North Chuckanut Bay Pollution Identification and Correction (PIC)
Water Quality Monitoring: Fecal Coliform
Quality Assurance Project Plan

Prepared by
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Whatcom County Public Works – Natural Resources
for
Whatcom County Marine Resources Committee
322 N. Commercial St.
Bellingham, WA 98273

June 2020

County: Whatcom
Grant No: SEANWS-2019-WhCoPW-00001

Purpose and Acknowledgements for Unified QAPP:

This Unified Quality Assurance Project Plan (QAPP) was visioned at a January 19, 2012 ad hoc meeting of local government and non-government organization representatives who sample and/or report on fecal coliform. The group's aim is to help alleviate confusion about the meaning of fecal coliform data, where different interpretations can be given to data which appear similar. These different interpretations stem from differences in sampling techniques, quality control procedures, reporting, and water quality standards.

The group decided that its first task was to start at the beginning of the process: the sampling, analysis, and quality assurance/quality control procedures for fecal coliform. This decision led to a series of meetings and development of a template for a QAPP to be used by local monitoring partners to guide individual QAPPs and to provide for consistency in sampling, analyzing, and quality control. The North Chuckanut Bay Pollution Identification and Correction QAPP was first developed in 2014. This QAPP is an update and revision of that document for Ecology approval.

Co-leads of the Unified QAPP work group:
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Assistance provided by RE Sources North Sound Baykeeper Interns, Ashley Westling and Keturah Witter.

Quality Assurance Project Plan

North Chuckanut Bay Pollution Identification and Correction

Water Quality Monitoring: Fecal Coliform

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Approved by:

This section should include key personnel involved in oversight of the project (e.g. project lead, organization manager, QAQC staff, grant coordinator, grant agency manager, etc.)

_____ Date: _____
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Marine Resources Committee Staff, Project Manager

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Natural Resources Manager

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Project Officer

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1.0 Abstract

The Whatcom County Marine Resources Committee works to demonstrate the value of the marine environment from the standpoint of human health and well-being. One of the targeted outcomes of the MRC is that marine water quality is healthy enough to sustain native marine species and habitats, and not threaten human health.

This QAPP provides a comprehensive and coordinated plan for water quality monitoring in the Chuckanut Watershed. It outlines a fecal monitoring program specific to North Chuckanut Bay using methods established through Whatcom County's routine fecal coliform monitoring program for watersheds that discharge to marine waters and shellfish growing areas.

The goal of this study is to characterize fecal coliform levels within the Chuckanut watershed and seasonal variation of those bacteria levels and to identify sources of pollutants to guide water quality improvement projects, attain water quality standards and protect beneficial uses (including recreational shellfish harvesting).

The routine sampling component of the North Chuckanut Bay fecal coliform monitoring program will use a fixed-network of sites sampled one or two times per month in each area of

the marine and freshwater. The geographic areas, watershed characteristics, sampling design and sampling methods are described in this document.

2.0 Project Management

This section describes project organization, individual roles, and timelines.

2.1 Distribution List

This section should include representatives of project partners.

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*Laboratory accredited for bacteria analysis identified for this project, under contract with Whatcom County Public Works for 2020

Whatcom County Marine Resources Committee Members

2.2 Project Organization

The following individuals are responsible for design and implementation of this project, and/or will be the primary data users and decision makers:

- **Gary Stoyka**, (360) 778-6218, Whatcom County Public Works (WCPW), Natural Resource Manager. Oversight of project management and implementation.
- **Austin Rose**, (360) 778-6286, Whatcom County Public Works, Planner I/Marine Resources Committee Staff. Project lead responsible for development and implementation of monitoring program, sample collection, and data entry, analysis and reporting. Responsibilities include quarterly and annual reports.
- **Whatcom County Public Works Field Staff**, (360) 778-6286. Field staff responsible for assisting with implementation of monitoring program, sample collection, and coordination of sampling schedule with volunteers and project partners.
- **Exact Scientific Services,** (360) 733-1205. Local lab (with Department of Ecology (DOE) accreditation for bacteria analysis identified for this project) responsible for laboratory analysis of routine water samples. This lab is currently under contract with WCPW for 2020 water quality analysis.

2.3 Project Schedule

This study will be conducted between November 2014 and September 2021. Table 1 describes the schedule for conducting project tasks. It is a guideline only as unforeseen circumstances and conditions may require adjustment to some or all of the following proposed dates.

Table 1. Timeline for the North Chuckanut Bay Water Quality Study**.**

Task	2014			2015				2016				2017			
Quarter	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Monitoring Plan			x					x				x			
Water Quality Sampling				x	x	x	x	x	x	x	x	x	x	x	x
Lab Analysis				x	x	x	x	x	x	x	x	x	x	x	x
Progress Reports				x	x	x	x	x	x	x	x	x	x	x	x
Draft and Final Report						x				x				x	

Task	2018				2019				2020				2021			
Quarter	1	2	3	1	2	3	4	4	1	2	3	4	1	2	3	4
Monitoring Plan	x			X					x							
Water Quality Sampling	x	X	X	X	x	x	X	X	x	X	X	X	X	x	x	
Lab Analysis	x	X	X	X	x	x	X	X	x	X	X	X	X	x	x	
Progress Reports	x	x	X	x	x	x	X	x	x	x	X	x	x	x	x	
Draft and Final Report			x			x					x				x	

3.0 Problem Definition/Background

This section provides project background, definition of the study area, beneficial uses, potential pollution sources, historic water quality data, and project goals and objectives.

3.1 Background

Shellfish - those both recreationally and commercially harvested - are a key marine resource for Whatcom County. Water quality degradation has been a concern for shellfish growing areas in Drayton Harbor, Birch Bay, Portage Bay, Lummi Bay and Chuckanut Bay. North Chuckanut Bay is a recreational shellfish harvesting area that supports many species of clams, including littlenecks, manila, butter, horse, and cockles. There have been concerns about bacteria levels in Chuckanut Bay for the past 20+ years. Initial water quality samples collected between 1989 and 1991 showed elevated bacteria levels at the sampling station closest to the shellfish harvesting area, just outside the railroad trestle. In 1994, the WA State Department of Health conducted a shoreline survey of Chuckanut Bay Park, and the resulting report recommended that the recreational shellfish harvesting area in the bay should be closed because of water quality and sewage disposal conditions (WSDOH 1994). However, the area has always been popular for recreational harvest despite the health advisory and shellfish closure.

Throughout 2008 and 2009, Department of Health began fecal coliform sampling at marine and freshwater sites inside the trestle over North Chuckanut Bay. These sites were chosen to augment freshwater sites already sampled on a monthly basis by the Whatcom Marine

Resources Committee. Fecal coliform levels were high in both freshwater and marine sites, especially during the spring and summer months. In July 2009, Department of Health decided to discontinue sampling until further improvements were made to suspected fecal coliform inputs to the bay.

The Whatcom Marine Resources Committee will continue work with the Whatcom County Health Department, Whatcom County Public Works Natural Resources, Washington Department of Health, citizen volunteers, and the local community to conduct more intensive sampling and community outreach, to a establish community-driven Pollution Identification and Correction (PIC) project in North Chuckanut Bay to restore the recreational shellfish area. Through this effort, the community will identify bacteria sources and implement water quality improvement projects to reduce bacteria levels. The water quality data collected from this study is part of a comprehensive water quality monitoring program administered by the County, and will be made available to the public and other interested parties. An annual report will summarize the bacterial water quality concerns within North Chuckanut Bay, outline the water quality monitoring program, characterize the current status of water quality at each monitoring station, and prioritize areas for water quality improvement projects.

