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State of Washington

Quality Assurance Project Plan

Lower Salmon Creek Watershed Fecal Coliform Bacteria Monitoring

September 2014

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Publication Information

Each study conducted by the Washington State Department of Ecology (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. After completing the study, Ecology will post the final report of the study to the Internet.

This Quality Assurance Project Plan is available on Ecology's website at https://fortress.wa.gov/ecy/publications/SummaryPages/1410051.html

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Data for this project will be available on Ecology's Environmental Information Management (EIM) website at www.ecy.wa.gov/eim/index.htm. Search Study ID BEDI0022

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Fecal Coliform Bacteria Monitoring

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1.0 Title Page and Table of Contents

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2.0 Abstract

Fecal coliform (FC) bacteria criteria are set by Washington State Department of Ecology (Ecology) to protect people who work and play in and on the water from waterborne illnesses. The criteria for bacteria in Salmon Creek and its tributaries are set to protect primary contact recreation. A TMDL technical report published by Ecology in 1995 (Cusimano and Giglio) reflected that certain sites on the mainstem and its tributaries were exceeding the water quality standards. However, a recent effectiveness monitoring study by Ecology (Collyard, 2009), analyzed FC data from 2005-2007 that had been collected by Clark County at the same historic sites used for the TMDL. The evaluation of these data shows that FC concentrations in Salmon Creek and its tributaries have improved significantly since the 1995 TMDL study. However, only the upper most station in the watershed met the water quality criteria for FC.

A new monitoring project was conducted in 2007 and 2008 (Hoxeng, 2009) focusing on the lower tributaries to Salmon Creek. Many of the sites had little to no previous water quality data. Data from this focused study showed that none of the monitoring stations met the state water quality criteria for FC.

The project described in this Quality Assurance Project Plan (QAPP) will focus on the Salmon Creek watershed downstream of Brush Prairie. Ecology staff will sample select tributaries and mainstem Salmon Creek locations. The goal of this project is to identify sources of FC that may be resulting in non-attainment of the FC water quality criteria. This project will provide information to assist local jurisdictions in directing implementation efforts.

3.0 Background

The presence of fecal coliform (FC) bacteria is a concern because it indicates the presence of biological waste that can negatively impact human health. The Salmon Creek watershed in Clark County Washington has experienced bacterial water quality problems for decades.

In response to bacterial health concerns, the local jurisdictions and community have been working to clean up Salmon Creek and its tributaries. In particular, Clark County Environmental Services, Clark County Public Health, Clark Public Utilities, and Clark Conservation District have been diligent in their efforts in the watershed. Some of their activities have included water quality monitoring, infrastructure improvements, riparian restoration, and public outreach and education. Concentrations of fecal coliform bacteria have decreased in some areas, but problems still exist.

In particular, recent data point to the lower Salmon Creek tributaries as areas of concern (Hoxeng, 2009). This 2014/2015 Ecology project will be focusing on the watershed downstream of Brush Prairie. Ecology staff will sample select lower tributaries based primarily on Hoxeng's study as well as some mainstem Salmon Creek locations.

3.1 Study area and surroundings

The Salmon Creek watershed (Figure 1), located in Clark County in southwest Washington, drains an area of approximately 90 square miles immediately north of the city of Vancouver. Major tributaries of Salmon Creek include Rock Creek, Mud Creek, Morgan Creek, Woodin Creek (Weaver Creek), Mill Creek, Curtin Creek (Glenwood Creek), Cougar Creek, and Little Salmon Creek. Salmon Creek is also fed by several small streams. The basin comprises a significant portion of the Salmon-Washougal Water Resource Inventory Area (WRIA) 28. Salmon Creek originates on the slopes of Elkhorn Mountain (elevation = 2230 ft), in the Cascades, and flows approximately 26 river miles to its confluence with Lake River (elevation = ~10 ft) on the Columbia River flood plain.

