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ECOLOGY
State of Washington

Quality Assurance Project Plan

Skagit Bay
Fecal Coliform Bacteria
Loading Assessment

November 2010
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303(d) listed Waterbody Numbers and Current Aliases.

Waterbody Name	Waterbody ID	Historical Waterbody ID
Skagit Bay and Similk Bay	390KRD	WA-PS-0010
Big Ditch / Maddox Slough	JK73SN	WA-03-2010
Browns Slough	VN02NL	WA-03-4000
Wiley Slough	EE73RP	WA-03-4100
Irvine Slough	HS19KT	WA-05-1010

Author and Contact Information

James Kardouni
Environmental Assessment Program
Washington State Department of Ecology
P.O. Box 47600
Olympia, WA 98504-7710
Phone: 360-407-6517; Email: jkar461@ecy.wa.gov

For more information contact Communications Consultant at 360-407-6834.

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

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

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Approved by:

Signature: Ralph Svrjcek, Client, Water Quality Program, NWRO	Date: November 2010
Signature: Dave Garland, Client's Unit Supervisor, Water Quality Program, NWRO	Date: November 2010
Signature: Kevin Fitzpatrick, Client's Section Manager, Water Quality Program, NWRO	Date: November 2010
Signature: James Kardouni, Author / Project Manager / Principal Investigator / EIM data Engineer, EAP	Date: November 2010
Signature: George Onwumere, Author's Unit Supervisor, EAP	Date: November 2010
Signature: Robert F. Cusimano, Author's Section Manager, EAP	Date: November 2010
Signature: Stuart Magoon, Director, Manchester Environmental Laboratory, EAP	Date: November 2010
Signature: Bill Kammin, Ecology Quality Assurance Officer	Date: November 2010

Signatures are not available on the Internet version.
NWRO: Northwest Regional Office.
EAP: Environmental Assessment Program.
EIM: Environmental Information Management system.

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Abstract

Skagit Bay and some tributaries were included on the Washington State 2008 303(d) list of impaired waterbodies for fecal coliform (FC) bacteria. Skagit Bay is in the northern part of the Puget Sound surrounded by the Skagit River delta, Camano Island, and Whidbey Island. The goal of this study is to help reduce FC contamination to the bay. The objective of this study is to evaluate FC concentrations, surface water discharge, and general water quality parameters within the watershed during 2010-2011. Targeted waterbodies include brackish and freshwater sources to Skagit Bay along its southern and eastern land borders. Data collected will form the basis for calculating FC contaminant loads to the bay. After completion of the study, a final report describing the results will be posted to the Internet.

Each study conducted by the Washington State Department of Ecology must have an approved Quality Assurance Project Plan. The plan describes the objectives of the study and the procedures to be followed to achieve those objectives.

Background

Areas of Skagit Bay, including freshwater tributaries, exceed the Washington State's surface water quality criteria for fecal coliform (FC) bacteria (Table 1 and Figure 1). The 303(d) listed waterbodies in Table 1 have not been addressed by a Total Maximum Daily Load (TMDL) study or other pollution management options. In order to fulfill Federal Clean Water Act requirements, section 303(d) listed waterbodies should be assessed for pollution and addressed with an approved watershed cleanup plan. The section 303(d) list is explained in the following "Federal Clean Water Act requirements" subsection. Other non-listed inputs to the bay will also be evaluated to provide a holistic assessment and to help prioritize pollution reduction efforts.

Table 1. Section 303(d) listed waterbodies for fecal coliform in the Skagit Bay study area.

Waterbody Name	Listing ID	Waterbody ID	Waterbody Type	Latitude or Township	Longitude Range Sec	Listing History
Skagit Bay and Similk Bay	53200	390KRD	Marine	48.285	-122.425	2008
	7170			48.335	-122.445	1996 - 2008
	7171			48.335	-122.415	1996 - 2008
	7172			48.325	-122.395	1996 - 2008
	7173			48.315	-122.385	1996 - 2008
	53165			48.265	-122.405	2008
	53166			48.265	-122.415	2008
	53197			48.275	-122.405	2008
Big Ditch / Maddox Slough	45650	JK73SN	River/Stream	33N - 4E - 31		2008
Browns Slough	7133	VN02NL	Marine	48.335	-122.415	1996 - 2008
Irvine Slough	43042	HS19KT	River/Stream	32N - 3E - 24		2004, 2008
Wiley Slough	7177	EE73RP	River/Stream	33N - 3E - 26		1996 - 2008
	45687			33N - 3E - 25		2008

Poor water quality such as elevated FC concentrations can affect the health of those who are in contact with the water or consume shellfish. Poor water quality can also impair beneficial uses. Skagit Bay, with its surface water inputs, is of concern because it is a shared waterbody of the state, has shellfish harvesting areas in the bay, and has 303(d) listed waterbodies. The Lower Skagit River FC TMDL (Lawrence, 2007) suggested a FC loading assessment be conducted for Skagit Bay. Excluding the Skagit River, other freshwater sources to Skagit Bay not evaluated in the TMDL may contribute to FC pollution and should be assessed. In addition, organizations such as the Tribes, Washington State Department of Health (DOH), the city of Stanwood, Snohomish County, and Skagit County have interest in reducing FC pollution to restore beneficial uses.

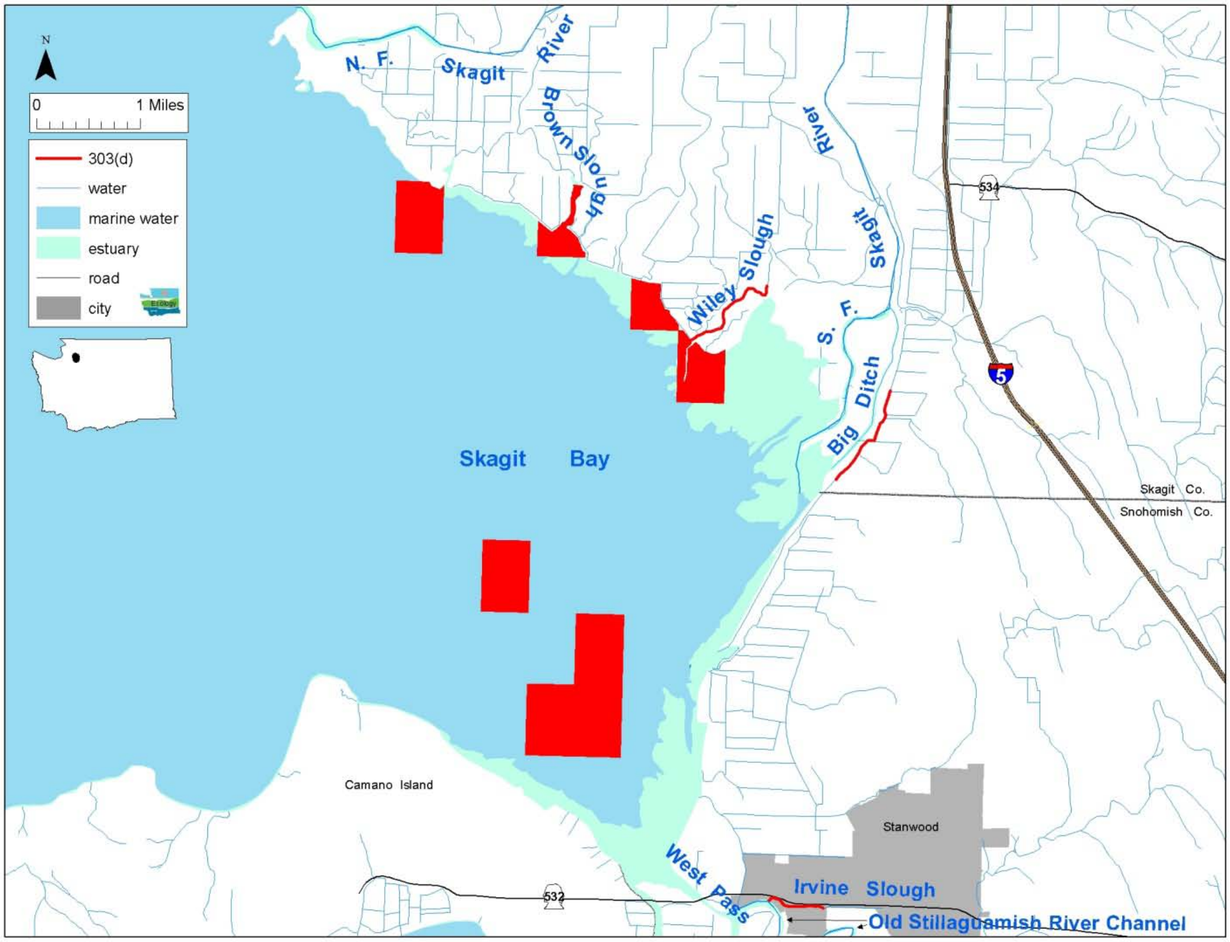

Figure 1. 303(d) listed waterbodies for fecal coliform in the southeast Skagit Bay area.