3.1.1 Land Use or Study Area Characteristics

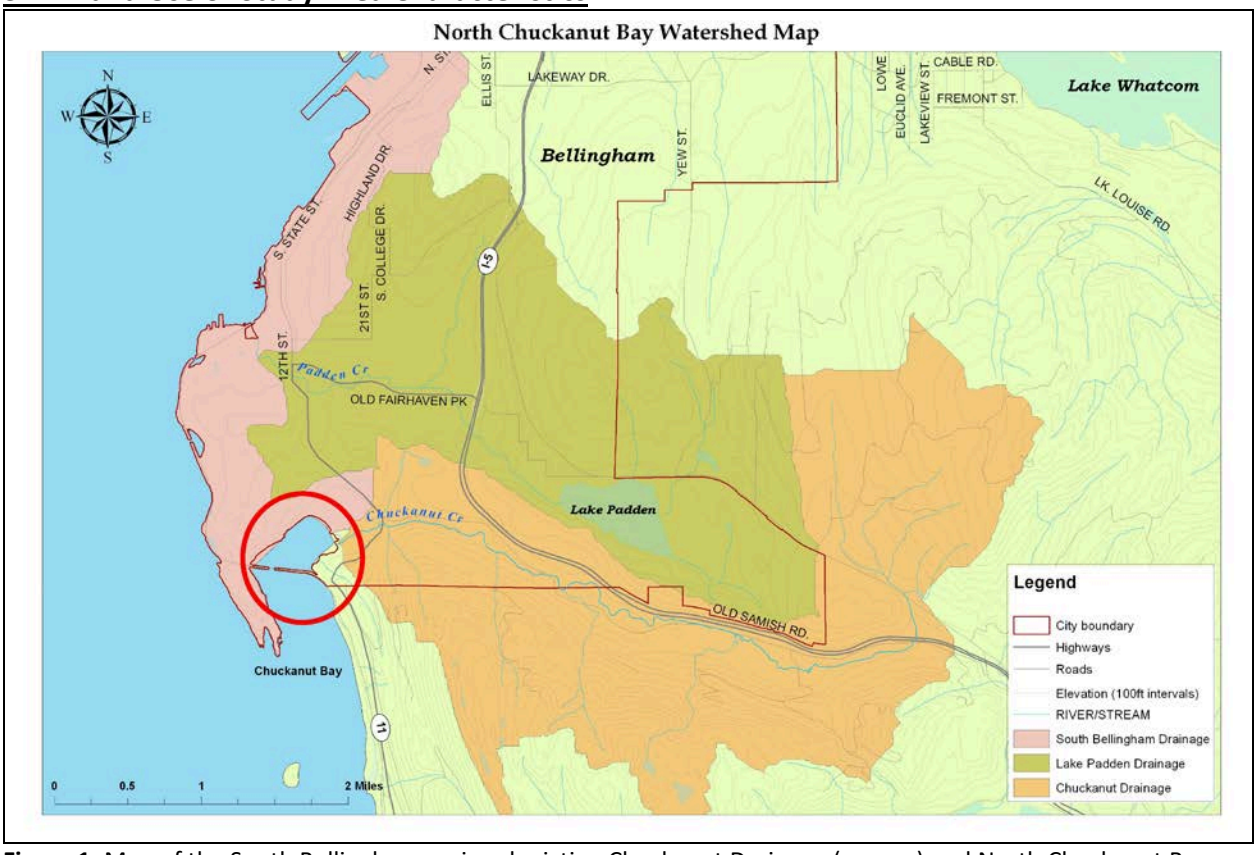

Figure 1. Map of the South Bellingham region depicting Chuckanut Drainage (orange) and North Chuckanut Bay (circled in red).

North Chuckanut Bay, often referred to as Mud Bay, is a small embayment in south Bellingham with a railroad trestle crossing the mouth and restricting tidal circulation. The primary freshwater discharge to this bay is Chuckanut Creek with a seven square mile watershed. There are also smaller drainages from the residential area on the northwest side of the bay and a seasonal creek that runs through the City of Bellingham Woodstock Farm. Land uses in the Chuckanut Creek watershed include a residential area (Chuckanut Village), a forested park with hiking and biking trails (Arroyo Park), and rural residential and forested areas in the upper watershed.

3.1.2 Beneficial Uses

Bacteria criteria are set to protect public health. Department of Ecology water quality standards use fecal coliform as an indicator bacteria. The presence of fecal coliform bacteria indicates the presence of fecal material from human or other warm-blooded animals in the waterbody (Mathieu and Sargeant 2008).

Department of Ecology water quality standards for each watershed are based upon beneficial uses, waterbody classifications, and water quality criteria. Overall, beneficial uses in Whatcom County coastal watersheds include:

- Water supply (domestic, industrial, agriculture, and stock watering)
- Fish, shellfish, and wildlife habitat (including salmonids)
- Recreation including primary contact, sport fishing, boating, and aesthetic

According to Department of Ecology water quality standards (WAC 173-201A) for aquatic life uses, marine waters in Drayton Harbor, Portage Bay, Lummi Island, Lummi Bay and Chuckanut Bay are identified as *Excellent Quality* and criteria are set to protect 1) salmonid and other fish migration, rearing, and spawning; 2) clam, oyster, and mussel rearing and spawning; and 3) crustaceans and other shellfish (crabs, shrimp, crayfish, and scallops) rearing and spawning. The Chuckanut watershed is classified as Primary Contact Recreation for bacteria criteria by the Washington State Department of Ecology.

In freshwater, the Primary Contact Recreation standards for fecal coliform are 1) a geometric mean of less than 100 cfu/100mL and 2) not more than 10% of the samples may exceed 200 cfu/100mL through December 31, 2020 when the state's freshwater bacteria standards for recreational use will transition to E. coli. In marine waters supporting shellfish growing areas, the standards for fecal coliform are 1) a geometric mean of 14 cfu/100mL and 2) an estimated 90^{th} percentile of less than 43 cfu/100mL. These standards were established to protect shellfish growing areas and will not change in 2021. This project is driven by improvement and protection of recreational shellfish harvesting and will continue to use fecal coliform targets at freshwater sites to track sources and water quality patterns in the watershed that may impact marine waters. The freshwater fecal coliform targets are 1) a geometric mean of 100cfu/100mL and 2) not more than 10% of samples may exceed 200 cfu/100mL. These targets align with long-term fecal bacteria datasets for Whatcom County coastal watersheds discharging to shellfish growing areas. Historically, meeting these freshwater targets has led to the water

quality improvements required to meet marine standards and reopen Whatcom County shellfish growing areas. Table 2 lists marine water quality standards and freshwater targets for fecal coliform bacteria in Whatcom County coastal watersheds that support shellfish growing areas.

Table 2. Water Quality Standards and Targets for Whatcom County coastal watersheds.

Marine Water Standards[1,2]	**Freshwater Targets**
Fecal Coliform Bacteria	Fecal Coliform Bacteria
• Geometric Mean- 14 MPN/ 100mL • 90th Percentile- 43 MPN/100mL	• Geometric Mean- 100cfu/ 100mL • Not more than 10% exceed 200 cfu/100mL

1- Washington State Department of Ecology (WAC173-201A)
2- National Shellfish Sanitation Program (https://www.fda.gov/food/federalstate-food-programs/national-shellfish-sanitation-program-nssp)

Table 3 summarizes how the 2018-2019 fecal coliform results at previously monitored sites in North Chuckanut Bay compare to the applicable state water quality standards for each watershed. The total number of sites, number of sites failing the standard, number of sites partially meeting the standard, and number of sites meeting the standard are summarized.

Table 3. Summary of North Chuckanut monitoring sites in comparison to fecal coliform targets from 2018-2019.

Watershed	**Number of Sites**	**Number of Sites Failing both parts of the Fecal Coliform standards**[a]	**Number of Sites Failing One part of the Fecal Coliform Standard**[b]	**Number of Sites Passing Both parts of the Fecal Coliform Standards**[c]
Chuckanut Coastal (freshwater)	7	0 (0%)	1 (14%)	6 (86%)
Chuckanut Coastal (marine)	5	1 (20%)	0 (0%)	4 (80%)

a- Indicates frequent elevated fecal coliform levels.
b- Indicates occasional elevated fecal coliform levels (or spikes).
c- Indicates consistently lower fecal coliform levels.

3.1.3 Potential Pollution Sources

The primary cause of pollution in Whatcom County's creeks and marine waters is nonpoint source pollution. Nonpoint source pollution is the term used to describe pollutants that come from many smaller sources, rather than a few large sources. This accumulation of pollutants often results from common activities in both urban and rural areas.

Although there are many types of water pollutants, Whatcom County focuses on fecal coliform bacteria as the primary indicator of surface water quality. Fecal coliform bacteria are found in the fecal matter of human and other warm-blooded animals. While most fecal coliform strains do not cause human illness, detection in a creek or bay does indicate that human and/or animal wastes and the associated harmful pathogens are polluting the water. Examples of pathogen-related illnesses are giardia, salmonella, viral gastroenteritis, hepatitis, and cholera. People are exposed to these pathogens through direct water contact, such as swimming, wading, or eating shellfish from waters with high bacteria levels.

The key potential sources of bacteria that have been identified in Whatcom County coastal drainages are (1) **animal waste** from agricultural operations, domestic pets, waterfowl, and urban wildlife, and (2) **human sewage** from failing on-site sewage systems (OSS), leaking sewers, or cross-connections.

3.1.4 Existing Water Quality Monitoring Data

A variety of water quality monitoring projects have been conducted in Whatcom County over the years providing characterizations of fecal coliform in freshwater systems, stormwater, and marine water. This section provides a brief overview of the freshwater monitoring that has been conducted in North Chuckanut Bay.

Whatcom County Marine Resources Committee - Coastal Drainages

In 2006, the Whatcom Marine Resources Committee began a volunteer water quality monitoring project at Drayton Harbor, Birch Bay, and Chuckanut Bay. Marine Resources Committee members, Whatcom County staff, and volunteers were trained to collect grab surface water samples for fecal coliform analysis and estimate stream flow by time of travel or catchment method. Sample collection and flow measurement occurred monthly during a low tide at up to four sites in Chuckanut Bay dependent on flow conditions. Fecal coliform bacteria were analyzed at a state Department of Ecology accredited lab and results were compared to water quality criteria to determine water quality status.

Table 4 provides a review of the water quality results for the period of August 2006 through October 2014, then January 2017 – December 2019. Sampling was inconsistent from November 2014 through December 2016, therefore not included in the table. The fecal coliform water quality standards include two parts – the geometric mean threshold and the 90th percentile estimate. Geometric means and the percent of samples exceeding the 90th percentile criteria were calculated and compared to applicable water quality standards for each watershed.

- A status of “meets both standards” indicates that the site met both parts of the standard.
- A status of “fails one standard” indicates that the one part of the standard was not met.
- A status of “fails both standards” indicates that the site did not meet either part of the standard.