Land use varies throughout the watershed, with commercial timberland and rural residences dominating the upper watershed and increasing urbanization moving downstream resulting in fairly developed commercial and residential areas in the lower watershed. Historical agriculture is rapidly converting to development and wetlands are largely drained (Clark County, 2010). The city of Battle Ground, north of the Salmon Creek mid-watershed, is the largest urban center. Some small communities are scattered throughout the mid and upper watershed. The majority of the lower watershed is within the City of Vancouver urban growth area. Rapid and diverse development within the basin has led to water quality degradation of Salmon Creek and its tributaries. Some of the problems include an increase in impervious surface, stormwater run-off, inadequate buffer vegetation, erosion, and sedimentation.

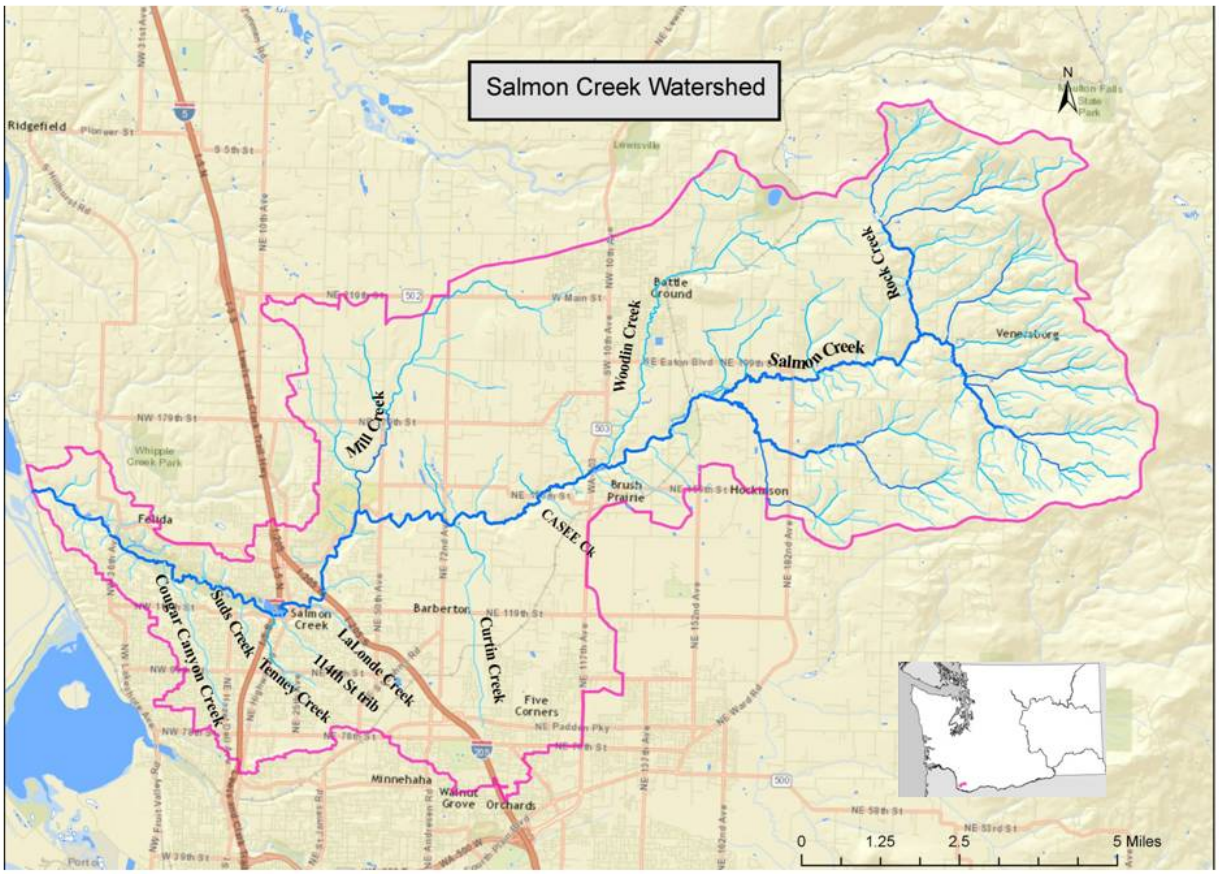

Figure 1. Overview of the Salmon Creek watershed.