Ecology's Water Quality Program identified the surface water inputs to Skagit Bay as a candidate for an FC loading assessment. Ecology's Environmental Assessment Program agreed to conduct the technical study. This study may contribute to a future TMDL study if considered necessary, or it may proceed with a "direct to implementation" strategy.

Watershed description

Skagit Bay is in the northern part of the Puget Sound surrounded by the Skagit River delta, Camano Island, and Whidbey Island (Figure 1). The study area includes all surface water inputs along the southern and eastern shores of Skagit Bay including a few miles upstream on the North and South forks of the Skagit River. Three counties and Water Resource Inventory Areas (WRIA) overlap the bay: Skagit County, Snohomish County, Island County; and WRIAs 03, 05, and 06. Freshwater inputs to Skagit Bay include the Skagit River, the Stillaguamish River via West Pass, and agricultural ditches and sloughs including Hall Slough, Brown Slough, Dry Slough, Freshwater Slough, Fisher Creek, Big Ditch, Douglas Slough, and Davis Slough. Several unnamed ditches also convey surface water to the bay.

The Skagit River is the largest river in Washington outside the Columbia River basin, and it contributes the majority of freshwater to Skagit Bay. River flows are mainly influenced by rainfall, glacial meltwater, snowmelt, tidal fluctuation, and reservoirs (in the upper watershed). Typically, peak streamflows occur in June, while the lowest (baseflow) occurs in September. High tides can affect the Skagit River upstream to Mount Vernon at roughly river mile (RM) 19. The Skagit River splits into the North and South forks before entering the bay. Approximately 40% of the Skagit River flows to the South Fork (Williams et al., 1975). The forks braid and enter the bay along 2.5 miles of marine shoreline consisting of shellfish growing areas and Washington Department of Fish and Wildlife (WDFW) wildlife refuges.

West Pass receives streamflow from the Stillaguamish River via the Old Stillaguamish River Channel. Approximately 20% of the Old Stillaguamish River Channel enters West Pass and the remaining 80% flows south into Port Susan via South Pass (Pelletier and Sullivan, 2006). Streamflow in the Stillaguamish River is influenced by rainfall, snowmelt, and tidal fluctuation. Typically, peak streamflows occur during the winter while baseflow occurs during late summer. West Pass acts much like a tidal slough during the dry season when freshwater inflow becomes limited. Tidal influence from Puget Sound can extend up the Stillaguamish River to Silvana. However, a tide gate at the head of the Old Stillaguamish River Channel operates during low-flow periods from July through October. The tide gate is in place to increase freshwater flushing of the Old Stillaguamish River Channel by blocking marine water infiltration.

Skagit Bay Land Use

Land use around Skagit Bay is primarily agriculture drained by slough and ditches with tide gates and pump stations to prevent flooding from high tides and high surface water flow. Other land uses include WDFW wildlife refuges, commercial and recreational shellfish harvesting areas, and urbanization with both on-site septic systems and municipal wastewater treatment facilities. Over the past 10 years Skagit County has experienced a 16% increase in population (population estimate: 119,534), and Snohomish County has experienced a 15% increase (population estimate: 694,571) according to the United States Census Bureau (http://www.census.gov/).

Cities along the Skagit River include Mount Vernon (population estimate 30,000), Burlington (8,120), and Sedro-Woolley (9,000). In 1999, a combined sewer overflow (CSO) from the Mount Vernon municipal wastewater treatment plant (WWTP) increased the FC concentrations in Skagit Bay (Lawrence, 2007). All three cities have municipal WWTP that discharge to the Skagit River. Urban stormwater runoff also flows into the Skagit River and can be carried into the bay.

Along the Old Stillaguamish River Channel, the city of Stanwood (population estimate: 3,500) is an urban area nearest to Skagit Bay. Two point source facilities are located in Stanwood: the municipal WWTP and Twin City Foods Inc.

The Stanwood WWTP discharges treated effluent directly into the Old Stillaguamish River Channel. During specified upset conditions, effluent is automatically diverted into a lagoon reducing the risk of contamination of the Old Stillaguamish River Channel.

Twin City Foods discharges water used to process and pack vegetables. The effluent is stored in two lagoons in an agricultural area. Birds often frequent the lagoons and surrounding fields potentially contributing FC. Wildlife inputs are part of natural background levels and are not a controllable source. The lagoon water is seasonally applied to adjacent agriculture fields. Drainage ditches along these fields empty into the Old Stillaguamish River Channel and South Pass. Waterbodies pertinent to this study near Stanwood include the Old Stillaguamish River Channel, West Pass, Douglas Slough, and Irvine Slough.

Federal Clean Water Act requirements

The federal Clean Water Act established a process to identify and clean up polluted waters. Under the Clean Water Act, each state is required to have its own water quality standards designed to protect, restore, and preserve water quality. Water quality standards consist of designated uses for protection, such as cold water biota and drinking water supply, as well as criteria, usually numeric criteria, to achieve those uses.

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

In Washington State, the 303(d) list is part of the larger Water Quality Assessment. The Water Quality Assessment is a list that tells a more complete story about the condition of Washington's surface water. This list divides waterbodies into five categories:

Category 1 – Meets standards for the parameter (or parameters) for which it has been tested.

Category 2 – Waters of concern.

Category 3 – Waters with no data available.

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

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

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

Water quality criteria and beneficial uses

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

The FC criteria have two statistical components: a geometric mean criterion and an upper limit criterion that 10% of the samples cannot exceed. FC samples collected randomly usually follow a log-normal distribution, which should be taken into account in the analysis. The upper limit statistic (i.e., not more than 10% of the samples shall exceed) has been interpreted as a 90th percentile value of the log-normalized values (Cusimano, 1997; Joy, 2000; Sargeant, 2002).

Freshwater and marine waterbodies are required to meet water quality standards based on beneficial uses. Numeric criteria for specific water quality parameters are intended to protect designated uses. Skagit Bay and its freshwater tributaries including brackish estuaries are classified as *Primary Contact* waters. Examples of *Primary Contact* beneficial uses are swimming, snorkeling, and activities where the water and skin or body openings (e.g., eyes, ears, mouth, nose, and urogenital) come into direct and extended contact. Potential sources of FC pollution to Skagit Bay include: CSOs, wastewater treatment plants, stormwater, failing onsite septic systems, agriculture, and wildlife (considered part of "natural background levels").

The application of freshwater and marine water quality criteria is based on salinity as described in the WAC 173-201A-260. Figure 2 shows the boundaries where certain water quality criteria apply to freshwater and marine water in the Skagit Bay FC study area. Freshwater criteria apply when 95% of salinity values are less than ten parts per thousand (ppt). Marine water quality criteria apply when salinity is 10 ppt or greater. Similarly, if data show a 95th percentile conductivity of 17,700 micromhos, equivalent to salinity greater than 10 ppt, marine criteria applies (Swanson, 2008).

Freshwater

FC criteria are set to protect people who work and play in and on the water from waterborne illnesses. FC is used as an "indicator bacteria" for the state's freshwaters by assuming the presence of waste from humans or other warm-blooded animals. Waste from warm-blooded animals is more likely to contain pathogens that will cause illness in humans than waste from cold-blooded animals. The FC criteria are set at levels that have been shown to maintain low rates of serious intestinal illness (gastroenteritis) in people.

The *Primary Contact* use is intended for waters "where a person would have direct contact with water to the point of complete submergence including, but not limited to, skin diving, swimming, and waterskiing." The use is to be designated to any waters where human exposure is likely to include exposure of the eyes, ears, nose, and throat. Since children are also the most sensitive group for many of the waterborne pathogens of concern, even shallow waters may warrant primary contact protection. To protect this use category *"Fecal coliform organism levels must not exceed a geometric mean value of 100 colonies/100 mL, with not more than 10% of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 200/colonies mL*" (WAC 173-201A-200(2)(b), 2007 edition).