Table 4. Comparison of Marine Resources Committee Data to Bacteria Criteria used in this study. "CB" represents freshwater. "CM" represents marine with GM 14MPN/100ml and Est. 90th percentile 43MPN/100ml.

	August 2006- October 2014				
Site	**N**	**Geometric Mean**	**% Exceeding 200FC/100mL**	90th Percentile- 43 FC/100mL *(marine)*	**Current Status**
Chuckanut Bay CB1	69	19.8	15.9		**Fails one standard**
CB2	87	25.2	5.7		**Meets both standards**
CB3	87	68.5	18.4		**Fails one standard**
CB4	78	49.7	12.8		**Fails one standard**
	January 2015 – December 2017				
Chuckanut Bay CB1	37	11.2	0		**Meets both standards**
CB2a	57	11.4	0		**Meets both standards**
CB3	58	14.6	0		**Meets both standards**
CB4	58	13.2	0		**Meets both standards**
CB5	35	16.0	0		**Meets both standards**
CB6	38	29.5	7.7		**Meets both standards**
CB7	37	48.0	21.4		**Fails one standard**
CM1	49	5.5		20.7	**Meets both standards**
CM2	46	31.2		398.2	**Fails both standards**
CM3	47	6.5		31.3	**Meets both standards**
CM4	49	4.6		17.8	**Meets both standards**
CM5	48	4.7		15.5	**Meets both standards**

	January 2016 - December 2018				
Site	**N**	**Geometric Mean**	**% Exceeding 200FC/100ml**	**90th Percentile- 43FC/100ml (marine)**	**Current Status**
Chuckanut Bay CB1	47	6.9	0		**Meets both standards**
CB2a	44	10.4	0		**Meets both standards**
CB3	45	15.1	6.3		**Meets both standards**
CB4	45	11.3	0		**Meets both standards**
CB5	30	15.0	0		**Meets both standards**
CB6	33	18.9	11.1		**Fails one standard**
CB7	25	9.2	8.3		**Meets both standards**
CM1	37	7.8		36.7	**Meets both standards**
CM2	34	30.4		283.7	**Fails both standards**
CM3	35	6.3		21.0	**Meets both standards**
CM4	37	5.4		21.7	**Meets both standards**
CM5	36	6.2		27.3	

		January 2017- December 2019				
Site		N	Geometric Mean	% Exceeding 200FC/100ml	90th Percentile-43FC/100ml (marine)	Current Status
Chuckanut Bay	CB1	57	12.7	0		Meets both standards
	CB2a	88	5.9	0		Meets both standards
	CB3	90	8.3	0		Meets both standards
	CB4	88	15.8	0		Meets both standards
	CB5	54	10.3	0		Meets both standards
	CB6	57	20.7	1.8		Fails one standard
	CB7	61	6.9	1.6		Meets both standards
	CM1	80	6.7		28.2	Meets both standards
	CM2	77	34.2		286.1	Fails both standards
	CM3	78	10.4		25.9	Meets both standards
	CM4	79	3.6		15.2	Meets both standards
	CM5	78	6.6		33.6	Meets both standards

4.0 Project Description

This QAPP provides the background information used in developing the plan for collection and analysis of water samples from the Chuckanut watershed. The basic field and analytical tasks required to achieve the objectives of this project are 1) collect grab samples of water from designated sites within this watershed and 2) analyze grab samples for the enumeration of fecal coliform. The quality assurance (QA) requirements described in this document are critical to the success of this project and are derived from EPA QA/R-5 EPA Requirements for Quality Assurance Project Plans (EPA 2001) and Washington State Department of Ecology Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies (https://fortress.wa.gov/ecy/publications/summarypages/0403030.html).

Table 5. Key Project Personnel

Name	Title	Contact Info	Responsibilities
Austin Rose	Marine Resources Committee Staff, Project Manager	arose@co.whatcom.wa.us 360-778-6286	Coordination of volunteers to assist with water quality sampling. Quality assurance of sampling protocols
Erika Douglas	Water Quality Program Manager	edouglas@co.whatcom.wa.us 360-778-6294	Coordination with Whatcom County Pollution Identification and

			Correction Program and Whatcom Clean Water Program.
Arati Kaza	Ecology Quality Assurance Officer	arati.kaza@ecy.wa.gov 360-407-6964	Reviews and approves the final QAPP.

4.1 Overview

This QAPP provides a comprehensive and coordinated plan for fecal bacteria monitoring in the Chuckanut Watershed. It outlines a monitoring program specific to North Chuckanut Bay using methods established through Whatcom County's routine fecal bacteria monitoring program for watersheds that discharge to marine waters and shellfish growing areas. Whatcom County Public Works (WCPW) coordinates regular monitoring of fecal coliform levels at approximately 90 sites in county watersheds that discharge to marine waters. The sampling conducted in the Chuckanut watershed is a subset of that sampling. Water samples are collected by WCPW staff and trained Marine Resources Committee (MRC) volunteers. Field teams are trained in sampling, storage, and lab delivery protocols. All samples are analyzed at laboratories accredited by DOE for the standard methods for fecal bacteria analysis as described in Section 6.3. Quality control steps are used to measure variability due to sampling methods and conditions. Results are compared against data quality objectives to measure precision of results. Sampling events are pre-scheduled, typically at least a month in advance, and provide data from a broad spectrum of environmental conditions throughout the year. Water quality data are used to prioritize drainages for pollution identification and control projects and to characterize general patterns in declining and improving water quality. The WCPW staff coordinates with County Health, County Planning and Development Services, Whatcom Conservation District, and State departments of Agriculture and Ecology to respond to drainages where elevated bacteria levels are consistently observed.

The routine sampling component of the North Chuckanut Bay fecal coliform monitoring program will use a fixed-network of sites sampled one or two times per month in each area. The specific number of sites and frequency of sampling runs are described below for each geographic area. Practical constraints, such as staff or consultant availability, weather conditions, stream flow, and safety concerns may limit the ability to collect the number of samples or at the sampling frequency described in the QAPP.

4.2 Objectives and Goals

The goal of this study is to characterize fecal coliform levels within the Chuckanut watershed and seasonal variation of those bacteria levels and to identify sources of pollutants to guide water quality improvement projects, attain water quality standards and protect beneficial uses (including recreational shellfish harvesting).

The primary objectives of this study are:

1) To identify fecal coliform concentrations in the Chuckanut watershed to use as a baseline.
2) To evaluate the effectiveness of water quality improvements projects as they are implemented in the watershed.
3) To monitor fecal coliform concentrations during the wet season in North Chuckanut Bay to better determine the relationship between freshwater and marine waters during this period.
4) To provide water quality data to the public and other interested parties.
5) To create community connections to water quality issues by using volunteer monitors.

4.3 Study Design

4.3.1 Sampling Component

The North Chuckanut Bay sampling for 2019-2020 will include twice per month sampling of 7 freshwater sites and 6 marine sites from October 2019 through September 2020. The same is expected for the 2020-2021 season. Monthly sampling will occur if twice per month is not possible due to weather, or field staff capacity. Sites (shown in Figure 2) were identified through review of historical monitoring programs, drainage areas, and land use types.

Figure 2. Map of proposed marine and freshwater sampling locations in North Chuckanut Bay

Grab samples will be collected and analyzed for fecal coliform bacteria. This monitoring plan includes sampling freshwater water quality, thus freshwater samples will be collected from the lower Chuckanut Creek sites during low tide to minimize tidal influence, unless it is too shallow to access by kayak. The intent is to be characterizing bacteria concentrations of the freshwater as it enters Northern Chuckanut Bay.

Data from the routine sampling will provide data sets to meet the following needs:

- Provide an estimate of annual and seasonal geometric mean and 90th percentile for fecal coliform and mean temperature. The schedule should provide at least 5 samples per site during the dry season (April through August) and at least 7 samples per site during the wet season (September through March).

Table 6. North Chuckanut Bay Routine Sampling Stations. "CB" represents freshwater. "CM" represents marine.

Site ID	Site Location	Lat / Long
CB1	Small Woodstock Farm creek at culvert below dam structure	122°29'.779"W 48°41'59.477"N
CB2a	Chuckanut Creek at Arroyo Park- near stream gage station	122°29'12.814"W 48°42'6.758"N
CB3	Chuckanut Creek 18th Street Alley Bridge	122°29'32.976"W 48°42'3.009"N
CB4	Mouth of Chuckanut Creek @ the end of the footpath from Woodstock	122°29'41.452"W 48°41'58.023"N
CB5	Culvert crossing at Chuckanut Dr.	122°29'15.573"W

		48°42'11.053"N
CB6	Small creek under bridge at the end of Fairhaven Ave.	122°29'45.893"W 48°42'8.411"N
CB7	Small outfall by trestle at NW corner of North Chuckanut Bay	122°30'25.547"W 48°41'54.625"N
CM1	Near center of bay within creek channel	122°29'56.511"W 48°41'59.49"N
CM2	Near mouth of Chuckanut Cr.	122°29'51.61"W 48°41'55.77"N
CM3	Just beyond bridge at the end of Fairhaven Ave	122°29'49.051"W 48°42'7.505"N
CM4	Near large boulders along North side	122°30'6.754"W 48°42'1.977"N
CM5	NW corner of bay near trestle	122°30'22.837"W 48°41'54.052"N
CM6	Approx. 100 ft. off shoreline in main channel of Chuckanut Creek	122° 29' 52.9188'' W 48° 42' 6.4872'' N

4.3.2 Sampling Coordination

Field measurements and sampling responsibilities will be shared by Whatcom County Public Works staff, and trained MRC volunteers. Prior to each sampling run, Whatcom County will prepare standard field data sheets (Appendix B), Chain of Custody forms (Appendix C), sample containers, coolers, and sampling equipment as necessary for the sampling groups. All samplers will be trained in the *Whatcom County Fecal Coliform Bacteria Sampling Standard Operating Procedures (SOP)* (Appendix D). All samples will be analyzed by a laboratory certified to do bacteria analysis in Ferndale, Washington. The quality control comparability section describes the steps that will be taken to ensure consistency between the sampling groups.

