H/R
D2C	24-Jun	H/R
D2 (1 ft)	11-Aug	H
O7A	11-Aug	H/R
O4C	11-Aug	H/R

Conclusions

High fecal coliform concentrations (up to 6,300 CFU/100ml concentrations) in Cain Creek were consistently measured over the seven month period of data collection during shoreline surveys and ebb tide marine sampling events. Highest concentrations were measured during dry months after a first flush storm event (August 10 and 11), at locations within one half mile upstream of the Cain Creek mouth. Cain Creek fecal coliform geometric means continue to exceed Washington State standards. Mean loading rates from Cain Creek discharge to Semiahmoo Bay were calculated at 34.71billion cfu/day (3.47×10^{10} cfu/100mL). This value is somewhat higher than the dry season average load observed during the Drayton Harbor TMDL evaluation (8.22 billion cfu/day), (Mathiue, 2010). Loading may have been underestimated because the loading value did not include the August 10 and 11 flushing event because it occurred during ebb tide sampling events when flows were not measured. These results concur with the TMDL evaluation in indicating that Cain Creek is a source of significant bacteria discharge to Semiahmoo Bay. Further, drogue studies demonstrated that DOH Station 15 at the mouth of Drayton Harbor may be negatively impacted by the Cain Creek discharge under certain high loading conditions during ebb tides.

Storm drains discharge along the Semiahmoo Bay shoreline between the mouth of Drayton Harbor and the Canadian border often, but they do not consistently, discharge stormwater with high fecal coliform concentrations. Concentration trends typically follow those measured in Cain Creek, suggesting that watershed sources and transport processes are widespread throughout the Cain Creek drainage area, likely influencing discharge emitting through storm drains and the Cain Creek channel.

Elevated fecal bacteria concentrations measured in storm drains discharging from the area where Semiahmoo Spit connects to the mainland indicate that there are sources of fecal bacteria loading to Drayton Harbor and Semiahmoo Bay that originate in the mainland drainage areas discharging to the storm drains.

Fecal coliform levels in Semiahmoo Bay, consistently high and were out of compliance with Washington State marine fecal coliform standards for shellfish harvest on 9 of 10 dates sampled. Corrective actions should be implemented to bring Semiahmoo Bay into compliance with water quality standards to protect its designated uses.

Fecal coliform bacteria concentrations were higher during ebb tides than flood tides in Semiahmoo Bay but a clear difference was not observes at DOH Station 15 just outside of the east entrance to Drayton Harbor. A predominance of samples collected during ebb tides in the vicinity of the Cain Creek discharge had densities 500 cfu/100mL or greater, and suggested that the influence of the Cain Creek discharge, and storm-water discharge drains was greater during ebb tide (outflow) events. Drogue tracks monitored during winter months tended to migrate towards the mouth of Drayton Harbor during flood tides. Together the combination of ebb tide accumulation of higher fecal coliform contents and movement westward out from the shoreline, followed by flood tide transport toward Drayton Harbor mouth indicate the potential for transport of fecal coliform from the Cain Creek mouth area into the mouth of Drayton Harbor is high.

Widespread and repeated presence of human and ruminant biomarkers were detected by MST analysis (*Bacteroides* host specific polymerase chain reaction) at 11 of 12 sites tested including Cain Creek, storm drains along the south-east near shore of Semiahmoo Bay, Semiahmoo Spit drains and discharges and marine locations in south east Semiahmoo Bay and DOH Station 15 at the Drayton Harbor mouth. Human biomarkers were found consistently at nearly all of the Cain Creek sites over the study period and throughout the drainage and suggesting that potentially chronic sources of fecal contamination are being discharged. Because Blaine is a sewered community with no known septic systems (Dodd 2010), the Cain Creek drainage should be investigated for the integrity of parts of the sewage collection system, and for potential illicit discharges below site CC0.4. Multiple occurrences of ruminant markers were common and cows were observed pasturing in the Cain Creek basin. While the extent of contamination found from human sources is probably most significant to human health, ruminant contamination is an important source of water quality degradation in the study area.

A technical work group of agencies, including representatives from Canada, met as a focal point to generate ideas for corrective actions to improve water quality in shared waters. The group focused on possible corrective actions to remediate potential human sources and they are included among recommendations presented in Appendix C.

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Figures

(See attached file)

Appendix A: Project Data

(See attached file)

Appendix B: Technical Work Group Meeting Summary

Drayton Harbor/ Semiahmoo Bay MST Phase 3 Technical Work Group Meeting Summary May 18, 2010.