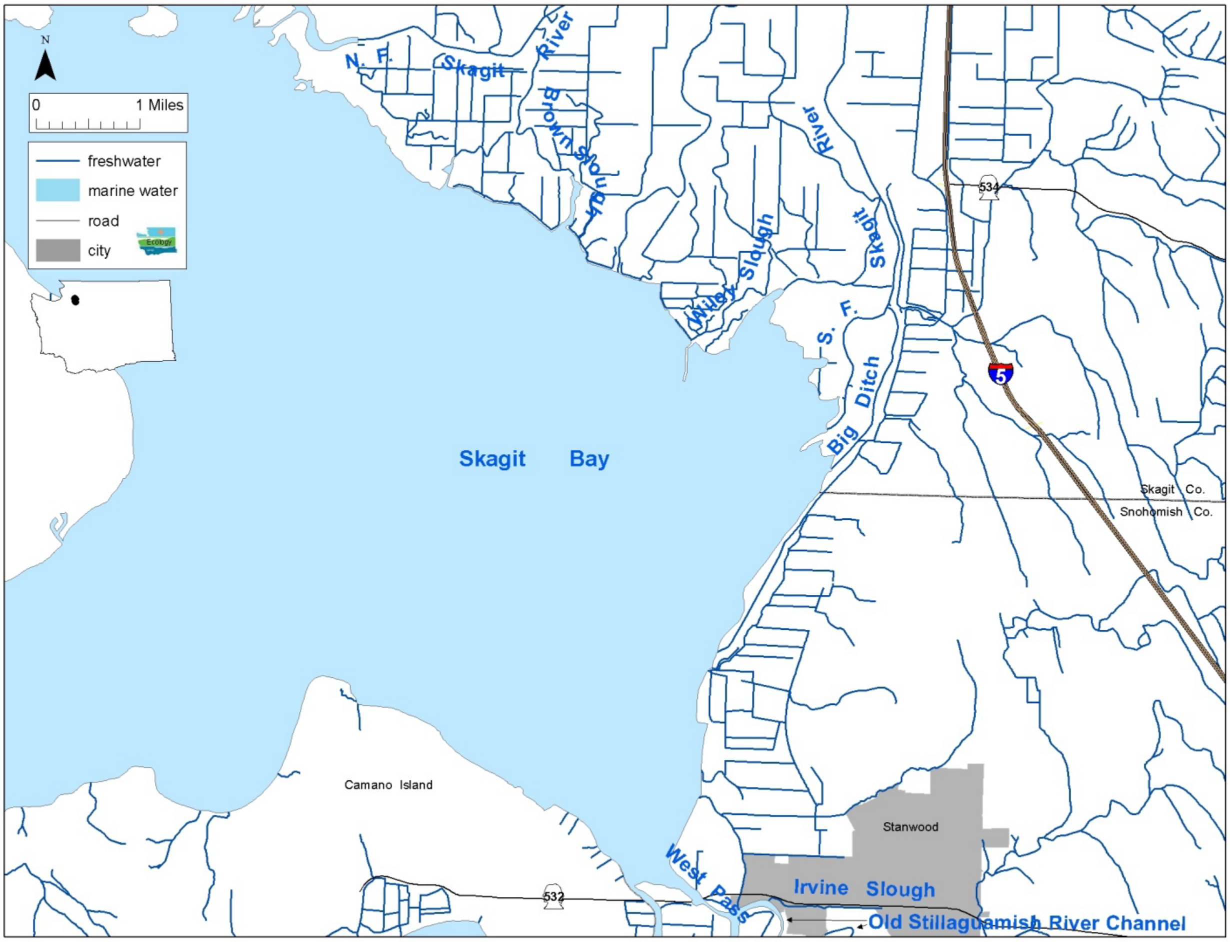

Figure 2. Freshwater and marine water boundaries for designated water quality criteria.

If natural levels of FC (from wildlife) cause criteria to be exceeded, the standards do not allow human sources to measurably increase bacterial pollution further. Warm-blooded animals, particularly those managed by humans and thus exposed to human-derived pathogens, are a common source of serious waterborne illness for humans.

Marine water

In marine (salt) waters, bacteria criteria are set to protect shellfish consumption and people who work and play in and on the water. In waters protected for both *Primary Contact Recreation* and *Shellfish Harvesting*, FC bacteria are used as indicator bacteria to gauge the risk of waterborne diseases.

To protect *Shellfish Harvesting* and *Primary Contact Recreation* (swimming or water play): "*Fecal coliform organism levels must not exceed a geometric mean value of 14 colonies/100 mL, with not more than 10% of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 43 colonies/100mL*" [WAC 173-201A-210(3)(b), 2007 edition].

The criteria set to protect *Shellfish Harvesting* and *Primary Contact Recreation* are consistent with National Shellfish Sanitation Program (NSSP) rules. FC concentrations in marine waters that meet shellfish protection requirements also meet the federal recommendations for protecting people who engage in primary water contact activities. Thus, the same criteria are used to protect both *Shellfish Harvesting* and *Primary Contact* uses in Washington State standards.

Previous studies

Washington State Department of Ecology

FC bacteria TMDL studies have been conducted on the lower Skagit River (Lawrence, 2007; Pickett, 1997; and Butkus et al., 2000) and the Stillaguamish River (Lawrence and Joy, 2005). Below is a summary of relevant conclusions and recommendations from the studies, excluding redundancies.

Lower Skagit River Fecal Coliform Total Maximum Daily Load Water Quality Implementation Plan

- Potential sources of FC pollution to Skagit Bay include: CSOs, wastewater treatment plants, stormwater, failing onsite septic systems, agriculture, and wildlife (considered part of "natural background levels").
- From 2004 through 2006 the Skagit River met freshwater FC water quality criteria. Although the South Fork met FC criteria, it did not meet the more stringent TMDL load allocation targeted to protect marine water quality criteria.
- FC data showed seasonal changes in concentration and loading. The Skagit River experienced a peak in the fall and Skagit Bay experienced seasonal FC elevations in July, November, and February-March.
- FC in the Skagit River can quickly affect Skagit Bay despite seasonal differences in loading/concentrations between the river and the bay. This was demonstrated by a CSO to the river that caused elevated FC concentrations in the bay that remained for several days.
- FC water quality has improved in the Skagit River but not in Skagit Bay except for the monitoring station near West Pass.
- Excluding the Skagit River, other freshwater sources to Skagit Bay not evaluated in the TMDL may contribute to FC pollution and should be assessed.
- FC monitoring on the Skagit River should continue with a focus on seasonal storms in order to characterize loading events to Skagit Bay. It may be important to determine how long after a storm FC concentrations remain elevated in the bay.
- DOH should conduct a dry-season and wet-season FC shoreline survey around Skagit Bay.

- West Pass needs 97% reduction in FC to meet water quality criterion.
- Douglas Slough needs 68% reduction in FC to meet water quality criterion.
- Irvine Slough needs 99% reduction in FC to meet water quality criterion.
- FC water quality violations are prevalent throughout the lower Stillaguamish watershed, especially during storm events.

Skagit County Public Works

Skagit County Public Works Department has completed over five years of water quality monitoring in and around agricultural areas (Skagit County, 2009). The goal was to determine if the Skagit County Critical Area Ordinance for Ongoing Agriculture protects natural resources by detecting trends over time. FC was assessed using Most Probable Number (MPN) method (Skagit County, 2009). The following is a brief summary of relevant conclusions from 2004 through 2008:

- All four sites on the Skagit River and its forks met the geometric mean and 10% water quality criteria for FC.
- Maddox Slough/Big Ditch at Milltown Road met the geometric mean water quality criterion for FC but did not meet the 10% criterion resulting in 12% of the samples > 200cfu/mL.
- Wiley Slough at Wylie Road met the geometric mean water quality criterion for FC but did not meet the 10% criterion resulting in 14% of the samples > 200cfu/mL.

Snohomish County Public Works

Beginning in 1994, Snohomish County Public Works Department has been monitoring and documenting the conditions of the Stillaguamish River watershed (Snohomish County, 2007). Their assessment provides recommendations to the Stillaguamish Clean Water District Advisory Board when addressing water quality for areas including the estuaries of Skagit Bay. Snohomish County has been coordinating efforts with tribes and local partners to develop a shellfish restoration plan for Port Susan and Skagit Bay.

Monitoring will continue with an innovative approach to prioritize source identification and corrective activities. Monitoring areas include FC sampling in freshwater and FC cleanup by improving land practices and onsite septic tank inspections as resources allow.

Washington State Department of Health

DOH Office of Shellfish and Water Protection monitors FC concentrations in Skagit Bay. Monitoring is designed to ensure that shellfish are safe to eat, beaches are safe for swimming, and onsite sewage treatment is functioning properly.

DOH classifies commercial shellfish beds in Washington State using the NSSP criteria (numeric criteria are the same as Ecology's marine criteria):

- Geometric mean less than or equal to 14 cfu/100 mL.
- No more than 10% of the samples greater than 43 cfu/100 mL.
- Statistics based on the last 30 samples collected.