5.0 Procedures

This section describes field and laboratory procedures, and sample storage and delivery.

5.1 Field Procedures

Field sampling and measurements will follow Whatcom County Public Works-Natural Resources SOPs which adhere to Standard Methods (APHA et al. 2005) found in Appendix D. Grab samples will be collected directly into sterile bottles supplied by the laboratory. Sample parameters, methods, containers, volumes, preservation requirements, and holding times are listed in Table 7. One field duplicate will be collected in a side-by-side manner, per every “set” of samples to assess field sampling variability. A set equals 10 or fewer samples; thus 8 samples would be considered 1 set and 1 field duplicate would be collected, whereas 11 samples would be considered 2 sets and 2 field duplicates would be collected.

Water samples for laboratory analysis will be delivered to the lab within 6 hours of collection, and will be run for analysis within 8 hours of collection.

Prior to grab sample collection, bottles will be labeled with the site identification, date, and time of sample. Site identification, sampling time, field/lab replicates, and other field observation comments will be recorded on the field data sheet. Site numbers, date, and time sampled will be transcribed for each sample to the Chain of Custody form prior to submitting samples to the laboratory.

5.1.1 Grab Samples for Fecal Coliform

Sample collection for fecal coliform analysis will follow the WCPW *SOP for Direct Grab Sample Collection with Sample Bottle for Fecal Coliform (2020)*. Water samples for fecal coliform analysis should always be collected prior to other field measurements to minimize opportunities for sample contamination. Sampling methods may vary slightly due to different conditions encountered in the field. Samples should not be collected from stagnant water or eddies. If a sample is collected under low flow conditions (e.g. surface sample) the conditions should be noted. The following is general guidance for sample collection with more details provided in the SOP.

Extension Pole Method: This is the most common method used for sample collection with the exception of sampling low flow creeks or outfalls (where it is difficult to collect a sample without disturbing the sediment) or from a kayak for marine sampling. This method is typically used to reach a more representative or undisturbed sample location from the stream bank, or when sampling a lake or slow moving stream.

1. Label the bottle with sample site ID, date, and time of sample collection prior to collecting the sample.
2. Secure the sample bottle in the extension pole clamp.
3. Move to a well mixed location, such as the deepest part of the active channel or another location where a representative sample can be reached with the pole.
4. Remove the bottle cap avoiding contamination of the cap or inside of the bottle.
5. Position the bottle over the desired sampling location.
6. Ensure the bottle is on the upstream side of the sampling apparatus while sample is collected. Invert the bottle and in one quick motion submerge the mouth of the bottle into the water column to a depth of approximately six inches or mid-way between the surface and the bottom if the stream reach is shallow. Slowly move the bottle upstream with the bottle mouth tipped toward the surface until the bottle fills to the bottle shoulder. For lake sampling, slowly move the tipped bottle away from the bottle entry point until it fills. If the bottle is overfilled, immediately dump some water from the bottle *Note: In shallow surface water, ensure that the sample bottle does not touch or disturb the stream bed, potentially contaminating the sample. Submerge the sample bottle to approximately the midpoint of the water column and tip upwards toward the direction of the flow. Samples should be collected far enough below the surface to avoid contamination from surface film and detritus. If a surface sample is unavoidable, note*

this on the field data sheet. Replace the cap securely, avoiding contamination to the inside of the bottle or cap.

Hand Dip Method: This method is typically used to collect samples in shallower waterbodies within reach of the water surface (when standing in or near the stream or from a small boat).

1. Label the bottle with sample site ID, date, and time of sample collection prior to collecting the sample.
2. Move to a well mixed location, such as the deepest part of the active channel or another location where a representative sample may be collected. Do not contaminate the sample location by wading upstream of it or by collecting a sample from an area that had been waded. *Note: Use the Extension Pole Method if sampling from a lake.*
3. Hold the base of the sample bottle with one hand and remove the bottle cap. Invert the bottle (open end facing down), reach upstream, submerge the bottle into the water about 6 inches or mid-way between the surface and the bottom if the stream reach is shallow, and then tip the bottle mouth upstream and toward the water surface. Allow the bottle to fill to approximately the shoulder and take it out of the water. If the bottle is overfilled, immediately dump some water from the bottle. *Note: In shallow surface water, ensure that the sample bottle does not touch or disturb the stream bed, potentially contaminating the sample. Submerge the sample bottle to approximately the midpoint of the water column and tip upwards toward the direction of the flow. Samples should be collected far enough below the surface to avoid contamination from surface film and detritus. If a surface sample is unavoidable, note this on the field data sheet.*
4. Replace the cap securely, avoiding contamination to the inside of the bottle or cap.

Hand Collection from Pipe Method: This method is typically used to collect samples within reach of the end of a stormwater pipe. A sample of stormwater discharge should be taken as a single uninterrupted event (i.e., grabbed at one time) from a single stormwater outfall.

1. Label the bottle with sample site ID, date, and time of sample collection prior to collecting the sample
2. Move to the end of a stormwater pipe where there is moderate flow with turbulence, if possible, so the stormwater discharge will be well-mixed and representative. When sampling a stormwater system, samples should be sampled from the system discharge point first to ensure samples are not contaminated by upstream sampling.
3. Hold the base of the sample bottle with one hand and remove the bottle cap. Hold the bottle under the stormwater discharge with its opening positioned into the flow of water so that water enters directly into the bottle without flowing over the bottle or hands during sampling to prevent contaminating the sample.
4. Allow the bottle to fill to approximately the shoulder and take it out of the water. If the bottle is overfilled, immediately dump some water from the bottle. *Note: Ensure that the sample bottle does not touch the outfall pipe, potentially contaminating the sample.*
5. Replace the cap securely, avoiding contamination to the inside of the bottle or cap.

5.1.2 Field Measurements

Following collection of grab samples, temperature will be measured in situ using an alcohol thermometer or calibrated YSI meter, by dipping the thermometer or probe into the waterbody. Temperatures collected with alcohol thermometers are less precise and accurate than a calibrated YSI meter and provide a general comparison between sites on a particular sampling day. These results are not intended to be compared to water quality standards. In tidally influenced areas, salinity will be measured using a Vee Gee Scientific STX-3 handheld refractometer (with salinity scale, 0-100ppt, +/-1.0ppt accuracy, 1.0ppt resolution) or a Model 85 YSI meter (salinity measurement range of 0 - 80ppt with a 0.1ppt resolution and accuracy of +/-2% or +/-0.1ppt). Salinity measurements will be used as a bacteria source identification tool to determine whether bacteria is originating upstream or downstream of the sample site. Results will be recorded on the field sheet along with qualitative comments regarding site conditions and adjacent land use activities. Dissolved oxygen will be measured in marine waters using the Model 85 YSI described above. The dissolved oxygen range on this particular YSI is 0-20mg/L with a resolution of 0.01mg/L.

5.2 Sample Custody and Documentation

Water samples for fecal coliform will be placed on ice in a cooler immediately after collection. Samples will be delivered to the laboratory with a Chain of Custody form within 6 hours of sample collection. Samples will be analyzed by the laboratory within 8 hours of sample collection. Samples must be below 10^{o}C for fecal coliform when submitted to the laboratory for samples to be accepted for analysis.

5.3 Laboratory Procedures

All water samples will be submitted to a local laboratory accredited by DOE for the bacteria analysis identified for this project. Freshwater samples will be analyzed for fecal coliform bacteria using the membrane filtration, standard method 9222D (APHA et al. 2005). Marine samples will be analyzed for fecal coliform bacteria using multiple tube fermentation, standard method 9221E. The analytical methods, preservation requirements, expected range of results, and detection limits are summarized in Table 7. Three dilutions of each sample are run to get a countable number on the plate between 20 and 60 colonies. Colonies that are atypical should be verified, or noted in some way by the laboratory.

As part of laboratory quality control, lab blanks of sterile diluent will be analyzed at the start of every sample run, every 10 samples, and at the end of the sample run. Lab blank analysis should show no colonies after incubation. Laboratory duplicates will be analyzed for every set of ten samples. Laboratory duplicates analyze the precision of the lab analysis and help characterize the overall variability.

Table 7. Summary of analytical methods.