In Attendance:

In person:

Julie Hirsch (Hirsch Consulting Services),

Geoff Menzies (Drayton Harbor Community Oyster Farm, Drayton Shellfish District Committee Chair),

Llyn Doremus (Nooksack Indian Tribe),

Jackie Goodsir (Drayton Shellfish District Committee),

Steve Banham (City of Blaine Public Works Director),

Elke Daugherty(Whatcom County Planning Department, Natural Resources),

Erika Stroebel (Whatcom County Public Works, Marine Resource Planner),

Mark Harting (Drayton Shellfish District Committee),

Carrie Baron and Lauren Peterson, (City of Surrey),

Erin Ridell, (Corporation of Delta),

Joanne Charles (Semiahmoo First Nation),

Jim Armstrong (Metro Vancouver),

Marlene Fuhrman, Corporation of White Rock,

Michael Jones (City of Blaine Planning Department),

Chuck Timblin (Whatcom Conservation District),

Kurt Niemeyer (Washington State Department of Agriculture, Livestock Program),

Kyle Dodd (Whatcom County Environmental Health),

Steve Cox (USGS)

By Telephone Conference:

Greg Combs and Laurence Sullivan (Washington State Department of Health, Office of Shellfish and Water Protection),

Nuri Mathieu, State Department of Ecology Environmental Assessment Program

Steve Hood (Washington State Department of Ecology Bellingham Field Office),

Stephanie Harris (USEPA, Region 10 Laboratory)

Cara McKinnon (Washington State Department of Agriculture),

Preparation

All in attendance were provided with a PowerPoint presentation in advance of the meeting, the executive summary, and a meeting agenda. Those attending by phone conference were able to follow the Hirsch PowerPoint presentation on their office computers.

Introductions and Background

Following introductions Julie Hirsch and Llyn Doremus provided an overview of the project and the objectives of the meeting. The Nooksack Tribe has unique interest in shellfish resources in Semiahmoo Bay as well as the shellfish classification in Drayton Harbor. They have been conducting water quality monitoring for over five years, are interested in pollution sources other than agriculture, and they have also participated with Environment Canada programs. This study was carried out to augment Ecology's TMDL evaluation with agreement from Ecology that the data would be used in the TMDL.

Cain Creek has a recent history of high fecal coliform levels and the potential to impact water quality in both Semiahmoo Bay and possibly Drayton Harbor. There has also been concern about the potential impacts from Cain Creek on DOH station 15 at the entrance to Drayton Harbor.

Julie Hirsch explained that the meeting summary would be included as an appendix in the final report and recommendations would be drawn from input from attendees for follow-up and corrective actions. The final report will be completed in July.

Hirsch Presentation and Discussion (see PowerPoint presentation for details)

Julie Hirsch presented the study findings with a PowerPoint presentation, which was the basis for much of the discussion around the table. Results confirm large flow and loading from Cain Creek. Microbial Source Tracking (MST) results from the EPA *Bacteroides* analysis show widespread and frequent human detections, much more so than in previous MST studies in the Drayton Harbor watershed.

A question was raised about salinity levels at the mouth of Cain Creek. There are times when there was saltwater influence. All data will be provided with the report.

In addition to Cain Creek, numerous other freshwater inputs to Semiahmoo Bay were identified, but most were monitored less frequently due to low dry season flows. The Cain Creek storm drain, and two storm drains on the east shoreline of Semiahmoo Bay (SD1 and SD2) had at least 5 data points and SS4 on Semiahmoo Spit just behind the Blaine sewage treatment plant, had enough flow to sample on 3 occasions. All sites sampled with the exception of one had multiple human *Bacteroides* detections.

Marine water testing showed localized spikes of fecal coliform bacteria and generally elevated FC concentrations during some sampling events. Human *Bacteroides* biomarkers were detected in 9 of 9 marine samples analyzed by the EPA laboratory.

A question was asked about the flow and discharge from the Little Campbell River compared to Cain Creek. This study did not measure flows from the Little Campbell but given the size of the watershed, flow from this source is obviously much larger than Cain Creek. Canadian representatives alerted the group that there are gauges on the Little Campbell and therefore flow measurements could be made available.