Sanitary surveys include the following classifications:

- *Approved* – The growing area is approved for direct marketing of commercial harvest and does not pose a public health risk.
- *Conditionally Approved* – The area is approved, but only during predictable periods. Typically, shellfish harvesting is prohibited following a rainfall event of predetermined magnitude for the length of time it takes water quality to recover from the event.
- *Restricted* – Restricted areas are not approved for direct commercial marketing but, due to limited pollution from non-human sources, shellfish can be relayed to an approved area for a specified amount of time to cleanse themselves before being sold commercially.
- *Prohibited* – In these areas pollution from fecal material or other sources poses a health risk to shellfish consumers; commercial shellfish harvest is not allowed.
- *Unclassified* – The growing area has no formal assessment conducted.

Figure 3 shows DOH water quality sampling locations and shellfish harvesting classifications in Skagit Bay (Sullivan, 2009). A status and trends report covering the past 10 years shows South Skagit Bay improving with negligible FC pollution in 2008 (DOH, 2010). A shoreline survey showed no direct or indirect impacts from FC pollution that would result in a classification downgrade (Berbells, 2009). Despite the trend showing a decline in FC concentrations, the shellfish harvesting area around West Pass remains prohibited based on potential upset conditions at the Stanwood WWTP, stormwater impacts, and other nearby nonpoint sources (Berbells, 2009).

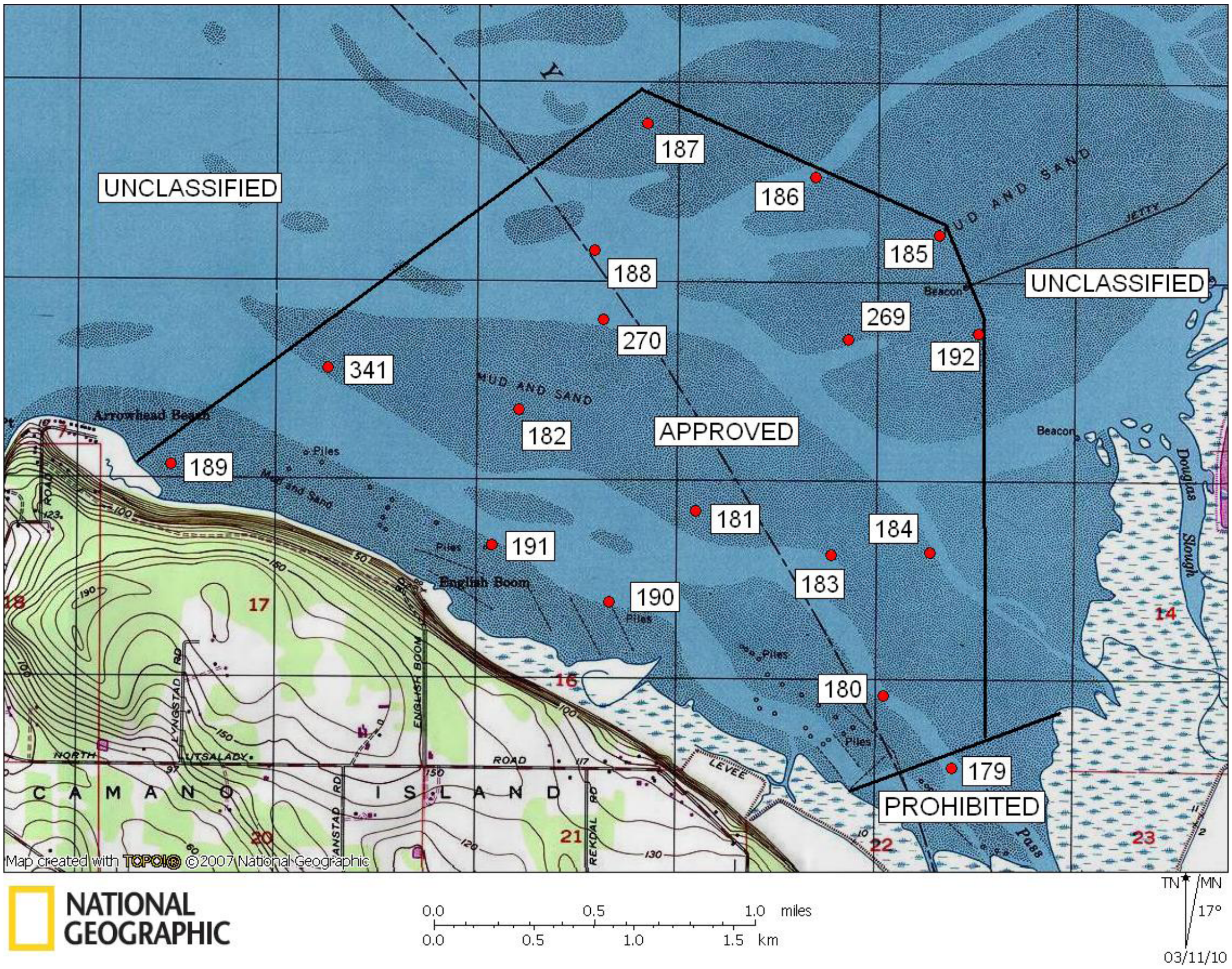

Figure 3. South Skagit Bay fecal coliform sampling locations and shellfish harvesting classifications. Map provided by DOH (Sullivan, 2009).

Project Description

The goal of this study is to help reduce FC and nutrient contamination to Skagit Bay. Targeted waterbodies include brackish and freshwater sources to Skagit Bay along its southern and eastern land borders comprising the study area. Study results will be used to guide water quality improvement projects. For example, FC concentrations/loads will be quantified and assessed spatially and then linked with land use practices and existing conditions. Tributaries and drainages that have high FC contamination will be prioritized during the cleanup process.

The primary objective of this study is to evaluate FC concentrations, surface water discharge, and general water quality parameters within the study area during 2010-2011. FC samples and streamflow measurements will be taken on major freshwater and brackish water inputs to the bay. Seasonality, storm events, and land use practices will be evaluated in order to achieve project objectives. Data collected will form the basis for calculating FC contaminant loads to the bay.

The secondary objective of the study is to collect nutrient samples during each storm survey. Nutrient data will be used to evaluate stormwater contributions to the bay and further develop Puget Sound environmental monitoring efforts.

Approximately 19 sampling sites have been chosen in consultation with Ecology's Water Quality Program, based on waterbody size, 303(d) listing, accessibility, and land uses that are potential pollutant sources. Figure 4 and Table 2 show the proposed sampling sites within the study area along the southern and eastern land borders of Skagit Bay. The proposed sampling sites are subject to change in order to meet project objectives and laboratory budget; they will remain consistent once established. Some sites may be omitted if the water is stagnant where streamflow is unattainable. Stormwater will be sampled at the proposed monitoring sites in order to characterize the contributions to the bay.

Potential constraints to field data collection and interpretation include: limited site accessibility, determining background conditions, synchronizing sampling with ebb tide cycles, storm events, and DOH sample schedule. Private lands or lack of roads may limit site access, prompting the use of boats or foot access over long distances. Permission to gain site access on private land will be obtained before collecting water samples. Sample coordination with DOH will be attempted but may be challenging due to potential schedule conflicts/constraints and tidal cycles. Coordination with DOH is further discussed in the *Sampling Process Design* section of this QA Project Plan.

The following conditions rank the priority representing the best possible timing of sampling:

1. Monthly sampling
2. Tidal cycles
3. Storm events
4. DOH sample schedule

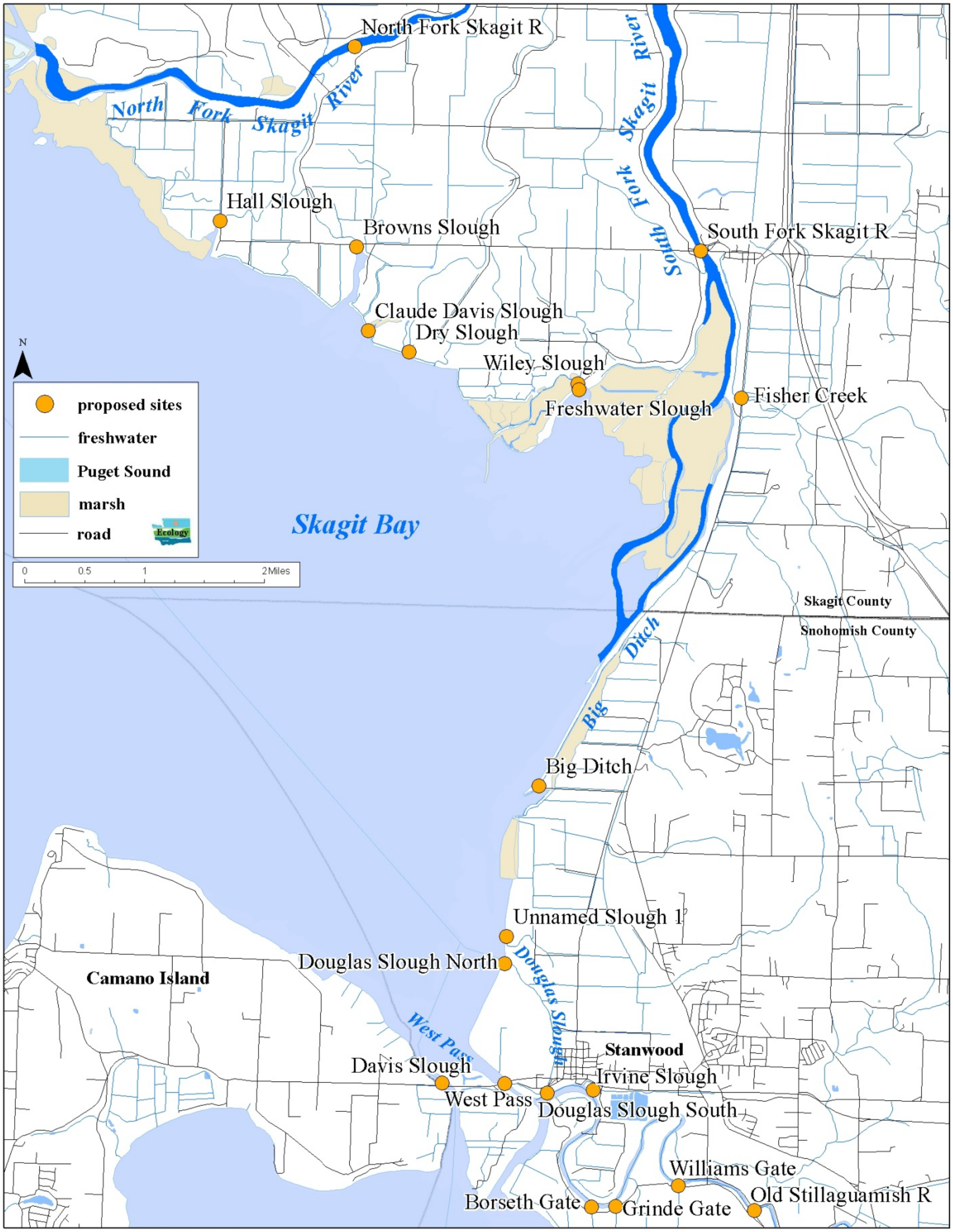

Figure 4. Proposed monitoring locations along Skagit Bay.

Table 2. Proposed monitoring locations along Skagit Bay including approximate latitude and longitude (NAD 1984 HARN State Plane Washington South).

Site Name	Site Description	Latitude	Longitude
Big Ditch	Big Ditch above tide gate at wildlife area	48.27619	-122.37867
Borseth Gate	Borseth Gate, Stillaguamish Flood Control District	48.22568	-122.36745
Brown Slough	Brown Slough at Fir Island Rd.	48.34081	-122.41409
Davis Slough	Davis Slough at Hwy 532	48.24002	-122.39491
Douglas Slough North	Douglas Slough north at Puget Sound	48.25464	-122.38416
Douglas Slough South	Douglas Creek at Stanwood	48.23914	-122.37582
Dry Slough	Dry Slough at wildlife area	48.3413	-122.39079
Fisher Creek	Fisher Watershed at Pioneer Ave.	48.32366	-122.34361
Freshwater Slough	Freshwater Slough at wildlife area, Wylie Rd.	48.32495	-122.37337
Grinde Slough	Grinde Gate, Stillaguamish Flood Control District	48.22573	-122.36291
Hall Slough	Hall Slough pump house at Maupin Rd.	48.34357	-122.43887
Irvine Slough	Irvine Slough at pump in Stanwood	48.23968	-122.36756
North Fork Skagit River	North Fork Skagit River at Moore Rd.	48.36743	-122.40575
Old Stillaguamish River	Old Stillaguamish River Channel at Marine Dr.	48.22555	-122.33787
South Fork Skagit River	South Fork Skagit River at Fir Island Rd.	48.34134	-122.35087
Unnamed Slough 1	Unnamed Slough 1 next to Douglas Slough North	48.25795	-122.38390
Claude Davis Slough	Claude Davis Slough at wildlife area	48.33073	-122.41151
West Pass	West Pass at Hwy 532	48.24018	-122.38358
Wiley Slough	Wiley Slough at pump house, Wylie Rd.	48.32418	-122.37313
Williams Gate	Stillaguamish Flood Control District	48.22843	-122.35173

Limited access may preclude routine sampling in Douglas Slough North (Table 2) or other nearby potential drainages. Douglas Slough North may be accessed over private property or by boat traveling long distances, making it time consuming. These drainages will be surveyed at least once using boat and foot access. Surface water discharge will be measured (if flowing) or estimated and FC grab samples will be taken during the survey.

Natural background FC sources from wildlife will be difficult to assess due to limited laboratory analysis capabilities. Approximate bird counts will be conducted during each site visit to roughly assess the potential of avian wildlife FC contributions.

Storm events may occur when the tide is too high and may result in sampling tidal marine waters. The right timing of the storm with sufficient ebb tide will be necessary to ensure freshwater sampling at all sites.

Organization and Schedule

The following people are involved in this project (Table 3). All are employees of the Washington State Department of Ecology.

Table 3. Organization of project staff and responsibilities.

Staff (all are EAP except client)	Title	Responsibilities
Ralph Svrjcek Water Quality Program Northwest Regional Office Phone: (425) 649-7165	EAP Client	Clarifies scopes of the project. Provides internal review of the QAPP and approves the final QAPP.
Dave Garland Water Quality Program Northwest Regional Office Phone: (425) 649-7031	Client's Unit Supervisor	Reviews the draft QAPP and approves the final QAPP.
Kevin Fitzpatrick Water Quality Program Northwest Regional Office Phone: (425) 649-7033	Client's Section Manager	Reviews the draft QAPP and approves the final QAPP.
James Kardouni Directed Studies Unit Western Operations Section Phone: (360) 407-6517	Project Manager/Principal Investigator	Writes the QAPP. Oversees field sampling and transportation of samples to the laboratory. Conducts QA review of data, analyzes and interprets data, and enters data into EIM. Writes the draft report and final report.
George Onwumere Directed Studies Unit Western Operations Section Phone: (360) 407-6730	Unit Supervisor for the Project Manager	Reviews the project scope and budget, tracks progress, provides internal review of the QAPP, approves the budget, and approves the final QAPP.
Robert F. Cusimano Western Operations Section Phone: (360) 407-6596	Section Manager for the Project Manager	Reviews the draft QAPP and approves the final QAPP.
Stuart Magoon Manchester Environmental Laboratory Phone: (360) 871-8801	Director	Reviews the draft QAPP and approves the final QAPP.
William R. Kammin Phone: (360) 407-6964	Ecology Quality Assurance Officer	Reviews the draft QAPP and approves the final QAPP.

EAP: Environmental Assessment Program.
EIM: Environmental Information Management system.
QAPP: Quality Assurance Project Plan.

The project schedule is outlined in Table 4.

Table 4. Proposed schedule for completing field and laboratory work, data entry into EIM, and reports.

Field and laboratory work	Due date	Lead staff
Field work begin	September 2010	James Kardouni
Field work completed	October 2011	James Kardouni
Laboratory analyses completed	October 2011	
Environmental Information System (EIM) database		
EIM user study ID	JKAR0002	
Product	Due date	Lead staff
EIM data loaded	January 2012	James Kardouni
EIM quality assurance	February 2012	George Onwumere
EIM complete	March 2012	James Kardouni
Final report		
Author lead	James Kardouni	
Schedule		
Draft due to supervisor	February 2012	
Draft due to client/peer reviewer	March 2012	
Draft due to external reviewer(s)	April 2012	
Final (all reviews done) due to publications coordinator (Joan)	May 2012	
Final report due on web	June 2012	

Quality Objectives

To meet the objectives of this study, all field sampling and lab analysis will follow strict protocols outlined in this QA Project Plan to ensure data credibility and usability.

Quality objectives are statements of the precision, bias, and lower reporting limits necessary to address project objectives. Precision and bias together express data accuracy. Other considerations of quality objectives include representativeness and completeness. Quality objectives apply equally to laboratory and field data collected by Ecology, to data used in this study collected by entities external to Ecology, and to modeling and other analysis methods used in this study.

Measurement quality objectives (MQO) state the acceptable accuracy for the data collected for a project. MQOs are discussed in detail in the *Quality Control* section. Sampling methods, protocols, and data analysis are discussed in detail in following sections.