Parameter	Method	Lab Method	Sample Container	Preservation	Holding Time
Fecal	Membrane	SM	125 or	10 °C, dark	8 hrs (deliver to

coliform bacteria (freshwater sites)	filtration method (MF)	9222D[1]	250mL sterile bottle		lab within 6 hrs)
Fecal coliform bacteria (marine sites)	Multiple tube fermentation method	SM 9221E[1]	125 or 250mL sterile bottle	10 °C, dark	8 hrs (deliver to lab within 6 hrs)

[1]APHA et al. 2005. Standard Methods for the Examination of Water and Wastewater, 21st Edition.

6.0 Data Quality Objectives

This section describes project objectives for bias and precision, reporting limits, and measurement quality objectives.

6.1 Bias and Precision

Systematic and random error in measurements due to bias and precision can be influenced by sample collection, handling and storage; contamination of equipment; natural variability in the parameters being measured; and normal variability in factors affecting measurement results (Lombard and Kirchmer 2001). Error due to bias will be minimized by following SOPs for sample collection and storage as described above and use of quality control procedures described in section 6.0. All field staff will receive training from lead field staff or project manager on SOPs to ensure consistent methods in sample collection, storage and handling. Bias will be evaluated in the analytical performance through use of positive and negative controls.

Precision will be assessed through the relative percent difference (RPD) of field duplicates and RPD of laboratory duplicates. One field replicate will be collected for each set of 10 samples during each sampling run (see section 4.1).

6.2 Reporting Limits

Table 8 describes the precision and reporting limits of the lab analysis for the parameters being measured in this project. Each of these elements falls within the range of expected results for this project based upon historical measurements.

6.3 Measurement Quality Objectives

To ensure quality and confidence in the data collected, the measurement quality objectives (MQO) described in Table 8 have been established for this project. The MQOs include both field and laboratory objectives where appropriate. Due to higher variability with low results in bacteria analysis, duplicate pairs for analysis of field precision (field replicates) should be separated into two groups: 1) pairs with a mean less than or equal to 20cfu/100mL and 2) pairs with a mean greater than 20cfu/100mL (Mathieu 2006). Fecal coliform results less than 20

cfu/100mL are well within the standard and would not result in follow up bacteria source tracking.

The project manager reviews field and laboratory replicates with preliminary data for follow up with lab and field staff if the RPD exceeds 100%. If a problem is found (e.g. suspected sample contamination, switched samples) that cannot be resolved, the samples will be flagged and noted in the database. These samples will not be used for analysis. Other samples from the concurrent sample run are reviewed in further detail; these samples are generally retained in the database and used for analysis if they meet this additional review. Field replicates with RPDs greater than 20% and 50% are flagged in the database. Laboratory replicates with RPDs greater than 40% are flagged in the database. The laboratory also reviews their laboratory duplicates in comparison with their Quality Control/ Quality Assurance Plan and objectives set for state accreditation. Project MQOs are reviewed on an annual basis.

Table 8. Objectives for data quality.

Analysis	Method	Field Duplicate MQO	Lab Duplicate MQO	Reporting Limits
Fecal coliform bacteria – membrane filtration (fresh water)	SM 9222D	50% of replicate pairs <20% RPD[1] and 90% of replicated pairs <50% RPD	40% RPD	2cfu/100mL
Fecal coliform bacteria- multiple tube fermentation (marine water)	SM 9221E	50% of replicate pairs <20% RPD and 90% of replicated pairs <50% RPD	40% RPD	1.8 MPN/100mL

[1] RPD- Relative percent difference

7.0 Quality Control

This section describes steps that will be taken to provide quality control in this project. Quality control provides confidence in sampling techniques, measurement results, and analysis of data.

7.1 Field Notes

Standard field data sheets will be used for each sampling run. The field sheets will provide sampling date, sampler names, weather and tidal conditions, sampling site identification, sampling site location, field measurements, and comments regarding water conditions and adjacent activities. Field staff cross-check field notes, bottle labels, and Chain of Custody forms prior to samples being submitted to the laboratory. Laboratory staff cross-check sample labels and Chain of Custody forms (site IDs and times) as samples are set up for analysis. Field data sheets will be stored in Whatcom County Public Works- Natural Resources project files (both paper and electronic forms).

7.2 Sample Identification

Prior to grab sample collection, bottles will be labeled with the site identification, date, and time of sample. Site identification, sampling time, field/lab replicates, and other field observation comments will be recorded on the field data sheet. Site numbers, date, and time sampled will be transcribed for each sample to the Chain of Custody form prior to submitting samples to the laboratory. Field staff will cross-check the number of samples with field data sheets and Chain of Custody forms prior to submitting samples to the lab.

7.3 Representative Sampling

The experimental design of this project is based upon a monthly sampling schedule over a two year period. The site location, monthly pre-determined schedule, and frequency of samples should provide representation of a full variety of spatial, temporal, and hydrologic differences encountered in the Chuckanut watershed. The experimental design is intended to capture both wet and dry season conditions, baseflow, and the most downstream location accessible for each of the major drainages. Freshwater samples will be collected at mid-stream locations or where there is adequate flow and mixing. Marine samples will be collected at sites selected with Washington State Department of Health to broadly characterize the shellfish growing area. For marine waters, 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." A minimum of thirty total marine samples are required for classification of shellfish growing areas by Washington State Department of Health using the National Shellfish Sanitation Program (USFDA 2017). The period of time covered by these thirty samples is determined by the sampling frequency. Coordinated marine and freshwater are needed to characterize freshwater impacts to marine waters and shellfish growing areas.

7.4 Field and Laboratory Replicates

Field replicates, or duplicate samples collected at the same site, provide a mechanism for evaluating variability of the individual results for each parameter. One field replicate will be collected, immediately following collection of the routine sample, for each set of 10 samples (see section 4.1). The site(s) at which the field duplicate is collected will be chosen randomly using a random number generator. All field duplicates will be submitted to the laboratory labeled as "Site ID- FD".

For every set of ten samples, one larger sample (typically 250ml) will be collected and submitted for lab duplicate analysis. Laboratory duplicates are run for 10% of samples (from 250ml bottle). Laboratory duplicates analyze the precision of the lab analysis and help characterize the overall variability. The precision of the lab duplicates will be measured against the MQOs presented in Section 5.3.

7.5 Comparability

Samples evaluated through this monitoring project will be collected by different sampling teams. All teams will use 2020 *WCPW SOP for Direct Grab Sample Collection with Sample Bottle*

for Fecal Coliform SOPs (see Procedures section above) for all sampling and measurements collected for the North Chuckanut Bay water quality monitoring project. Efforts will be made to sample all sites on the same day. All water samples will be analyzed by the lab selected for this project. Field training of SOPs will be provided to all field crew members as needed.

7.6 Completeness

The goal of the sampling strategy is to collect and analyze 100% of the scheduled samples at 100% of the sites for a complete data set. However, unforeseen circumstances can affect the ability to collect or analyze samples such as, but not limited to, low or high flow conditions, site access or other safety issues. This project aims to capture a minimum of five samples during the wet season and five samples during the dry season. Given the currently proposed sampling schedule, this should be an achievable goal.

8.0 Data Management Procedures

The field data sheets, Chain of Custody forms, and laboratory reports will be used to document and track sampling events and results. All of these forms will include sample site, sample date and time, and sampler's name. Field data sheets will also record weather conditions and notes regarding human and animal activity within the drainage. Field data sheets and copies of the Chain of Custody forms will be provided to Whatcom County Public Works within two days of a sampling event when samples are collected by MRC volunteers. Laboratory results and field data will be entered into an Excel spreadsheet by Whatcom County Public Works staff. Data will be uploaded to the WRIA1 Water Quality Monitoring Database (housed at Whatcom County Public Works- Natural Resources) on at least an annual basis. Field sheets or field notebooks, Chain of Custody forms, QC sample records, and laboratory reports will be stored on site at Whatcom County Public Works in project data files for a minimum of ten years in either a hardcopy or scanned format.

9.0 Reports

The project manager will be responsible for completing quarterly and an annual final report for the monitoring project. Quarterly reports will be provided to staff listed on the distribution list. Fact sheets summarizing the water quality monitoring project and results will be prepared or updated on a quarterly basis for community outreach efforts. The final report will include a quality control section which will include a description of any errors or corrective actions identified and the associated responses (by field or laboratory staff). Corrective actions include but are not limited to adding a field blank and checking incubator temperatures.

10.0 Data Review, Verification, and Validation

Preliminary laboratory results for fecal coliform are provided by the lab to the Whatcom County project manager (or other designated county staff), who reviews the results within two working days of the sampling run and compares to the project objectives. Sample results that exceed 1000 FC/mL will be reported to local and state partner agencies for potential follow up source tracking. Errors or corrective actions identified in any of these reviews will be reported to field or laboratory staff.

All data for this project will be reviewed and verified against the quality objectives described in section 4, *Data Quality Objectives* and *Quality Control*. Field staff, which include Whatcom County Staff in the water quality monitoring program, will review data sheets prior to leaving each sampling site for missing or unusual data. Field staff will cross-check data sheets, bottle labels, and Chain of Custody forms prior to submission to the laboratory. Lab results entered in Excel files will be considered and marked draft/preliminary until data review and verification has been completed by Public Works water quality staff.

Laboratory results will be reviewed by Public Works water quality staff and the project manager for missing or unusual data. If needed, laboratory staff will be contacted to verify reported results and/or estimated results. Data entry into spreadsheets will be double-checked with field sheets by Public Works water quality staff.