The climate is dominated by the mild, wet maritime weather regime typical of lower elevation areas of western Washington. The air temperatures in Battle Ground reach an average daily high of 79°F (26°C) in July and August with the average daily low dropping to 31°F (-0.6°C) in January (Mathieu, 2013). The watershed receives an average of 58 inches of precipitation annually, over half of which falls from November through February.

The geology of the watershed is characterized by older consolidated bedrock that has been filled, particularly at lower elevations, by a series of younger sedimentary deposits (Mundorff, 1964). In general, the surficial geology consists of the older bedrock unit in the upper Salmon Creek watershed and an unconsolidated sedimentary aquifer in the lower watershed (Turney, 1990). Due to its productivity, the Troutdale gravel aquifer unit is the primary source of groundwater in Clark County. This unit begins in the mid to upper Salmon Creek watershed as the surface unit and is present throughout the rest of the watershed (down gradient), immediately beneath the unconsolidated sedimentary aquifer unit. During the late Pleistocene era, the Missoula floods deposited large quantities of sediments over the Troutdale Formation.

3.1.1 Logistical problems

The majority of the fixed-network sites are located in the public access corridor. Permission will be obtained from private landowners as needed. If permission is not granted this may hinder our ability to narrow down on possible source areas.

Unforeseen illness of personnel and scheduling conflicts, logistics with sample bottle delivery, vehicle problems or bad weather may interfere with sampling. Any circumstance that interferes with scheduled data collection and quality will be noted and discussed in the final report.

3.1.2 History of study area

Euro-Americans settled along Salmon Creek beginning in 1852. At that time most of the area was primarily covered by forest and wetland. The environment started to change as people continued to move into the area. Lands were cleared for homes and to support various business and agricultural uses. This growth then led to an increase in roads and parking lots with impervious surfaces. Increased development, agricultural operations, and forest practices all can contribute to impaired water quality when not managed effectively. Refer to Collyard, 2009, and Cusimano, 1995, for additional history information.

3.1.3 Contaminant of concern

Previous studies often monitored for parameters in addition to FC. However, FC bacteria is the only contaminate of concern for this water quality project. In Washington, surface water quality standards use FC as an "indicator bacteria" for the state's freshwaters (e.g. lakes and streams). The presence of FC indicates the presence of waste from humans or other warm-blooded animals. The water quality standards for bacteria are set to protect people who work and play in the water from waterborne illnesses, and to protect shellfish harvesting areas where present. The potential sources of FC are from stormwater runoff, pet waste, wildlife, leaking or failing septic systems, leaking sewer lines, and agricultural wastes.

3.1.4 Results of previous studies

In 1995, Ecology published the Salmon Creek Nonpoint Source Pollution TMDL technical report (Cusimano and Giglio, 1995). The TMDL targets were established by analyzing data collected by the Clark County Conservation District and the Clark County Department of Community Development during 1988-89 and 1991-1994. The report described that fecal coliform contamination was one of the most significant water quality problems in the Salmon Creek drainage. However, they also identified high turbidity, nutrients, temperature, and low dissolved oxygen in the watershed. Land-use and stream corridor disturbances were identified as the most likely cause. It was recommended that control measures be implemented followed by an effectiveness monitoring project. Percent reductions were identified for fecal coliform and turbidity concentrations in order to meet water quality criteria.