Precision

Precision is defined as the measure of variability in the results of replicate measurements due to random error. Random error is imparted by the variation in concentrations of samples from the environment as well as other introduced sources of variation (e.g., field and laboratory procedures). Precision for replicates will be expressed as percent relative standard deviation (RSD). RSD = (standard deviation of the sample population) × 100 / (mean of the sample population).

Bias

Bias is defined as the difference between the sample value and true value of the parameter being measured. Bias affecting measurement procedures can be inferred from the results of quality control (QC) procedures involving the use of blanks, check standards, and spiked samples. Bias in field measurements and samples will be minimized by strictly following measurement, sampling, and handling protocols. Method blanks will be carried out by MEL for both fecal coliform and nutrients. Field measurement bias for dissolved oxygen and temperature is further discussed in the *Quality Control*' section.

Sampling Process Design (Experimental Design)

In late September 2010, Ecology will begin field work (Figure 4 and Table 2) collecting FC samples, streamflow, and general water quality parameters. Routine sampling will occur once per month and span the course of 13 months. In addition, storm events will be sampled once per annual season including autumn, winter, spring and summer. Capturing storm events will characterize seasonal storm contributions to Skagit Bay. Stormwater will be sampled for FC, streamflow, and nutrients. Specific nutrient samples are discussed at the end of this section. Sampling will be targeted near low tide when possible to help ensure the collection of a freshwater sample. The experimental design will achieve the study objectives by assessing the relevant water quality parameters within the study area.

The following is an estimated sampling schedule:

2010

- September 20 and 21
- October 18 and 19
- November 16 and 17
- December 13 and 14

2011

- January 24 and 25
- February 7 and 8
- March 21 and 22
- April 18 and 19
- May 16 and 17
- June 13 and 14
- July 4 and 5
- August 8 and 9
- September 26 and 27

Representativeness and completeness

The study was designed to have enough sampling sites and sufficient sampling frequency to adequately characterize FC spatial and temporal patterns in the study area. This method is a form of random sampling, since the day of the month is independent of environmental factors. FC values are known to be highly variable over time and space. Sampling variability can be somewhat controlled by strictly following standard procedures and collecting quality control samples, but natural spatial and temporal variability can contribute greatly to the overall variability in the parameter value. Storm sampling is designed to assess how pollutants of concern in stormwater runoff may affect the bay on a seasonal basis.

The U.S. Environmental Protection Agency (EPA) has defined completeness as a measure of the amount of valid data needed to be obtained from a measurement system (Lombard and Kirchmer, 2004). The goal for this study is to correctly collect and analyze 100% of the FC samples for all sites, plus 100% of the storm event samples. However, unavoidable problems occasionally arise during sample collection and can interfere with this goal. Examples of these problems include flooding, inadequate rain for storm sampling, site access problems, or sample container shortages. A lower limit of five samples per season per site will be required for comparison to state criteria. This limit should be met with the current sampling design. In this case the season is defined by wet season (November – April) and dry season (May – October) and not applied to season storm sampling (spring, summer, fall, winter). WAC 173-201A states:

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

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

Comparability

Sample coordination with DOH

Ecology will coordinate sampling to coincide with DOH Skagit Bay sampling to the extent possible. Ecology will sample around low tide, attempting to ensure freshwater flow to the bay. Salinity will be measured to determine the type of water sampled (fresh or brackish). DOH will sample at high tide to ensure access to shallow areas of the bay. At best, freshwater sampling is projected to occur one or two tide cycles before marine water sampling.

Synchronized freshwater and marine water sampling will help form a relationship between freshwater FC concentrations (or loads) and marine FC concentrations. Modeling this relationship is currently beyond the scope of this project. FC transport/settling, die-off, and Skagit Bay circulations are important factors to consider when forming the relationship. FC bacteria are sensitive to saltwater; more bacteria die when traveling from freshwater to marine water.

MF and MPN Lab Methods

FC bacteria concentrations can be determined using the membrane filter (MF) or most probable number (MPN) laboratory methods. Ecology typically uses the MF method while DOH and Skagit County use the MPN method. Saltwater samples are analyzed using the MPN method for regulatory reasons. Ecology will collect split samples for MF and MPN analyses at approximately three stations while sampling. The number of comparative MPN samples may be adjusted in order to meet the proposed lab budget. Both DOH and Ecology use accredited environmental laboratories for sample processing (WAC 173-50).

MPN results have a wider confidence interval than MF and an inherent positive statistical bias (APHA et al., 2005, Gronewold and Wolpert, 2008, and Swanson, 2008). Some researchers believe the MPN method is better at enumerating injured or stressed organisms, as well as organisms in turbid or saline waters (Joy, 2000). Ecology uses the MF method in streams because of its practicality, precision, and relatively low laboratory cost.

One constraint with MPN sampling is the timing of sample delivery to the Manchester Environmental Laboratory (MEL). Due to sample processing, MEL prefers to accept MPN samples on Mondays and Tuesdays, but can also accept samples Wednesday through Friday if they are informed in advance and can allocate staff resources for the weekend processing. Therefore MPN sampling should occur on Monday or Tuesday mornings. MEL is contracted at a 50% discounted cost to process the water samples. As an alternative, Ecology may request MPN analysis from DOH laboratory. In this event, MPN samples will be delivered along with DOH samples. Timing of the change in sample custody will be a constraint.

Nutrient samples will be collected during seasonal storm events for general water quality and Puget Sound assessment. Analyses include: Ammonia, Nitrate-Nitrite, Total Persulfate Nitrogen, Orthophosphate, and Total Phosphorus. Nutrient samples will provide additional data to ongoing projects in the area. Results will be summarized in the final technical report.

Sampling Procedures

Field sampling and measurement procedures will follow Standard Operating Procedures (SOP) developed by Ecology's Environmental Assessment Program including:

- EAP010 *Field Measurement of Conductivity/Salinity*
- EAP012 *Sampling Bacteria in Water*
- EAP015 *Grab Sampling – Fresh water*
- EAP023 *Winkler Determination of Dissolved Oxygen*
- EAP033 *Hydrolab DataSonde and MiniSonde Multiprobes*
- EAP035 *Measurement of Dissolved Oxygen in Surface Water*
- EAP056 *Measuring and Calculating Stream Discharge*
- EAP060 *Measuring Stream Discharge from a Bridge*
- EAP071 *Minimizing the Spread of Aquatic Invasive Species from areas of Moderate Concern*

SOP documents can be found on the web at: www.ecy.wa.gov/programs/eap/quality.html.

Grab samples will be collected directly into pre-cleaned containers supplied by MEL and described in the MEL *Lab Users Manual* (2008). FC samples for laboratory analysis will be stored on ice and delivered to MEL within 24 hours of collection. Specifications for sample containers, preservations, and holding times are presented in Table 5.

Samples will be collected from the stream thalweg (center of flow) whenever possible. Samples taken in freshwaters will be collected at approximately six inches below the surface of the water, with the sampler standing downstream from the collection point. Samplers will try to avoid stirring up sediment in streams with slow current velocities or shallow channels. In stratified sloughs, drainages, and at mouths of streams, conductivity samples will be taken at two or three depths in the water column.

Chain-of-custody forms and sample tags for each parameter will be prepared before each field study, adhering to MEL (2008) guidelines. Information on the sample tags includes: project name, sample identification number, site identification, date, time, and parameter. Samples will be collected in appropriate containers and delivered to the laboratory along with a chain-of-custody form. Date and time will be recorded on the sample tags at the time of field collection. Information on the sample tags will match with the information on the chain-of-custody form.

Field logs will document each sampling event. Field logs will include information such as: project name, site identification, date, time, water quality parameters (listed in the "Measurement Procedures" section), general weather conditions, stream velocity measurements, bird counts, and comments.

Table 5. Containers, preservation requirements, and holding times for samples collected (MEL, 2008).

Parameter	Sample Matrix	Container	Preservative	Holding Time
Fecal Coliform	Surface water, groundwater, effluent, and runoff	250 or 500 mL glass/poly autoclaved	Cool to 4ºC	24 hours
Dissolved Oxygen	Surface water, effluent	300 mL BOD bottle & stopper	2 mL manganous sulfate reagent + 2 mL alkaline-azide reagent	4 days
Ammonia	Surface water, groundwater, effluent, and runoff	125 mL clear poly	H_2SO_4 to pH<2; Cool to 4ºC	28 days
Nitrate/Nitrite	Surface water, groundwater, effluent, and runoff	125 mL clear poly	H_2SO_4 to pH<2; Cool to 4ºC	28 days
Total Persulfate Nitrogen	Surface water, groundwater, effluent, and runoff	125 mL clear poly	H_2SO_4 to pH<2; Cool to 4ºC	28 days
Orthophosphate	Surface water, groundwater, effluent, and runoff	125 mL amber poly w/ Whatman Puradisc™ 25PP 0.45um pore size filters	Filter in field with 0.45 um pore size filter; Cool to 4°C	48 hours
Total Phosphorous	Surface water, groundwater, effluent, and runoff	60 mL clear poly	1:1 HCl to pH<2; Cool to 4°C	28 days

Table 6 shows the estimated lab budget for this study based on 15 sampling sites. The lab budget includes an additional 15% for unexpected costs. For example, Table 2 shows 19 potential sampling locations that may be established in order to achieve the project objectives. However in contrast, some sampling locations may be removed due to temporal lack of flowing water (stagnation or dry), limited accessibility, or lack of contribution to the project's primary goal. In either case, the lab budget is projected to cover expenses necessary to this study.