Regarding circulation from Cain Creek on ebb tides, drogues deployed near the mouth of Cain Creek moved predominantly in a Northwesterly direction often reaching or passing the Canadian border. On one occasion drogues deployed well away from the mouth of Cain Creek moved south-westerly toward the entrance of Drayton Harbor but never reached the harbor entrance. This instance occurred during a minimal swing in tidal elevation and with very little wind influence. During the flood tide sampling events, no drogues released near the border monument reached the mouth of Drayton Harbor. In most cases water movement was in a Southeasterly direction as would be expected. It was generally agreed that although this study did not show that water from Cain Creek reaches the mouth of Drayton Harbor, this remains a possibility and cannot be ruled out

PCR Methods and Results Format Explanation – Stephanie Harris

The technique is designed to detect the presence or absence of two ruminant, two human, and one general *Bacteroides* biomarkers. Samples are filtered through small porosity membranes. DNA is extracted and submitted to five dilutions for each single sample for each biomarker. This is the same lab technique that was used previously in the Phase 1 and Phase 2 MST studies in the California Creek and Dakota Creek drainages and in Drayton Harbor. Results for each of the five biomarkers for each sample are shown as either “P” present, or “A” absent. Contaminants are listed as either “R’ for ruminant or “H” for human.

Jim Armstron PowerPoint Presentation; Boundary Bay Ambient Monitoring Program (BBAMP)

Jim Armstrong of Metro Vancouver presented fresh and marine water sampling results for Semiahmoo Bay and fresh water inputs (Nicomekyl, Serpentine, and Little Campbell Rivers) This Power Point presentation was made available to attendees via email following the meeting.

He explained that it is unusual for Metro Canada to do this type of work but through numerous partnerships, including the Puget Sound Partnership as well as governmental organizations and nonprofits in BC, they have taken the lead on this trans-boundary work. The three components of the assessment program are water quality, sediment, and biota. Their marine protocol has been to collect samples from 3 meters below the surface; obviously very different than the surface to 6” depth protocol of DOH for shellfish classification. Their marine fecal coliform results were very low, nothing in excess of 2FC/100 ml. Jim Armstrong indicated that his program would begin sampling fecal coliform in Boundary Bay using protocol comparable to the DOH method.

Discussion of possible corrective actions and investigations.

There was additional discussion about flow and loading from the Little Campbell River. There is at least one gauge but its location was unclear. There was also discussion about the size of the little Campbell watershed. It would be worthwhile to compare watershed size between the Little Campbell and the Drayton Harbor watershed. *(The area of the Drayton Harbor watershed is 57 square miles (36,278 acres)).*

Department of Health staff commented that they are not too concerned about human detections in Cain Creek having an impact inside Drayton Harbor based on the results of the circulation studies discussed above.

Steve Banham, City of Blaine Public Works Director commented that there are some older sewage collection facilities in some of the Cain Creek drainage. He is aware of at least twelve storm drains West of the interstate highway that flow into Cain Creek. He described many of the lateral systems in this area as antiquated. He thought it possible that some homes mistakenly discharge sewage via storm pipes rather than sewer lines which would result in direct discharges of sewage to Cain Creek. The City of Blaine does not have a routine sewer collection system video program although they have done some video work on a case-by-case basis. There was discussion if developing a storm water sampling program to monitor water quality of all known storm drains into Cain Creek. A particular area of focus should be between sites CC 0.4 and upstream to site CC 1.3 due to the generally higher counts at site CC 0.4, which may reflect contaminated inputs upstream of this location. There was also limited discussion of the potential of combined sewer and storm collection systems which during large flows could result in bypass of sewage to storm drains. Historically this had been a problem along Portal Way, but was remedied in the early 1990s. Steve Banham expressed his intention to follow-up with additional investigations.

Also discussed was the potential for discharge from septic systems that might remain within Blaine City limits. Julie Hirsch asked about the possibility of existing OSS in the Cain Creek drainage area. Kyle Dodd commented that undocumented OSS are difficult to locate.

The trucking facility in the area was mentioned by Carrie Baron as a possible problem site but based on the drainage, flow from that facility would be measured at CC 1.3, which are not significantly high.

It was mentioned that an inventory of Cain Creek should be done to identify all freshwater inputs to the Creek.

It was also mentioned and confirmed by Stephanie Harris, that there is no clear correlation between PCR detections and elevated fecal coliform concentrations.

Nuri Mathieu with Ecology commented that in the TMDL evaluation, Cain Creek was well above freshwater standards for fecal coliform bacteria and that bacterial loading was higher than shown in this study. The bacteria load from Cain Creek can actually be higher than the loading from Dakota Creek and

therefore it may very well have an impact on Drayton Harbor itself. Julie Hirsch added that loading data from Ecology's sampling in 2008 will be referenced in the report for this project.

Ecology staff suggested that the Drayton Harbor TMDL report may go out by Friday, May 21, Steve Hood commented that there is not a lot of prioritization for implementation in the Drayton Harbor TMDL…. All of the areas need to be addressed.