Since the TMDL study, many pollution reduction actions have been implemented. Some of these include decommissioning high-risk on-site sewage treatment systems, implementing

stricter regulations, identifying illicit discharges, installation of riparian fencing and plantings, and improving stormwater treatment. The effectiveness of the intervening implementation activities was investigated by Ecology and reported in 2009 (Collyard, 2009). In the Effectiveness Monitoring Project, Collyard used data collected by Clark County Environmental Services from 2005 through 2007 were used to compare to TMDL target limits and water quality criteria. Data were collected monthly at the same eight monitoring sites and were methods used for analysis were similar to those used in the TMDL. The evaluation showed that there was a significant improvement in fecal coliform concentrations in Salmon Creek and the tributaries. However, only the uppermost site met the water quality criteria. All of the sites met the TMDL target limits for turbidity. The cause for this improvement was said to be related to a combination of implementation activities and the loss of large- and small-scale agriculture or animal feeding operations (specifically dairies). Significant decreasing trends were found in nitrate-nitrogen and total phosphorus in many stations. Both dissolved oxygen and pH violated their respective water quality criteria.

Clark County Environmental Services conducted an additional assessment for fecal coliform and turbidity in the lower watershed. The project focused on six tributaries to Salmon Creek that had little to no water quality data (Hoxeng, 2009). Sampling was conducted bimonthly by Clark County staff and trained volunteers. The results from this water quality study were a driver for Ecology's proposed work. The results from Hoxeng's water quality analysis showed that the water quality criterion for fecal coliform was not met at any of the stations. In tributaries with multiple stations, there was an increase in FC concentrations from the upper stations to the lower stations. Seasonal differences were also found.

Turbidity often exceeded the water quality criterion. The turbidity levels were significantly higher during the wet weather when compared to dry weather. However, levels were not significantly different between dry weather in the dry season and dry weather during the wet season.

Recommendations were made for locating and removing sources of FC and turbidity to stormwater and surface water (for example, technical assistance; septic system inspections; education; BMP implementation; source control activities and continued monitoring in specific locations).

The most recent study conducted in the Salmon Creek Watershed by Ecology was in 2011-2012 (Mathieu, 2013). The study was designed to characterize dissolved oxygen (DO) and pH values in the watershed and investigate the influence of natural processes. The results lead to the recommendation to rank DO listings in the watershed as low priority. Mathieu expects that, though human-caused influences likely impact DO in the water bodies, the ongoing temperature and non-point TMDL will improve DO levels. The report also recommended removing 5 pH listings from the 303(d) list of impaired waters due to natural condition of low pH in the watershed during large winter storms.

Refer to Collyard, 2009, and Ecology's TMDL website (http://www.ecy.wa.gov/programs/wq/tmdl/SalmonCr/SalmonCr.html) for more information and additional links to water quality studies and implementation being done in the watershed.

3.1.5 Regulatory criteria or standards

Washington State water quality standards are based on the designated beneficial uses of a water body and the criteria to achieve those uses. For the Salmon Creek watershed, the designated beneficial uses are the aquatic life uses of *core summer salmonid habitat* and *salmonid spawning, rearing, and migration*. Other non-aquatic life uses include *water supply* (domestic; industrial; and agricultural); *stock watering*; *fish and shellfish harvesting*; *wildlife habitat*; *recreation* (primary contact recreation; sport fishing; boating; and aesthetic enjoyment); and *commerce and navigation*.

The water quality standard for FC in the Salmon Creek watershed is for *Primary Contact Recreation*. FC criteria are set to protect people who work and play in and on the water from waterborne illnesses. FC are used as an "indicator bacteria" for the state's freshwaters by assuming that the presence of FC in water indicates 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 in people.

The *Primary Contact designated* 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." (WAC 173-201A, 2011). The use is designated to any waters where human exposure is likely to include exposure of the eyes, ears, nose, and throat. Since children are 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] (Table 200 (2) (b)).

The upper limit statistic has been interpreted as a 90^{th} percentile value of the log-normalized values. This statistic will be also be used in this project specifically in the box-plot graphics.

Compliance is based on meeting both the geometric mean criterion and the 10% of samples (or single sample if less than ten total samples) limit. These two measures used in combination ensure that bacterial pollution in a water body will be maintained at levels that will not cause a greater risk to human health than intended.

Results of water samples collected randomly from one site and analyzed for bacteria typically follow a lognormal distribution, which is why the geometric mean is used for central tendency of the data set. The geometric mean is a mathematical expression of central tendency (average) of multiple sample values in a group of lognormal sample values.