Environmental ethics and Washington law (RCW 77.15.290) prohibit the transportation of *any* plants or animals. While there are exceptions, such as for scientific study, field staff must ensure that sampling activities do not spread viable organisms from one sampling location to another.

Most sampling will require little more than careful cleaning and visual inspection. Sampling equipment with areas that cannot be visually inspected (e.g., outboard jet pump engines, plumbing systems in boats, sample tubing) may require some additional decontamination procedures if rinsing alone won't remove aquatic plant parts, mud, and debris.

Table 6. Estimated lab budget for the Skagit Bay fecal coliform assessment study.
Costs include 50% discount for Manchester Environmental Laboratory (MEL).

Parameter	Cost/ Sample	Number of Sites	Number of Samples (including field QA)	Number of Surveys	Total Number of Samples	Total Cost
Ammonia (NH3)	13.50	15	17	4	68	918
Nitrite-Nitrate (NO2/NO3)	13.50	15	17	4	68	918
Total Persulfate Nitrogen (TPN)	17.65	15	17	4	68	1200
Orthophosphate (OP)	15.57	15	17	4	68	1059
Total Phosphorus (TP)	18.69	15	17	4	68	1271
Fecal Coliform (MF)	23.88	15	18	17	306	7307
Fecal Coliform (MPN)	44.64	3	4	17	68	3036
Additional samples (opportunistic, additional sites, or possible source ID)						2356
					Total:	$18,065

Measurement Procedures

Instantaneous streamflow measurements and water quality measurements, including grab samples, will be taken during each visit to a site whenever it is safe and practical. FC and nutrient loads will be calculated by multiplying concentration by streamflow rate.

High tide can back up surface water flow, making streamflow difficult to assess. Therefore measuring streamflow above tidal influence will help ensure quality data collection. The use of continuous stage height measurements may by employed to estimate streamflow. Tide gates and tide fluctuations influence stage heights, making streamflow difficult to measure. This influence will be considered during streamflow measurements by assessing the relationship between specific tide height, tide gate open/closure, and surface water flow/backup. In some locations near tide gates and pump stations, streamflow measurements may be unattainable using standard methods. Alternative procedures may be used, such as estimating streamflow based on tide gate/pump station specifications and functionality during tidal fluctuations (Swanson, 2008).

Additional water quality parameters will be measured using a multi-probe/data-Sonde following the *Standard Operating Procedure (SOP) for Hydrolab® DataSonde® and MiniSonde® Multiprobes* (Swanson, 2007). Parameters measured by the *Hydrolab®* and recorded in the field log include: temperature (°C), dissolved oxygen (mg/L), specific conductivity (µS/cm), pH, and salinity (ppt). The *Hydrolab®* calculates salinity using an algorithm that is based on specific conductivity and temperature measurements (Miller, et al., 1988, or APHA, 2005).

Quality Control Procedures

Field

Before each sampling event, field instruments will be assessed for proper function. Table 7 shows the general specifications of field instruments used for this study. The Marsh McBirney flow meter will be checked and adjusted according to factory specifications. The *Hydrolab®* multi-meter will be calibrated to standards both before and after each sampling event. Table 8 shows the precision MQO for the *Hydrolab®* post field calibration. If any of these QC procedures are not met, the associated results will be qualified and used with caution, or not used at all.

Table 7. Field instrument specifications.

Analysis	Instrument	Method	Range	Accuracy	Resolution
Stream Velocity	Marsh McBirney Flowmate	EAP056	0.01 to 5.00 feet/second	± 0.05 ft/s	0.01 ft/s
Water Temperature	Hydrolab Sonde®	SM2550B-F	-5C° to 50°C	± 0.10°C	0.01°C
Specific Conductivity	Hydrolab Sonde®	EPA120.1M	1 to 100,000 µS/cm	± (0.5% of reading + 1 µS/cm)	0.1 to 1 µS/cm
Dissolved Oxygen	Hydrolab Sonde®	Hach 10360	1 to 60 mg/L	± 0.1 mg/L at ≤ 8 mg/L, ± 0.2 mg/L at > 8 mg/L	0.01 mg/L
pH	Hydrolab Sonde®	EPA150.1M	0 to 14 pH units	± 0.2 units	0.01 units
Salinity	Hydrolab Sonde®	SM2520-F	0 to 70 parts per thousand	± 0.2 ppt	0.01 ppt

Table 8. Field instrument calibration measurement quality objectives (MQO) for precision.

Measured Field Parameter	Units	Data Qualifier and Definition		
		accept	estimate	reject
Specific Conductivity (SpCond)	µS/cm	≤ ± 5%	> ± 5% and ≤ ± 10%	> ± 10%
Dissolved Oxygen	% saturation	≤ ± 5%	> ± 5% and ≤ ± 15%	> ± 15%
pH	standard units	≤ ± 0.25	> ± 0.25 and ≤ ± 0.5	> ± 0.5

The *Hydrolab®* dissolved oxygen (DO) probe will be checked against grab samples for QC/QA purposes. Approximately 20% of the monitoring sites will include a DO grab sample to be analyzed using the Winkler titration method (SM4500OC) described in Ecology's SOP manuals. The results from the titration and *Hydrolab®* will be compared using RSD. RSD values greater than 10% will result in using a data qualifier to flag the field data fulfilling precision MQOs for DO. Bias will be evaluated between *Hydrolab®* reading and Winkler titrations by calculated the average residual. *Hydrolab®* DO data will be corrected if significant bias is calculated.

Laboratory

MEL follows the MQO described in their *Lab Users Manual* (2008). Analysis for samples such as FC, Winkler DO, and nutrients will be conducted according to the specifications outlined in Table 9. The field sampling MQO is included as well because of the inherent relationship with lab analysis in the overall sampling process. Twenty percent of FC samples and ten percent of nutrient samples will be duplicated in the field in a side-by-side manner to assess field and lab variability.

The higher percentages of variability in lower results limit the effectiveness of the RSD and RPD statistics for evaluating precision of water quality data, especially with bacteria parameters. For example, replicate results of 2 and 5 cfu/100 mL yield a RSD of 61% and a RPD of 86%, whereas results of 22 and 25 yield a RSD of 9% and a RPD of 13%. Each replicate pair is only 3 cfu apart; however, the RSD and RPD between the two pairs are dramatically different. For this reason, projects where the mean of replicate pairs is relatively low may have difficulty meeting precision standards and will be reviewed separately by the project manager. (Mathieu, 2006)

Table 9. Field and laboratory precision measurement quality objectives (MQO) for laboratory samples.

Analysis	Method	Field Replicate MQO	Lab Duplicate MQO	Reporting Limits and Resolution
Fecal Coliform MPN	MPN 9221 E1	Insufficient data to accurately compare replicate pair statistics	40% RPD[2]	1.8 MPN/100 mL
Fecal Coliform MF	SM 9222D	50% of replicate pairs < 20% RSD 90% of replicate pairs < 50% RSD[1]	40% RPD[2]	1 cfu/100 mL
Dissolved Oxygen	SM4500OC	10% RSD[2]	n/a	0.1 mg/L
Ammonia	SM 4500-NH3-H	20% RSD[2]	20% RPD[2]	0.01 mg/L
Nitrate/Nitrite	SM 4500 NO3- I	20% RSD[2]	20% RPD[2]	0.01 mg/L
Total Persulfate Nitrogen	SM 4500 NO3-B	20% RSD[2]	20% RPD[2]	0.025 mg/L
Orthophosphate	SM 4500-PG	20% RSD[2]	20% RPD[2]	0.003 mg/L
Total Phosphorous	SM 4500-PF	20% RSD[2]	20% RPD[2]	0.005 mg/L

[1] replicate results with a mean of less than or equal 20 cfu/100 mL will be evaluated separately.
[2] replicate results with a mean of less than or equal to 5X the reporting limit will be evaluated separately.
SM: Standard Methods for the Examination of Water and Wastewater, 21th Edition (APHA et al., 2005).
MPN: most probable number relative.
MF: membrane filter.
RSD: standard deviation.
RPD: relative percent difference.