Again it was mentioned that even though this study did not show drogues entering Drayton Harbor from the mouth of Cain Creek, a connection might be shown under higher loading conditions.

Joanne Charles with the Semiahmoo First Nation mentioned that shellfish harvesting in Semiahmoo Bay has been prohibited since 1975 which is unacceptable to the Semiahmoo First Nation as a people who for thousands of years have benefited from local shellfish as a food source and she thanked everyone for participating in this type of work

When Stephanie Harris was asked By Erika Stroebel about the numerous detections of human biomarkers in Semiahmoo Bay when compared to previous work in Drayton Harbor, she commented that protocols in both studies were identical. It is possible that the incidence of detection was higher because marine sampling locations may have been closer to the actual freshwater sources.

Julie Hirsch mentioned that a goal of the discussion was to explore possible corrective actions and investigations for implementation and that the group would be asked to respond when reviewing the meeting summary.

Recommendations from the meeting participants will be evaluated by the members of the Drayton Harbor Shellfish Protection District Advisory Committee for incorporation into their Drayton Harbor Status Report and Water Recovery Plan.

Appendix C: Recommendations

One of the goals of the Drayton Harbor Shellfish Protection District and the EPA Region 10 Laboratory is utilization of the MST results to move forward in implementing actions that improve water quality. As part of this project a technical work group was convened in May 2010 among agency representatives from the U.S. and Canada. The group explored possible corrective actions to remedy fecal contamination in Semiahmoo Bay and Drayton Harbor with an emphasis on correcting human sources. These recommendations are incorporated below. A prioritization scheme was developed to assist in guiding corrective actions:

- Highest priority-Sites with multiple human biomarker occurrence AND multiple fecal coliform occurrence >1,000 FC/100mL. (CC0.01, CC0.2, CC0.4, CCSD)
- High priority-Sites with multiple human biomarker occurrence AND more than 10% of samples exceeding 100FC/10mL. (SD1, SD2, SS4)
- Medium priority-Sites with multiple human biomarker occurrences. (CC1.3)

- Because human biomarkers were predominantly observed and found in sewered areas and because ruminant markers in an urban environment can be due to multiple sources, corrective actions should emphasize remedying human fecal contamination.
- Multiple occurrences of ruminant markers were common and cows were observed pasturing in the Cain Creek basin. While the extent of contamination found from human sources is probably most significant in regard to human health, ruminant contamination is an important source of water quality degradation in the study area. Buffers and fencing should be encouraged to keep livestock from riparian areas.
- City of Blaine should follow-up with investigations of potential discharges to Cain Creek. A particular area of focus should be between sites CC 0.4 and upstream to site CC 1.3 due to the generally higher counts at site CC 0.4, which may reflect contaminated inputs upstream of this location. A proposal of follow-up investigations and corrective actions should be generated that includes investigation of stormwater inputs, potential sewer cross connections and combined sewer/stormwater outfalls.
- The absence of OSS in the Cain Creek sub-basin should be verified.
- An interagency map of the Cain Creek sub-basin should be generated as a management tool that includes sewer/storm drains, any OSS and livestock.

- Metro Canada and the Boundary Bay Ambient Monitoring Program samples fecal coliform bacteria in Semiahmoo Bay at a depth of 3 meters resulting in undetectable fecal coliform concentrations (Armstrong, 2010). The DOH protocol (DOH, 1996) that samples 6 inches from the surface, should be used so that data can be compared with US agencies. (Jim Armstrong has agreed to make this change and he has been provided with the DOH protocol.)

- Fecal coliform loading data for the Little Campbell River should be provided regularly to the DHSPD and to Ecology as part of TMDL implementation.

- The Hay Study should be updated using an adjustable layer model, using updated data and it should include Cain Creek.

- The Port of Bellingham will discontinue monitoring a site on Tongue Shoal (POB-P) in October 2010. Monitoring at this site should be continued as a reference to monitor the quality of water entering Semiahmoo Bay and Drayton Harbor from Puget Sound.

- The Nooksack Tribe should add SS4 to their sampling regime. This is a high priority site (based upon the prioritization above) that discharges to Treaty protected shellfish harvest areas of NIT. It is in the proximity of a NIT sampling site that exceeds the fecal coliform water quality standard.

- The Drayton Harbor Shellfish Protection District supported through TMDL implementation, should reconvene a technical work group to cooperate in implementing corrective actions and in a potential modeling effort. This group should include partners such as DHSPD, Whatcom County, City of Blaine, Nooksack Indian Tribe, City of Surrey Ecology and others as evaluated.