While some discretion exists for selecting sample averaging periods, compliance will be evaluated for annual, monthly (if five or more samples exist) and seasonal data sets.

If FC concentrations in the water exceed the numeric criteria, human activities that would increase concentrations above the criteria need to be managed in order to allow waters to meet standards. The state, in collaboration with local governments, and watershed stakeholders, will work to ensure that human activities are conducted in a manner that will bring FC concentrations back into compliance with water quality standards.

4.0 Project Description

This project comes subsequent to many studies that have been undertaken to characterize and correct water quality problems in the area (see details in Section 3), specifically bacteria. Many of the watershed studies have focused on Salmon Creek and the larger tributaries. This project will focus on identifying and finding the sources of high FC bacteria in the lower Salmon Creek watershed, particularly in smaller tributaries

4.1 Project goals

The goal of this project is to identify sources of FC in the study area. This project will provide information on key areas to focus implementation efforts.

4.2 Project objectives

Objectives of the study are:

- Collect FC samples every two weeks at a fixed-network of stream locations.
- Investigate potential sources for elevated FC concentrations identified at the fixed-network locations by establishing a flexible intensive investigative sampling network.
- Compare the FC results to the Primary Contact Recreation criteria to determine whether waters are meeting standards.
- Provide high quality data to guide implementation efforts.

4.3 Information needed and sources

Information will be needed to assess options for closing in on potential bacteria sources, e.g. maps of roads, storm and sewer system. We will continue to talk with local jurisdictions for assistance in identifying potential sources in areas where high FC bacteria concentrations are identified.

4.4 Target population

The target population for this study is select surface water tributaries to the lower Salmon Creek watershed. Select mainstem sites will also be monitored.

4.5 Study boundaries

Water Resource Inventory Area (WRIA) and 8-digit Hydrologic Unit Code (HUC) numbers for the study area:

WRIA
- 28-Salmon/Washougal

HUC number
- 17080001

4.6 Tasks required

Not Applicable

4.7 Practical constraints

See section 3.1.1

4.8 Systematic planning process

The number of samples collected each event may vary depending on the number added for intensive sampling for source identification. Field staff will contact Manchester Environmental Laboratory's (MEL's) microbiologists Nancy Rosenbower (360-871-8827) *and* Edlin Limmer (360-871-8810) at the end of each event with the actual number of samples that will arrive at MEL the following day.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

Table 1. Organization of project staff and responsibilities.

Staff	Title	Responsibilities
Brett Raunig Water Cleanup and Technical Assistance Unit. WQP-SWRO-VFO Phone: 360-690-4660	Lower Columbia Water Quality Management Area TMDL Coordinator/ Client	Clarifies scope of the project. Provides review of the draft Quality Assurance Project Plan (QAPP) and approves the final QAPP. Assists with field sampling. Reviews and approves the technical report.
Betsy Dickes Water Cleanup and Technical Assistance Unit WQP-SWRO- Phone: 360-407-6296	Project Manager/Field Lead	Writes the QAPP. Conducts field sampling and arranges logistics for transportation of samples to the laboratory. Conducts quality assurance review of the data, analyzes and interprets data, and enters data into EIM. Writes the draft and final technical report.
Andrew Kolosseus WQP-SWRO- Phone: 360-407-7453	Unit Supervisor for the Project Manager	Reviews the project scope and budget, and tracks project progress. Provides review of the draft QAPP and approves the final QAPP. Reviews and approves the technical report.
Rich Doenges WQP-SWRO Phone: 360-407-6271	Section Manager for the Project Manager	Approves the budget. Reviews and approves the final QAPP. Reviews and approves the technical report.
Joel Bird MEL Phone: 360-871-8801	Director	Reviews and approves the draft and final QAPP.
Mike Herold Phone: 360-407-6434	WQP Quality Assurance Officer	Reviews and approves the draft and final QAPP.