Data Management Procedures

Field measurement data will be entered into a notebook of waterproof paper and then carefully entered into EXCEL® spreadsheets (Microsoft, 2007). Data will be checked to ensure transfer accuracy. This database will be used for preliminary analyses and Quality Assurance/Quality Control (QA/QC). Data will be uploaded into Ecology's Environmental Information Management (EIM) System after verification and validation.

Sample results received from MEL by Ecology's Laboratory Information Management System (LIMS) will be loaded into EIM, exported, and added to a cumulative spreadsheet for laboratory results. This spreadsheet will be used to informally review and analyze data during the course of the project. Final data statistical analysis will be done using WQHydro (Aroner, 2003), SPSS (Arbuckle, 2005), or statistical roll back software (Ott, 1995).

An EIM user study (JKAR0002) has been created for this TMDL study and all monitoring data will be available via the internet. The web address for this geospatial database is: www.ecy.wa.gov/eim/. All finalized data will be uploaded to EIM by the EIM data engineer.

All spreadsheet files, paper field notes, and Geographic Information System (GIS) products created as part of the data analysis will be kept with the project data files. Data that do not meet acceptability requirements will be separated from data files and not used for analysis.

Audits and Reports

The project manager is responsible for verifying data completeness. The project manager is also responsible for writing the final technical report to the Water Quality Program watershed lead. The final technical report will undergo the peer review process by staff with appropriate expertise.

The final report will include analyses of results that form the basis of conclusions and recommendations. Results will include site-specific information of FC concentrations and loading, stormwater characteristics, water quality parameters, stream/drainage discharge measurements, and seasonal summaries.

Data Verification

Data verification

Laboratory data will be verified by MEL. Laboratory-generated data reduction, review, and reporting will follow the procedures outlined in the MEL Users Manual (MEL, 2008). Lab results will be checked for missing or improbable data. Variability in lab duplicates will be quantified using the procedures outlined in the MEL Users Manual (MEL, 2008). Any estimated results will be qualified and their use restricted appropriately. A standard case narrative of laboratory QA/QC results will be sent to the project manager for each set of samples.

Field data will be verified by the project manager. Field notebooks will be checked for missing or improbable measurements before leaving each site. Data entry will be checked against the field notebook data for errors and omissions.

As soon as FC data are verified by MEL, the laboratory microbiologist will notify the project manager by e-mail or by phone of FC results greater than 200 cfu/100 mL in freshwater, and results greater than 43 cfu/100 mL in marine water. The project manager will then notify the Northwest Regional Office Water Quality Program client, supervisor, and section manager by e-mail of these elevated counts in accordance with EA Program Policy 1-03. Water Quality Program personnel will notify local authorities or permit managers as appropriate. This notification process typically happens within a week of sample collection.

Data validation

Once field data are entered into EXCEL® (Microsoft, 2007), it will be checked for errors against field notebooks and corrections will be made as needed. Once data have been vetted (QA/QC) they will be ready for analytical use, report writing, and loaded into EIM. *Hydrolab®* post field calibration results will be compared to quality objectives in Table 7 and qualified accordingly.

Data received from MEL through the Laboratory Information Management System (LIMS) will be checked for omissions against the Laboratory Analysis Request forms by the project manager. Data can be in EXCEL® spreadsheets (Microsoft, 2007) or downloaded tables from EIM. Field replicate sample results will be compared to MQOs in Table 8. Data requiring additional qualifiers will be reviewed by the project manager. After data validity and data entry tasks are complete, it will be considered final and relevant data uploaded into the EIM system. EIM data will be independently reviewed by another Environmental Assessment Program employee for errors at an initial 10% frequency. If significant entry errors are discovered, a more intensive review will be undertaken.

Data Quality (Usability) Assessment

The project manager will verify that all measurement and data quality objectives have been met for each monitoring station. If the objectives have not been met (such as percent RSD for FC replicates exceeds the MQO or a *Hydrolab®* was recording bad data), then consideration will be taken to qualify the data, how to use it in analysis, or whether it should be rejected. Documentation of the data quality and decisions on data usability will provide accuracy and transparency of the QA/QC procedures. FC reported as non-detects will not be used in the data quality assessment process; for example, a percent RSD value will not be calculated for a replicate pair with 2 non-detect values. The data quality assessment methods and results will be documented in individual project data files and summarized in the final technical report.

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Appendix. Glossary, Acronyms, and Abbreviations

Glossary

Baseflow: The component of total streamflow that originates from direct groundwater discharges to a stream.

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

Conductivity: A measure of water's ability to conduct an electrical current. Conductivity is related to the concentration and charge of dissolved ions in water.

Dissolved oxygen (DO): A measure of the amount of oxygen dissolved in water.

Fecal coliform: That portion of the coliform group of bacteria which is present in intestinal tracts and feces of warm-blooded animals as detected by the product of acid or gas from lactose in a suitable culture medium within 24 hours at 44.5 plus or minus 0.2 degrees Celsius. Fecal coliform are "indicator" organisms that suggest the possible presence of disease-causing organisms. Concentrations are measured in colony forming units per 100 milliliters of water (cfu/100 mL).

Geometric mean: A mathematical expression of the central tendency (an average) of multiple sample values. A geometric mean, unlike an arithmetic mean, tends to dampen the effect of very high or low values, which might bias the mean if a straight average (arithmetic mean) were calculated. This is helpful when analyzing bacteria concentrations, because levels may vary anywhere from 10 to 10,000 fold over a given period. The calculation is performed by either: (1) taking the nth root of a product of n factors, or (2) taking the antilogarithm of the arithmetic mean of the logarithms of the individual values.

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

Nutrient: Substance such as carbon, nitrogen, and phosphorus used by organisms to live and grow. Too many nutrients in the water can promote algal blooms and rob the water of oxygen vital to aquatic organisms.

Parameter: A physical chemical or biological property whose values determine environmental characteristics or behavior.

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

pH A measure of the acidity or alkalinity of water. A low pH value (0 to 7) indicates that an acidic condition is present, while a high pH (7 to 14) indicates a basic or alkaline condition. A pH of 7 is considered to be neutral. Since the pH scale is logarithmic, a water sample with a pH of 8 is ten times more basic than one with a pH of 7.

Point source: Sources of pollution that discharge at a specific location from pipes, outfalls, and conveyance channels to a surface water. Examples of point source discharges include municipal wastewater treatment plants, municipal stormwater systems, industrial waste treatment facilities, and construction sites that clear more than 5 acres of land.

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

Stormwater: The portion of precipitation that does not naturally percolate into the ground or evaporate but instead runs off roads, pavement, and roofs during rainfall or snow melt. Stormwater can also come from hard or saturated grass surfaces such as lawns, pastures, playfields, and from gravel roads and parking lots.

Streamflow: Discharge of water in a surface stream (river or creek).

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

Total Maximum Daily Load (TMDL): A distribution of a substance in a waterbody designed to protect it from exceeding water quality standards. A TMDL is equal to the sum of all of the following: (1) individual wasteload allocations for point sources, (2) the load allocations for nonpoint sources, (3) the contribution of natural sources, and (4) a Margin of Safety to allow for uncertainty in the wasteload determination. A reserve for future growth is also generally provided.

Turbidity: A measure of water clarity. High levels of turbidity can have a negative impact on aquatic life.

Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

303(d) list: Section 303(d) of the federal Clean Water Act requires Washington State to periodically prepare a list of all surface waters in the state for which beneficial uses of the water – such as for drinking, recreation, aquatic habitat, and industrial use – are impaired by pollutants. These are water quality limited estuaries, lakes, and streams that fall short of state surface water quality standards and are not expected to improve within the next two years.

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

Acronyms and Abbreviations

cfu	colony forming unit
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
et al.	And others
FC	Fecal coliform bacteria
GIS	Geographic Information System software
MEL	Manchester Environmental Laboratory
MF	Membrane filter
MPN	Most probable number
MQO	Measurement quality objective
NSSP	National Shellfish Sanitation Program
QA	Quality assurance
RM	River mile
RPD	Relative percent difference
RSD	Relative standard deviation
SOP	Standard operating procedures
TMDL	(See Glossary above)
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WRIA	Water Resources Inventory Area
WWTP	Wastewater treatment plant

Units of Measurement

°C	degrees centigrade
cfs	cubic feet per second
cfu/mL	bacteria colony forming unit per milliliter
ft	feet
ft/s	feet per second
mg	milligram, a unit of mass
mg/L	milligrams per liter
mL	milliliter
uS/cm	microsiemens per centimeter, a unit of conductivity