- Recommendations from this work will be evaluated by the DHSPD. They should also be evaluated for incorporation into the TMDL implementation plan.

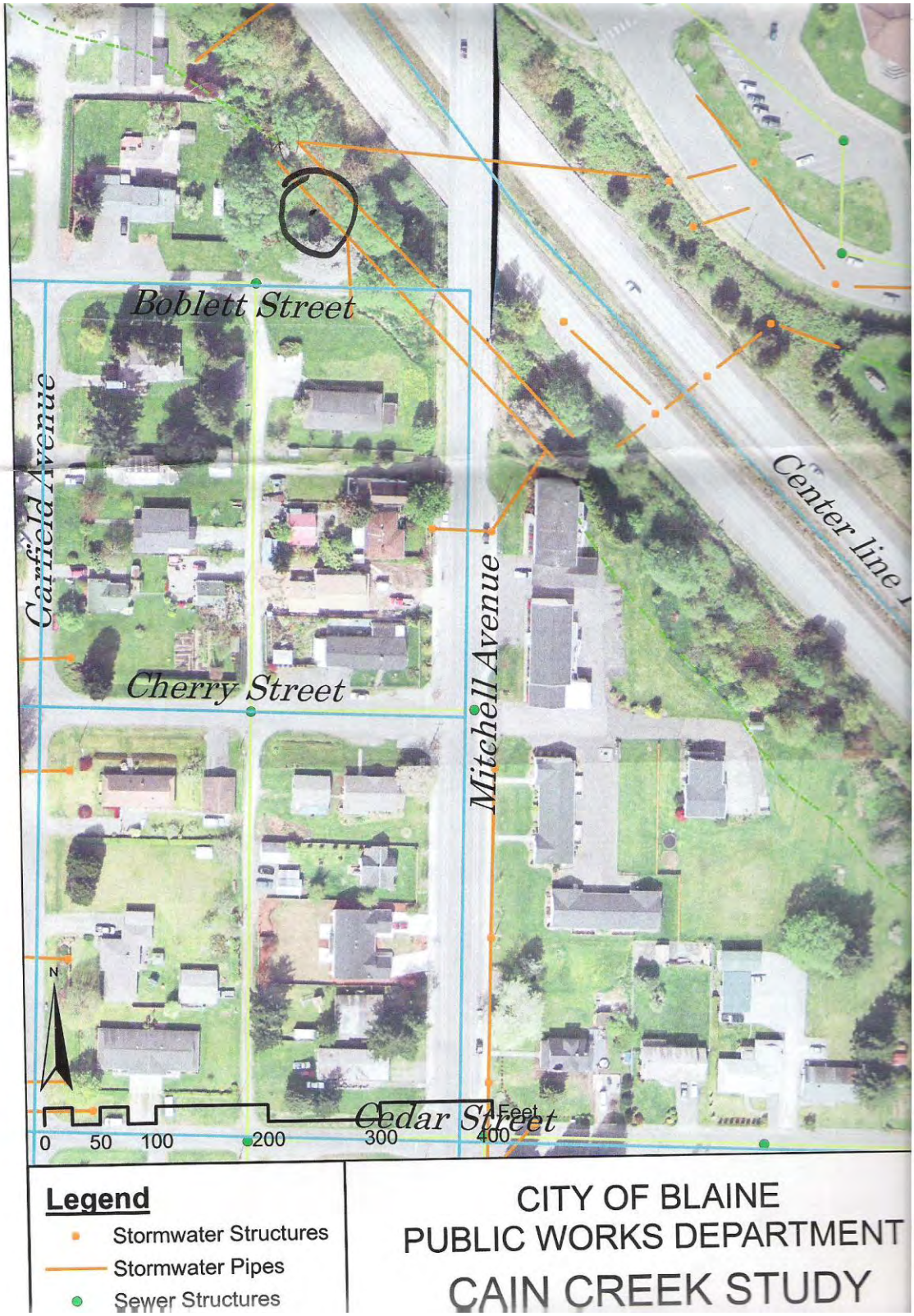
Appendix D: Addendum to Drayton Harbor Watershed Fecal Coliform TMDL; Phase I, Water Quality Study Design: Quality Assurance Project Plan

(See attached file)