WQP: Water Quality Program
SWRO: Southwest Regional Office
VFO: Vancouver Field Office
EIM: Environmental Information Management database

5.2 Special training and certifications

The Project Manager/Field Lead has over ten years of experience collecting bacteria samples and analyzing the data. All field staff working on the project will be aware of the Standard Operating Procedures (SOPs), (see Section 8.1) and will follow them.

5.3 Organization chart

See 5.1 Table 1.

5.4 Project schedule

Table 2. Proposed schedule for completing field and laboratory work, data entry into EIM, and reports.

Field and laboratory work	Due date	Lead staff
Field work completed	Sept 2015	Betsy Dickes
Laboratory analyses completed	Sept 2015	
Environmental Information System (EIM) database		
EIM Study ID	BEDI0022	
Product	Due date	Lead staff
EIM data loaded	December 2015	Betsy Dickes
EIM complete	January 2016	Betsy Dickes
Final report		
Author lead	Betsy Dickes	
Schedule		
Draft due to supervisor	May 2016	
Draft due to client/peer reviewer	July 2016	
Draft due to external reviewer(s)	August 2016	
Final (all reviews done) due to publications coordinator	October 2016	
Final report due on web	November 2016	

5.5 Limitations on schedule

See Section 3.11

5.6 Budget and funding

Table 3 summarizes the expected laboratory costs for the FC characterization at fixed sites and the flexible intensive source investigation sampling. MEL will perform all analyses using the membrane filtration (MF) method. The funding source for this project will be from the Water Quality Program's Natural Resource Transfer fund.

Table 3. Lab budget for the 2014/2015 study.

Parameter	Number of Samples/month	Number of QA (20%) Samples/month	Total Number of Samples/month	Cost Per Sample	MEL Subtotal/ 12 months
Fecal Coliform (MF) at Fixed Sites	34 (17x2)	8 (4x2)	42	24.93	12,564.72
FC-MF Source Investigation	34	8	42	24.93	12,564.72
			Total		25,129.44

6.0 Quality Objectives

6.1 Decision quality objectives (DQOs)

Not Applicable

6.2 Measurement quality objectives

Field sampling procedures and laboratory analyses inherently have associated uncertainty, which results in data variability. Measurement quality objectives (MQOs) state the acceptable data variability for a project. *Precision* and *bias* are data quality criteria used to indicate conformance with MQOs. The term *accuracy* refers to the combined effects of precision and bias (Lombard and Kirchmer, 2004).

Table 4. Measurement quality objectives.

Parameter	Method	Precision Field Replicates	Lab Duplicate MQO	Reporting Limits
Fecal Coliform – MF	SM 9222 D	50% of replicate pairs < 20% RSD 90 % of replicate pairs <50 % RSD	40% RPD	1 cfu/100 mL

Field sampling precision and bias will be measured by submitting replicate samples. MEL will assess precision and bias in the laboratory through the use of duplicates and blanks.

Table 4 outlines analytical methods, expected precision of sample duplicates, and method reporting limits. The targets for precision of field replicates are based on historical performance by MEL for environmental samples taken around the state by Ecology's Environmental Assessment Program (Mathieu, 2006). The reporting limits of the methods listed in the table are appropriate for the expected range of results and the required level of sensitivity to meet project objectives. The laboratory's MQOs and QC procedures are documented in the MEL *Lab Users Manual* (MEL, 2008).

6.2.1 Targets for precision, bias, and sensitivity

6.2.1.1 Precision

Precision is a measure of the 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 laboratory duplicate samples will be expressed as relative percent difference (RPD). Precision for field replicate samples will be expressed as the relative standard deviation (RSD) for the group of duplicate pairs.

6.2.1.2 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 QC procedures. Bias in field measurements and samples will be minimized by strictly following Ecology's measurement, sampling, and handling protocols. Field sampling precision bias will be addressed by submitting replicates. MEL will assess bias in the laboratory through the use of duplicates and blanks.