Laboratory blanks should equal zero. Laboratory blanks are run for every ten samples. If a blank result is not 0 cfu/100mL, the result is reported with a qualifier (CB – contaminated blank). If a blank is grossly contaminated (over 2 cfu/100 mL), Whatcom County Public Works staff will be contacted by the lab to discuss options. All samples are held in the fridge for 24 hours in case Whatcom County Public Works would like to re-analyze the sample with a qualifier out of holding time. That decision is made by Whatcom County Public Works staff. If a problem cannot be resolved or identified, the 10 samples associated with the blank will be flagged in the database and not included in the analysis. For each sample, the desirable range of countable colonies on a plate is 20 to 60 to determine fecal coliform concentrations. If no dilutions result in a plate with colonies in the desirable range, an estimate will be calculated and the result will be flagged.

Routine results will be compared with field replicates and lab duplicates to ensure the MQOs presented in Section 6.3 are met. Due to higher variability with low results in bacteria analysis, duplicate pairs for analysis of field precision should be separated into two groups: 1) pairs with a mean less than or equal to 20FC/100mL and 2) pairs with a mean greater than 20FC/100mL (Mathieu 2006). Results exceeding objectives will be noted in the Excel dataset, quarterly, and final reports and values of individual samples or entire sets of samples will be flagged as estimates (J), where MQOs are exceeded for field or lab duplicates, respectively. Until these data quality checks have been completed, data should be reported as preliminary.

11.0 Data Quality Assessment

The field staff and project manager will verify that data quality objectives have been met for each monitoring site. If objectives are not met, the project manager will determine results that will be estimated and qualified or rejected as described above. The data quality assessment will be included in the final report. Data that are rejected will be considered missing data in the completeness target.

12.0 References

APHA (American Public Health Association), AWWA (American Water Works Association) and WEF (Water Environment Federation) 2005. *Standard Methods for the Examination of Water and Wastewater*. 21st edition. Available at https://www.standardmethods.org/doi/book/10.2105/SMWW.2882.

DOE (Department of Ecology) 2001. *Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies*. Washington State Department of Ecology. Publication # 01-03-003.

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Lombard, S. and C. Kirchmer 2001. *Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies*. Washington State Department of Ecology, Environmental Assessment Program.

Mathieu, N. 2006. *Replicate Precision for 12 TMDL Studies and Recommendations for Precision Measurement Quality Objectives for Water Quality Parameters*. Washington State Department of Ecology. Publication # 06-03-044.

USFDA (United States Food and Drug Administration). 2017. *Guide for the Control of Molluscan Shellfish.* National Shellfish Sanitation Program. Available at https://www.fda.gov/media/117080/download

WAC (Washington Administrative Code) 173-201A. *Water Quality Standards for Surface Waters of the State of Washington.*

Washington State Department of Health (WSDOH). 1994. *Shoreline Survey of Chuckanut Bay Park (Whatcom County)*.

WCPW (Whatcom County Public Works- Natural Resources) 2020. *Standard Operating Procedures: Direct Grab Sample Collection with Sample Bottle for Fecal Coliform or Nutrient Analysis.*

Appendix A: Definitions

303(d) List[1]: 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.

Clean Water Act[1]: 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.

Extraordinary Primary Contact[1]: Waters providing extraordinary protection against waterborne disease or that serve as tributaries to extraordinary quality shellfish harvesting areas.

Fecal Coliform[1]: The portion of the coliform group of bacteria which is present in intestinal tracts and feces of warm-blooded animals as detected by the product of acid or gas from lactose in a suitable culture medium within 24 hours at 44.5 plus or minus 0.2 degrees Celsius. Fecal coliform bacteria are indicator organisms that suggest the possible presence of disease-causing organisms. Concentrations are measured in colony forming units per 100 mililiters of water (cfu/100mL).

Field Duplicate[1]: A generic term for two (or more) field samples taken at the same time in the same location. They are intended to represent the same population and are taken through all the steps of the analytical procedure in an identical manner and provide precision information for the data collection activity.

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.

> **Calculation: Multiply all of the data points, and take the n-th root of this product.**
> Example: Suppose you have data (Enterococci bacteria/100 mL sample) from different dates:
> 6 ent./100 ml, 50 ent./100 ml, 9 ent./100 ml, 1200 ent./100 ml
> Geometric Mean = 4th root of (6)(50)(9)(1200) = 4th root of 3,240,000
> Geometric Mean = **42.4 ent./100 ml**
> http://www.waterboards.ca.gov/water

In situ[2]: In place, the original location, in the natural environment.

Lab Duplicate[2]: Two or more representative positions taken from one homogeneous sample by the laboratory and analyzed in the same laboratory. Laboratory duplicate samples are quality control samples that are used to assess the intralaboratory preparatory and analytical precision.

Loading Capacity[1]: The greatest amount of a substance that a waterbody can receive and still meet water quality standards.

Nonpoint Source[1]: Pollution that enters any waters of the state from any dispersed land-based or water-based activities, including but not limited to atmospheric deposition, surface water runoff from agricultural lands, urban areas, or forest lands, subsurface or underground sources, or discharges from boats or marine vessels not otherwise regulated under the 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.

Point Source[1]: Sources of pollution that discharge at a specific location from pipes, outfalls, and conveyance channels to a surface water.

Pollution[1]: Such contamination, or other alteration of the physical, chemical or biological properties, of any water 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 create a nuisance or render such waters harmful, detrimental or injurious to (1) public health, safety or welfare, (2) domestic, commercial, industrial, agricultural, recreational or other legitimate beneficial uses, (3) livestock, wild animals, birds, fish or other aquatic life.

Primary Contact Recreation[1]: Activities where a person would have direct contact with water to the point of complete submergence including but not limited to, skin diving, swimming and water skiing.

Quality Assurance[2]: An integrated system of activities involving planning, quality control, quality assessment, reporting and quality improvement to ensure that a product or service meets defined standards of quality with a stated level of confidence.

Quality Control[2]: The overall system of technical activities whose purpose is to measure and control the quality of a product or service so that it meets the needs of users.

Relative Percent Difference[2]: A measure of precision in the lab used as a quantitative indicator of QA/QC for repeated measurements where the outcomes are expected to be the same. This calculation is used to compare two measurements to determine the precision of the technique

used; the lower the Relative Percent Difference, the more precise the results. This calculation can also measure accuracy when one of the results is the true value (such as the quality control lab results for a split sample or the actual concentration of a known or unknown sample).

RPD = $[X_1 - X_2\}/X_{ave}$ x 100 , where:
X_1 = concentration observed with the first detector or equipment;
X_2 = concentration observed with the second detector, equipment, or absolute value; and
X_{ave} = average concentration = ((X1 + X2) / 2)

Total Maximum Daily Load (TMDL)[1]: 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.

Watershed[1]: 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.

[1] www.ecy.wa.gov/biblio/0803105.html
[2] http://www.epa.gov

Appendix B: Field Sheets

Date: March 26, 2020

Project: North Chuckanut Bay Fecal Coliform Monitoring ***(MARINE SAMPLES)***

Purpose: Whatcom MRC North Chuckanut Bay PIC Program

Field Team: Cevan Schmitt

Weather/Tides: **high tide** 6:48am (8.12ft), **low tide** 1:10pm (1.68ft)

Collect one field duplicates (labeled FD) with each sampling run (randomly selected ahead of time).

(Refractometer) (Thermometer)

Site	Location	Time	Salinity	Temp (°C)	Observations/Comments[2]
CB7	Small outfall by trestle at NW corner of North Chuckanut Bay				*Freshwater site sampled with marine sites due to access*
CM5	NW corner of bay near trestle -122.507607 48.69817				
CM4	Near large boulders along North side -122.503333 48.700288				YSI Conductance: _____ D.O:_____%_____mg/L Salinity: _____ppt Temp _____**°C**
CM1	Near center of bay within creek channel -122.500366 48.699712				
CM2	Near mouth of Chuckanut Cr. -122.496357 48.699916				YSI Conductance: _____ D.O:_____%_____mg/L Salinity: _____ppt Temp _____**°C**
CM6	Approx. 100 ft. off shoreline in main channel of Chuckanut Creek. -122.498344				

	48.699155				
CM3	Just beyond bridge at the end of Fairhaven Ave -122.498033 48.701802				
Field duplicate taken at:					

[2]Describe: **flow** (dry, stagnant, low flow, moderate flow, high flow, or flooding), **clarity** (clear, cloudy, turbid), **color** (tannin, brown, yellow), **surface conditions** (bubbles, surface film, foam), **plants/algae**, **tidal activity, odors, unusual circumstances, surface sample** (if taken), and any other observations . Record notes on approximate number of adult and juvenile fish observed at site. Include fish type if known. Note pets, livestock or wildlife presence like raccoon prints, ducks/geese near sample site, etc.

Date: March 26, 2020

Project: North Chuckanut Bay Fecal Coliform Monitoring ***(FRESHWATER SAMPLES)***

Purpose: Whatcom MRC North Chuckanut Bay PIC Program

Field Team: Leah Robison

Weather/Tides: **high tide** 6:48am (8.12ft), **low tide** 1:10pm (1.68ft)

Collect one field duplicates (labeled FD) with each sampling run (randomly selected ahead of time).