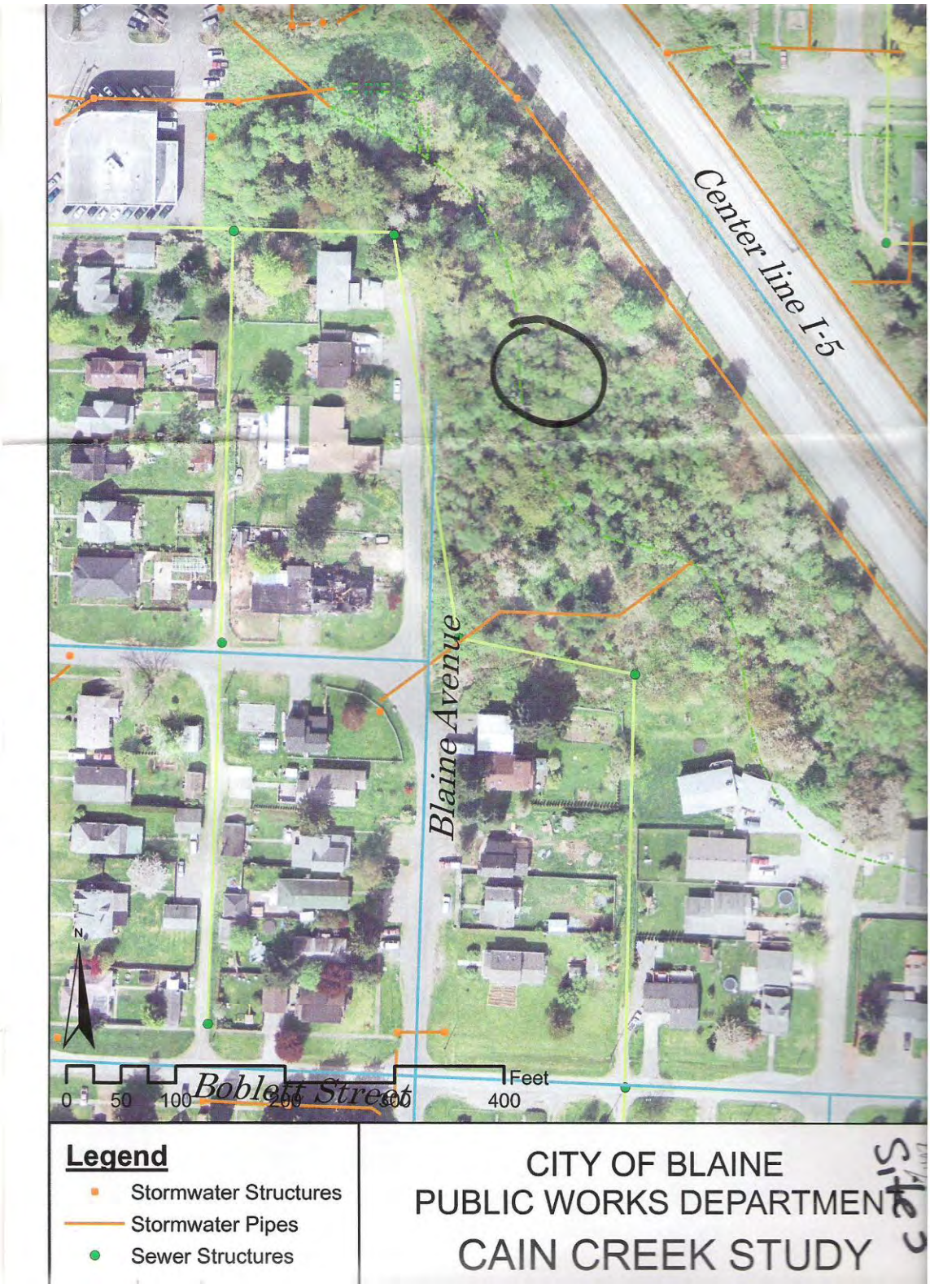
Appendix E: Marine Drogue Studies Map Data

(See attached file)

