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

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Contents

List of Tables

List of Figures

(Attached file)

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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 90^{th}% 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 90^{th} 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 90^{th} 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 90^{th} 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 90^{th} 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 x 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.

References

APHA, 1998. *Standard Methods for the Analysis of Water and Wastewater, 20th Edition*. American Public Health Assn., Washington D.C.

Armstrong, J. 2010. Power Point presentation: Boundary Bay Ambient Monitoring Program. Presented at project technical work group meeting, May, 18 2010.

Avocet Environmental Testing, 2009. Quality Assurance Manual, 2009. Bellingham, Washington, January 2009. AET QA/QC Manual, Rev 1/2009, 16 pp.

City of Blaine, 2009. Unpublished weather data. City of Blaine Sewer Treatment Plant, Blaine WA.

Dodd, K., 2010. Personal communication, Whatcom County Department of Health, Bellingham, WA.

DOH, 1996. *Regulations, Policies, and Procedures, 1996 Revision. Procedure #003, Marine Water Sampling.* Washington State Department of Health, Office of Shellfish Programs, Olympia WA, 5 pp.

Drever, J.I., 1988. *The Geochemistry of Natural Waters*. Prentice Hall, Inc., Englewood Cliffs, N.J., 437 pp.

EPA, 2006. *Quality Assurance Project Plan for Drayton Harbor Microbial Source Tracking Pilot Study*. *EPA Region 10, Washington Operations Office*, prepared by EPA Region 10, Office of Environmental Assessment Laboratory, Port Orchard, Washington. 64 pp.

EXTECH Instruments Incorporated, 2003. *User's Guide, Portable Salinity Refractometer with ATC Model RF20.* Extech Instruments Incorporated, Waltham MA, 4 pp.

Ecology, 2006. *Water Quality Standards for Surface Water of the State of Washington(Revised). Chapter WAC-173-201A-612 Washington Administrative Code*, Olympia WA.

Farallon Consulting and Hirsch Consulting Services, 2009. *2009 Blaine Harbor Water Quality Monitoring Report.* Prepared for the Port of Bellingham, Bellingham WA, 5 pp.

Fleming, S.W., and E.J. Quality, 2006. A Novel Approach: Reconnaissance Analysis of the Little Campbell River Watershed. Report prepared for the Environmental Quality Section, Lower Mainland Region, B.C. Ministry of the Environment. Aquatic Informatics Inc., Vancouver.

Freeze, R.A. and J.A. Cherry, 1979. *Groundwater*. Prentice Hall Inc., Englewood Cliffs, N.J. 604 pp.

GPS Visualizer.com, 2010. http://www.gpsvisualizer.com/, Portland OR.

Hay and Company Consultants Inc., 2003. Semiahmoo Circulation Study Technical Report. Report prepared for Environment Canada, March 2003, ENVI-003, Vancouver, BC. Canada. 20 pp plus appendices.

Harris S., 2010. Personal communication, EPA Region 10 Laboratory, Washington Operations Office, Port Orchard, Washington.

Hirsch Consulting Services, 2009**a**. *Drayton Harbor Watershed Microbial Source Tracking Pilot Study Phase 2: California Creek, Dakota Creek and Cain Creek Sub-watersheds*. Prepared for Whatcom County Public Works, Natural Resources, Bellingham, WA, 22 pp.

Hirsch Consulting Services, 2009**b**. Quality Assurance Project Plan: Addendum to Drayton Harbor Watershed Fecal Coliform TMDL; Phase I, Water Quality Study Design Prepared for Nooksack Indian Tribe Natural Resources Department, Deming WA, 18 pp.

Hirsch Consulting Services, 2008. *California Creek and Drayton Harbor Microbial Source Tracking Pilot Study.* Prepared for Puget Sound Restoration Fund, Bainbridge Island, WA, 38 pp.

Hood S. and N. Mathieu, 2010 *DRAFT Drayton Harbor Watershed Fecal Coliform Total Maximum Daily Load, Water Quality Improvement Report.* Washington Department of Ecology Publication No. (in publication).

Mathieu, N., 2010. Personal communication, and unpublished spreadsheet. Washington Department of Ecology, Lacey WA.

Mathieu, N. and D. Sargeant, 2008. *Drayton Harbor Watershed Fecal Coliform Total Daily Maximum Load: Phase I Water Quality Study Design (Quality Assurance Project Plan),* Olympia Washington. March 2008. Washington Department of Ecology Publication No. 08-03-105, 88 pp.

Menzies, G., 2003. *Blaine Harbor Circulation Studies, January through April 2003.* April 2003. Prepared for the Puget Sound Restoration Fund, Bainbridge Island, Washington and submitted to Whatcom County Water Resources Division, Bellingham, Washington.

National Shellfish sanitation Program (NSSP), 1997. *Guide for the Control of Molluscan Shellfish*. Food and Drug Administration, National Shellfish Sanitation Program, International Shellfish Sanitation Conference, Washington D.C. 406 pp.

NOAA, 2010. http://tidesandcurrents.noaa.gov/

Rantz, S.E. and others, 1982. *Measurement and Computation of Streamflow: Volume 1: Measurement of Stage and Discharge,* Chapter 5 Measurement of Discharge by Conventional Current-Meter Method, USGS Water-Supply Paper 2175, 284 pp.

Shanks, O.C., Domingo JW, Lu J, Kelty CA, Graham JE.2007. *Identification of Bacterial DNA Markers for the Detection of Human Fecal Pollution in Water.* Appl. Environ Microbiol. 2007 Apr;73(8):2416-22. Epub 2007 Jan 5.

Weather Underground 2010 (www.wunderground.com/global/stations/71785.html S. Surrey/White Rock).

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

<u>PCR Methods and Results Format Explanation – Stephanie Harris</u>

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.

<u>Jim Armstron PowerPoint Presentation; Boundary Bay Ambient Monitoring Program (BBAMP)</u>

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)