Site	Location	Time	Flow[1]	Temp (°C)	Observations/Comments[2]
CB6	Small creek under bridge at the end of Fairhaven Ave. (parking area for the beach)				
CB3	Chuckanut Creek under 18th Street alley bridge in Chuckanut Village				
CB5	Culvert crossing under Chuckanut Drive (park in driveway off Chuckanut Dr.)				
CB2a	Chuckanut Creek at Arroyo Park				
CB4	Mouth of Chuckanut Creek halfway down footpath to Woodstock Farm				
CB1	Woodstock Farm creek at end of footpath - small culvert/ pipe below dam structure				
CBB	Field blank				
Field duplicate taken at:					

[1]Describe: **flow** (dry, stagnant, low flow, moderate flow, high flow, or flooding), **clarity** (clear, cloudy, turbid), **color** (tannin, brown, yellow), **surface conditions** (bubbles, surface film, foam), **plants/algae**, **tidal activity, odors, unusual circumstances, surface sample** (if taken), and any other observations

[2]Record notes on approximate number of adult and juvenile fish observed at site. Include fish type if known. Note pets, livestock or wildlife presence like raccoon prints, ducks/geese near sample site, etc.

[3]SMALL CRAFT ADVISORY? *Check box if no sampling* ☐

Appendix C: Chain of Custody

Exact Scientific Services, Inc.
1355 Pacifi
Suite 101
Ferndale, V
phone: 360-73
fax: 888-818-2
email: lab@ex

General Chain of Custody

Client Information:	
Company:	Whatcom County Public Works -Natural Resources
Address:	322 N. Commercial Street
	Suite 110
PO Number:	
Project Name:	Chuckanut Bay

Page __1__ of _1___

Contact Information:	
Contact Person:	Erika Douglas, Monette Boswell, Austin Rose
Phone:	Erika (360) 778-6294, Monette (360) 448-6233
Email:	edouglas@co.whatcom.wa.us, mboswell@co.whatcom.wa.us, arose@co.whatcom.wa.us

#	Sample Name / Description / Location / Lot	Sample Date	Sample Time	ESS Lab#	SM9222D MF Fecal Only	SM9221E MPN Fecal Only
1	CB6	2/27/2020			x	
2	CB6FD	2/27/2020			x	
3	CB3	2/27/2020			x	
4	CB5	2/27/2020			x	
5	CB2a	2/27/2020			x	
6	CB4	2/27/2020			x	
7	CB1	2/27/2020			x	
8	CB7	2/27/2020			x	
9	CM5	2/27/2020				x
10	CM4	2/27/2020				x
11	CM1	2/27/2020				x
12	CM1FD	2/27/2020				x

Appendix D: Standard Operating Procedure

Whatcom County

Public Works- Natural Resources
Updated May 4, 2020

STANDARD OPERATING PROCEDURE

DIRECT GRAB SAMPLE COLLECTION WITH SAMPLE BOTTLE FOR FECAL BACTERIA ANALYSIS

* Adapted from City of Portland (Oregon), Environmental Protection Agency, and Washington State Department of Ecology SOPs

1.0 Purpose and Scope

This document is the Whatcom County Public Works- Natural Resources Standard Operating Procedure (SOP) for collecting grab samples directly into sample bottles or containers for the purposes of surface water and/or stormwater sampling and analysis.

2.0 Scope and Applicability

The procedures described in this document pertain to the proper collection of grab samples for laboratory analysis of fecal bacteria and/or nutrients. Samples are intended to be collected from surface water and stormwater monitoring sites with direct access to the flow stream or sample medium. It is intended that this document pertain only to surface water and stormwater sampling sites that allow access to the entire flow stream and/or when sampling is done just beneath the water's surface (i.e. up to 12 inches beneath the water's surface). If the flow stream is well-mixed and the chemistry is relatively uniform, the methods described in this SOP are sufficient to represent the water body. The procedures in this SOP may be used to collect bacteria samples such as fecal coliform, E. coli, Enterococci, etc. Standard Methods contains analytical procedures for laboratory analysis.

3.0 Definitions

Fecal bacteria- Members of two bacteria groups, coliforms and fecal streptococci, are used as indicators of possible sewage contamination because the bacteria groups are commonly found in human and animal feces. Although generally not harmful themselves, coliforms and fecal streptococci indicate the possible presence of pathogenic (disease-causing) bacteria, viruses, and protozoans that also live in human and animal digestive systems (EPA https://archive.epa.gov/water/archive/web/html/vms511.html).

Fecal coliform- A group of bacteria that inhabit the intestinal tract of warm-blooded animals and remain viable in freshwater for a variable period of time. The presence of fecal coliform bacteria in surface water indicates fecal

contamination by a warm-blooded animal; harmful bacteria and viruses associated with fecal contamination may also be present.

4.0 Equipment and Materials

The following is a list of equipment for collecting surface water and stormwater grab samples.

- Sterile, plastic sample bottles (provided by lab)
- Extension sampler pole and/or bridge sampler and sampling ropes
- Cooler containing ice
- Field data sheet or field log book
- Chain of Custody form
- Site files detailing sampling locations, sample site information, site identification codes, and past site visits
- Orange safety vest for sites accessed from roadways
- Anti-bacterial hand sanitizer
- Personal Floatation Device (PFD) -for sites and/or situations where deemed necessary
- Latex gloves (recommended)

Figure 1. Example of sample bottles for fecal bacteria.

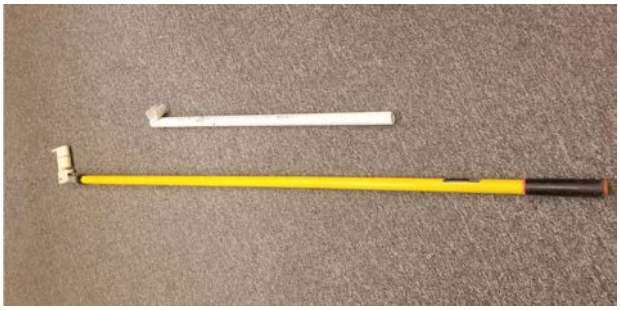

Figure 2. Example of extension poles used for sampling.

4.1 Sample Containers

The typical bacteria sample containers are 150mL or 250mL pre-autoclaved polypropylene bottles. Masking tape with black lines sealing the bottle lid indicates the bottle was autoclaved. Pre-autoclaved bottles should not be used if the tape is missing or black lines are not present. The laboratory may provide one-time use sterile plastic bottles. These bottles will have a label sealing the lid and should not be used if the seal has been broken.

When chlorine is suspected to be present in the sample water, bottles with sodium thiosulfate (thiosulfate) added should be requested from the laboratory. Thiosulfate will not affect samples if chlorine is not present.

5.0 Procedures

The following procedures relate to the direct collection of surface water and stormwater samples with the sample container itself.

5.1 Field Preparation

1. Gather necessary field/sampling documentation and site-specific information.
2. Reference the project checklist and/or field file to determine appropriate number of sample bottles and assemble sampling/safety equipment.
3. Obtain sample bottles from the accredited [1]laboratory that will analyze the samples. Care should be used at all times to avoid contamination of the inside of the sample bottle or bottle cap. The sample needs to be placed in ice in a cooler as soon as possible after collection. *Note: Non-drinking water bacteria samples have a maximum holding time of 24 hours (APHA 2000).*
4. For bacteria analysis: If the range of bacteria concentration can be estimated before sampling, let the lab microbiologist know so that a set of dilutions that bracket the expected concentration range can be prepared.
5. Notify the laboratory in advance of sampling with the approximate number of samples, requested analysis, and time of delivery. *Bacteria analysis on Saturday and Sundays must be pre-approved by the laboratory.*

[1] Laboratories receive accreditation through the Washington State Department of Ecology for specific laboratory analysis. Ensure that the samples are delivered to a laboratory accredited to conduct the requested analysis according to prescribed methods.

5.2 General Sampling Techniques

Bacteria sampling requires careful attention to sampling methods to avoid contamination of the bottle and water sample and ensure a representative sample is collected. The following guidance should be consistently considered:

1. Avoid contamination of the inside of the bottle cap and mouth. These should not be touched by hands or any other surface that may have bacteria exposure.
2. The bottle should not be rinsed or have water poured from another container that is not sterilized.
3. Avoid disturbing the sediment from the stream bed, particularly in slow moving waters.
4. Avoid sample collection from the surface layer (top inch of water column), near the streambank, and from eddies and side channels. In shallow depths, make notes on field form if a surface sample is unavoidable.
5. Avoid sample collection from stagnant waters (generally less than 0.1 ft/s).
6. Collect samples from the active part of the stream where there is sufficient mixing to ensure the sample is representative.
7. If sample is collected from a motorized boat, collect upstream of the boat's engine to avoid hydrocarbon contamination.

5.3 Sample Collection

Extension Pole Method: This is the preferred sampling method typically used to reach a representative or undisturbed sample location from the stream bank or when sampling a lake or slow moving stream. The extension pole method will be used unless collecting a sample from a shallow streamflow, a bridged waterway that can't be accessed from the streambank, or from a kayak or similar low boat.