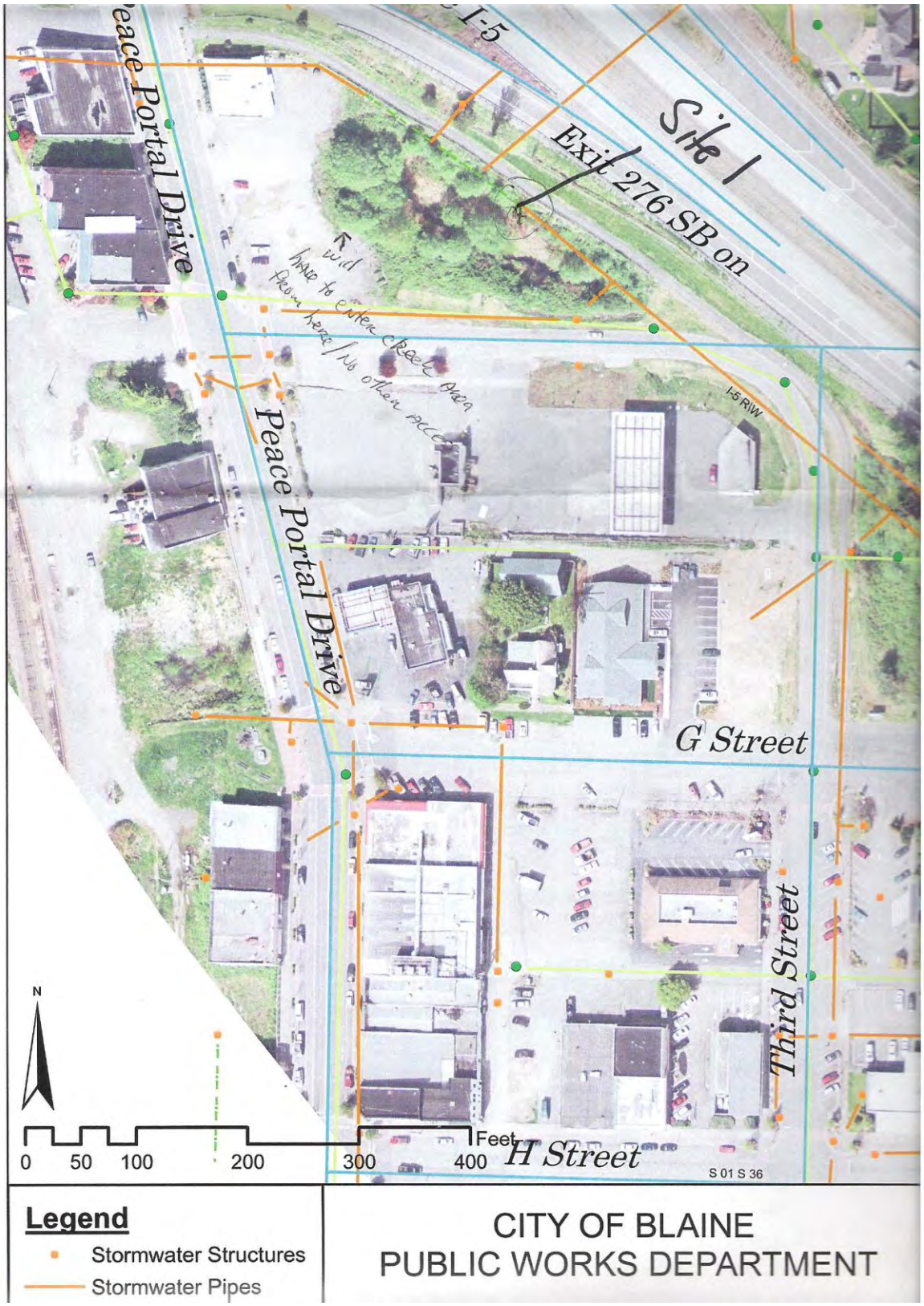
Appendix A Figure 1. Sewer and stormwater conveyances in the vicinity of CC1.2, behind Pro Pack and west of I-5.



Appendix A Figure 2. Sewer and stormwater conveyances in the vicinity of CC0.8, end of Boblett and Mitchell Ave.



Appendix A Figure 3. Sewer and stormwater conveyances in the vicinity of CC0.6, end of Blaine Ave. and Steen.



Appendix A Figure 4. Sewer and stormwater conveyances in the vicinity of CC0.15, between Peace Portal Dr. and I-5.

Whatcom Community Foundation Grant, Cain Creek Project Data

Whatcom Community Foundation Grant
Cain Creek Project Data

[1]Station	Date	Time	Temp °C	pH	Dissolved oxygen (mg/L)	Conductivity(mS/cm)	[2]24-hour rainfall (in.)	[2]72 hour rainfall (in.)	Discharge (ft^3/sec)	Fecal coliform/100mL (MF)	[3]MST	Comments
CC1.2	1/26/2012	915	3.68	7.15	9.31	0.1	0.14	0.41	1.96	**64**		
CC0.8	1/26/2012	1000	3.96	7.02	8.05	0.11	0.14	0.41	1.88	**176**		
CC0.8FD	1/26/2012	1000					0.14	0.41		**102**		
CC0.6	1/26/2012	1100	4.48	7.43	10.64	0.04	0.14	0.41	3.79	**304**		
CC0.15	1/26/2012	113	4.57	7.1	11.28	0.12	0.14	0.41	1.44	**185**		
CC1.2	2/16/2012	0842	4.59	7.13	9.25	0.223	0	0.12	0.42	33		
CC0.8	2/16/2012	0836	5.58	7.34	11.31	0.243	0	0.12	0.81	61		
CC0.8FD	2/16/2012	0836	5.62	7.34	11.24	0.245	0	0.12				
CC0.6	2/16/2012	1020	5.78	7.42	10.69	0.213	0	0.12	0.89	567		
CC0.6FD	2/16/2012	1020	5.76	7.44	10.87	0.21	0	0.12	0.85	140		
CC0.15	2/16/2012	1055	5.83	7.49	11.5	0.232	0	0.12	1.15	410		
Travel blank											Absent	
CC1.2	3/14/2012	0915	3.82	7.42	9.24	0.172	0.15	0.35	0.83	23		
CC1.2FD	3/14/2012	0915	3.83	7.4	9.19	0.172	0.15	0.35	0.84	17		
CC0.8	3/14/2012	0845	4.76	7.96	10.9	0.195	0.15	0.35	1.05	50	GB	
CC0.8LD	3/14/2012	0845									GB	
CC0.6	3/14/2012	0945	4.97	7.51	11	0.205	0.15	0.35	1.68	12	GB	
CC0.15	3/14/2012	1015	5.08	7.4	11.32	0.197	0.15	0.35	1.56	12	H(HF 183)	
PC1	3/13/2012	22:00									GB	Human, 2
CC1.2	4/11/2012	1000	8.75	7.16	6.91	0.228	0	0	0.23	93		
CC0.8	4/11/2012	0845	9.24	7.33	9.4	0.251	0	0	0.59	10	Absent	
CC0.8LD	4/11/2012	0845									H(HF 183)	
CC0.6	4/11/2012	0920	9.46	7.44	8.87	0.255	0	0	0.5	0	H(HF 183)	
CC0.15	4/11/2012	1030	9.47	7.48	9.28	0.283	0	0	0.65	20	H(HF 183)	
CC0.15FD	4/11/2012	1035	9.47	7.47	9.28	0.283	0	0	0.65	21		
PC2	4/11/2012	11:00									H(HF183)	Raw sewage, Lighthouse Pt STP
CC1.2	5/23/2012	0900	11.63	7.31	5.07	0.73	0	0.86	0.38	511		
CC0.8	5/23/2012	0830	12.56	7.79	7.96	0.324	0	0.86	0.18	160	R(CF193)	
CC0.8LD	5/23/2012	0830									GB	
CC0.6	5/23/2012	0950	12.82	7.8	7.36	0.231	0	0.86	0.3	48	H(HF183)	
CC0.15	5/23/2012	1010	12.66	7.83	8.17	0.228	0	0.86	0.42	75	GB	
CC0.15FD	5/23/2012	1010	12.66	7.81	8.15	0.235	0	0.86	0.42	65		
PC3	5/22/2012	1600									GB	Four cows
PC3LD	5/22/2012	1600									GB	

[2] PC = Microbial source tracking positive control sample, FD = field duplicate, LD = laboratory duplicate

[1]Rainfall from Weather Underground, http://www.wunderground.com/weatherstation/WXDailyHistory.asp?ID=KWABLAIN13

3 MST = Bacteroides host specific polymerase chain reaction (HSPCR)

Station Id	Date	Time	Temp °C	Discharge (ft^3/sec)	Conductance (mS/cm)	Dissolved oxygen (mg/L)	[2]	Fecal coliform/100mL (MF)	Fecal coliform load (cfu/day)	Fecal coliform/100 mL (MPN)	MST Id	Comments
MD2	12/9/2009	1200		no flow								
SS1	12/9/2009	1300		no flow								
SS2	12/9/2009	1305		submerged								
SS3	12/9/2009	1307		no flow								
SS6	12/9/2009	1315		no flow					\			
SS7	12/9/2009	1320		no flow								
SS4	12/9/2009	1230	7.8	0.341	0.164	13.87		6	5.01E+07		H(HF183)	
SS8	12/9/2009	1240		no flow								

[1] Rain data from Blaine STP, 2009.

[2] Estimated due to sample dilution, the number of colonies counted is outside the desired yield of 20-60 per plate;

[3] Microbial source tracking identification by host specific polymerase chain reaction EPA Region 10 Laboratory;
HF183,R=ruminant primers CF128 and CF 193,GB=general Bacteroides primer BAC32, A= absent LD=laboratory duplicate.

MF = Membrane filter analysis; Standard Methods (SM) 9222D

MPN = Most Probable Number analysis; SM9221E

NM=Not measured, QA=Quality assurance sample