1. Label the bottle with sample site ID, date, and time of sample collection prior to collecting the sample.
2. Secure the sample bottle in the extension pole clamp. *Note: The type of clamp may vary by extension pole used. Ensure the sampling bottle is tightly secured.*
3. Move to a location where a representative sample can be reached with the pole.
4. Remove the bottle cap avoiding contamination of the cap or inside of the bottle.
5. Position the bottle over the desired sampling location.
6. Invert the bottle and in one quick motion submerge the mouth of the bottle into the water column to a depth of approximately six inches. Slowly move the bottle upstream with the bottle mouth tipped toward the surface until the bottle fills to the bottle shoulder. For lake or marine sampling, slowly move the tipped bottle away from the bottle entry point until it fills. If the bottle is overfilled, immediately dump some water from the bottle. *Note: In shallow surface water, ensure that the sample bottle does not touch or disturb the stream bed or substrate, potentially contaminating the sample. Submerge the sample bottle to approximately the midpoint of the water column and tip upwards toward the direction of the flow. Samples should be collected far enough below the surface to avoid contamination from surface film and detritus. If a surface sample is unavoidable, note this on the field data sheet.*
7. Replace the cap securely, avoiding contamination to the inside of the bottle or cap.

Hand Dip Method: This method is typically used to collect samples within reach of the water surface (when standing in or near the stream or from a small boat). Using this method in shallow water helps to ensure the streambed is not disturbed during sample collection.

1. Label the bottle with sample site ID, date, and time of sample collection prior to collecting the sample.
2. Move to a well mixed location, such as the deepest part of the active channel or another location where a representative sample may be collected. Do not contaminate the sample location by wading upstream of it. *Note: Use the Extension Pole Method if sampling from a lake shoreline or wide stream or river.*
3. Hold the base of the sample bottle with one hand and remove the bottle cap. Invert the bottle, reach upstream, and submerge the bottle into the water about 6 inches, and then tip the bottle mouth upstream and toward the water surface. Allow the bottle to fill to approximately the shoulder and take it out of the water. If the bottle is overfilled, immediately dump some water from the bottle. *Note: In shallow surface water, ensure that the sample bottle does not touch or disturb the stream bed or substrate, potentially contaminating the sample. Submerge the sample bottle to approximately the midpoint of the water column*

and tip upwards toward the direction of the flow. Samples should be collected far enough below the surface to avoid contamination from surface film and detritus. If a surface sample is unavoidable, note this on the field data sheet.

4. Replace the cap securely, avoiding contamination to the inside of the bottle or cap.

Hand Collection from Pipe Method: This method is typically used to collect samples within reach of the end of a stormwater pipe. A sample of stormwater discharge should be taken as a single uninterrupted event (i.e., grabbed at one time) from a single stormwater outfall.

1. Label the bottle with sample site ID, date, and time of sample collection prior to collecting the sample.
2. Move to the end of a stormwater pipe where there is moderate flow with turbulence, if possible, so the stormwater discharge will be well-mixed and representative. When sampling a stormwater system, samples should be sampled from the system discharge point first to ensure samples are not contaminated by upstream sampling.
3. Hold the base of the sample bottle with one hand and remove the bottle cap. Hold the bottle under the stormwater discharge with its opening positioned into the flow of water so that water enters directly into the bottle without flowing over the bottle or hands during sampling to prevent contaminating the sample.
4. Allow the bottle to fill to approximately the shoulder and take it out of the water. If the bottle is overfilled, immediately dump some water from the bottle. *Note: Ensure that the sample bottle does not touch the outfall pipe, potentially contaminating the sample.*
5. Replace the cap securely, avoiding contamination to the inside of the bottle or cap.

Bridge Sampling Method: This method is typically used to collect samples when standing on a bridge when an extension pole cannot reach the waterbody. *Note: This method is rarely used by Whatcom County Public Works.*

1. Label the bottle with sample site ID, date, and time of sample collection prior to collecting the sample.
2. Secure the sample bottle in the bridge sampler and attach the sampling rope.
3. Move to a location where a representative sample can be reached with the sampler.
4. Remove the bottle cap avoiding contamination of the cap or inside of the bottle. Hold the cap with your free hand or set the cap upside down on a surface to avoid contamination of the inside of the cap (e.g. road, bridge, or clipboard).
5. Position the bottle and sampler over the desired sampling location. Lower the sampler to the water surface and allow the bottom of the sampler to touch the water surface to remove any debris from the bottom of the bottle and sampler. Raise the sampler off the water surface to allow debris to wash downstream. *Note: Ensure debris is not dislodged from the bridge while lowering the sampler. This step is intended to prevent sample contamination from any debris attached*

to the sampler.

6. Without submerging the mouth of the bottle, lower the sampler into the water and allow the current to position the sampler so the bottle is on the upstream side. Rapidly lower the sampler so the mouth of the bottle to a depth of approximately 6 inches. The rapid motion is intended to minimize collection of the surface film. Allow the bottle to fill to approximately the shoulder and take it out of the water. If the bottle is overfilled, immediately dump some water from the bottle. *Note: In shallow surface water, ensure that the sampler does not touch or disturb the stream bed, potentially contaminating the sample. If a surface sample is unavoidable, note this on the field data sheet*.
7. Replace the cap securely, avoiding contamination to the inside of the bottle or cap.

5.4 Field Processing

1. Ensure the bottle label matches the desired sample site and includes the correct date and time.
2. Place the sample bottle in cooler.
3. Record the sample site ID, data, time of sample collection on the field data sheet and *Chain of Custody* (COC) form. Other notes on conditions of the sampling site, adjacent land activities, or sample collection method should be recorded on the field data sheet (e.g. surface sample).

6.0 Records Management

Field sheets, COC forms, and field/laboratory results will be stored in project files at Whatcom County Public Works- Natural Resources. Additionally, field sheets, COCs, and lab results will be scanned and stored on the Public Works-Natural Resources network drive. After approximately six years, the documents will be boxed and archived. Laboratory results will be reviewed and verified. Data will be entered into an Excel spreadsheet for the project and saved on the Whatcom County network.

7.0 Quality Control and Quality Assurance

QA/QC procedures will be addressed thoroughly on a project-by-project basis in the Quality Assurance Project Plan (QAPP) or monitoring plan. General QA/QC procedures will include field notes, sample identification, representative sampling, field duplicates, comparability, and completeness. Personnel collecting water samples will have received training on the sampling protocol from a lead field staff.

Public Works- Natural Resources staff will review sampling techniques, data entry processes, and discuss new challenges as needed or at least annually.

Table 1. Summary of typical analytical methods for fecal bacteria analysis.

Parameter	Description	Method	Sample Container	Preservation	Holding Time	Precision/ Quantification Limits
Fecal coliform bacteria (freshwater)	Membrane filtration (MF)	SM9222D[2]	125mL or 250mL, sterile	10°C, dark	8 hours, maximum 24 (delivered to lab w/i 6 hrs, 2 hrs until sample processed)	20% RPD[2] 2 cfu/100mL
Fecal coliform bacteria (marine)	Multiple tube fermentation method (MPN)	SM 9221E	125mL or 250mL, sterile	10°C, dark	8 hours, maximum 24 (delivered to lab w/i 6 hrs, 2 hrs until sample processed)	20% RPD[2] 2 cfu/100mL
E. coli bacteria (freshwater)	MF partition method following MF for fecal coliform	SM9222G	125mL or 250mL, sterile	10°C, dark	8 hours, maximum 24 (delivered to lab w/i 6 hrs, 2 hrs until sample processed)	20% RPD[2] 2 cfu/100mL

[1]APHA et al. 2005. Standard Methods for the Examination of Water and Wastewater, 21st Edition.
[2] RPD- Relative percent difference

Data quality control consists of three elements: 1) Sample collection, handling, and storage will be conducted in a manner consistent with the methods outlined in the SOP, 2) field quality control samples will be collected with each sampling run and 3) lab duplicates and blanks. The field duplicate is a replicated sample collected immediately after the routine sample at the same location. One field duplicate (field quality control sample) will be collected in a side-by-side manner, per every "set" of samples to assess field sampling variability. A set equals 10 or fewer samples; thus 8 samples would be considered 1 set and 1 field duplicate would be collected, whereas 11 samples would be considered 2 sets and 2 field duplicates would be collected. The site where the field duplicates are collected will be pre-determined before the sampling run using a random number table or generator. If there is not adequate flow to sample at the pre-determined site, the field duplicate will be sampled at the next site in the sampling run. Variability of field duplicates will be analyzed against pre-determined data quality objectives. Results exceeding objectives will be flagged and qualified or rejected.

8.0 Safety

- Field staff will typically work in a team of two and carry a cell phone. In some circumstances, field staff will collect samples independently. In this case, it is essential that a cell phone is carried.
- High-visibility safety vests will be worn, particularly when working from or near a roadway.
- Personal Floatation Devices (PFDs) will be used at sites or in situations where deemed necessary.

- Field staff should use caution when approaching sampling sites. Sites may have slippery or unstable conditions. If field staff have concerns regarding accessing a site safely due to environmental conditions, construction, or other factors, the sample collection for that site should be aborted. The reason for not collecting a sample should be noted on the field sheet. If the condition is permanent, the site may need to be relocated.
- Gloves should be worn or hands washed after sampling surface waters.

9.0 References

American Public Health Association (APHA). 2005. Standard Methods for the Examination of Water and Wastewater. 21st Edition.

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