6.2.1.3 Sensitivity

Sensitivity is a measure of the capability of a method to detect a substance. It is commonly described as detection limit. In a regulatory sense, the method detection limit (MDL) is usually used to describe sensitivity.

6.2.2 Targets for comparability, representativeness, and completeness

6.2.2.1 Comparability

Studies in the watershed have analyzed water quality samples for FC bacteria using both MF and MPN. This project will have MEL analyze bacteria samples using the MF method as typical for Ecology's freshwater studies. We are confident that MPN and MF values are comparable for characterizing the conditions in a freshwater system (Joy, 2000 and Swanson, 2008).

Comparability to previously collected data will be established by strictly following EAP protocols and adhering to data quality criteria. Data collected in previous studies had QAPPs

and samples were analyzed in accredited laboratories. For specific information refer to the reports prepared by Cusimano and Giglio, 1995, and Collyard, 2009.

6.2.2.2 Representativeness

The study is designed to have enough sampling sites at sufficient sampling frequency to meet study objectives. Bacteria values are known to be highly variable over time and space. Sampling variability can be somewhat controlled by strictly following standard procedures and collecting QC samples, but natural spatial and temporal variability can contribute greatly to the overall variability in the bacteria value. Resources limit the number of samples that can be taken at one site spatially or over various intervals of time.

6.2.2.3 Completeness

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 the lower Salmon Creek study is to correctly collect and analyze 100% of the samples for each of the sites. However, problems occasionally arise during sample collection that cannot be controlled; thus, a completeness of 95% is acceptable. Example problems are flooding, site access problems, sample container shortages, or lack of water. If a completeness of less than expected occurs the Project Manager/Field Lead will review the causes for the short fall and determine the implications. The information will be included in the final report.

7.0 Sampling process design (experimental design)

7.1 Study design

The study objectives will be met through characterizing annual and seasonal FC bacteria concentrations and by increasing the intensity of sampling when high bacteria concentrations are identified.

FC concentrations will be monitored at multiple fixed locations within the study area from October 2014 through September 2015. The seasonal determination will follow that of the TMDL and effectiveness monitoring. The wet season will be defined as November through April and dry season as May through October.

There will be a fixed network of sites sampled twice monthly throughout the sampling period. Additional intensive investigative sampling will occur when high FC concentrations are identified. Investigative sampling will use a targeted or above/below sampling approach. Looking for sources via infrastructure and land-use maps will assist in narrowing in on actual sources.

It is expected that storm-events resulting in run-off conditions will be captured during the routine bi-monthly sampling events. If we seem to be missing run-off events, we will work with weather forecasts, our schedule, and MEL to see if we can characterize these events. We will also have to work within the budget.

Data from the fixed network will provide an estimate of the annual and seasonal geometric mean and 90th percentile statistics. The schedule should provide at least 24 samples per fixed site to develop the annual statistics, including 12 samples per site during the dry season and 12 samples per site during the wet season.

The proposed locations of the fixed-network water sites are listed in Table 5 and shown in Figure 2. Sites were selected based on historical site locations and associated high FC concentrations, desire to find sources, as well as access capability. Sites may be added or removed from the sampling plan due to field observations and preliminary data analysis.

7.1.1 Field measurements

Field measurements, for other water quality parameters and discharge, are not planned for this study.

7.1.2 Sampling location and frequency

The fixed-network monitoring stations are shown in Figure 2 and described in Table 5 for this project. The locations were chosen using the Hoxeng report (Hoxeng, 2009) as well as the ability to access the site and obtain a representative sample at locations. Additionally, the CASEE site (28-CAS-0.5, #17) was chosen at the request of the Clark County Conservation District due to high FC concentrations identified during student sampling events.

The fixed-network sites will be sampled routinely twice a month. The additional intensive investigative sampling sites will be sampled as determined by the ability to narrow in on the source or source area and professional judgment. The local jurisdictions will be consulted as well as maps and on-the-ground investigation. We will be looking for land-use activities, seeps, tributaries, pipes, culverts, etc. as part of the investigation efforts.

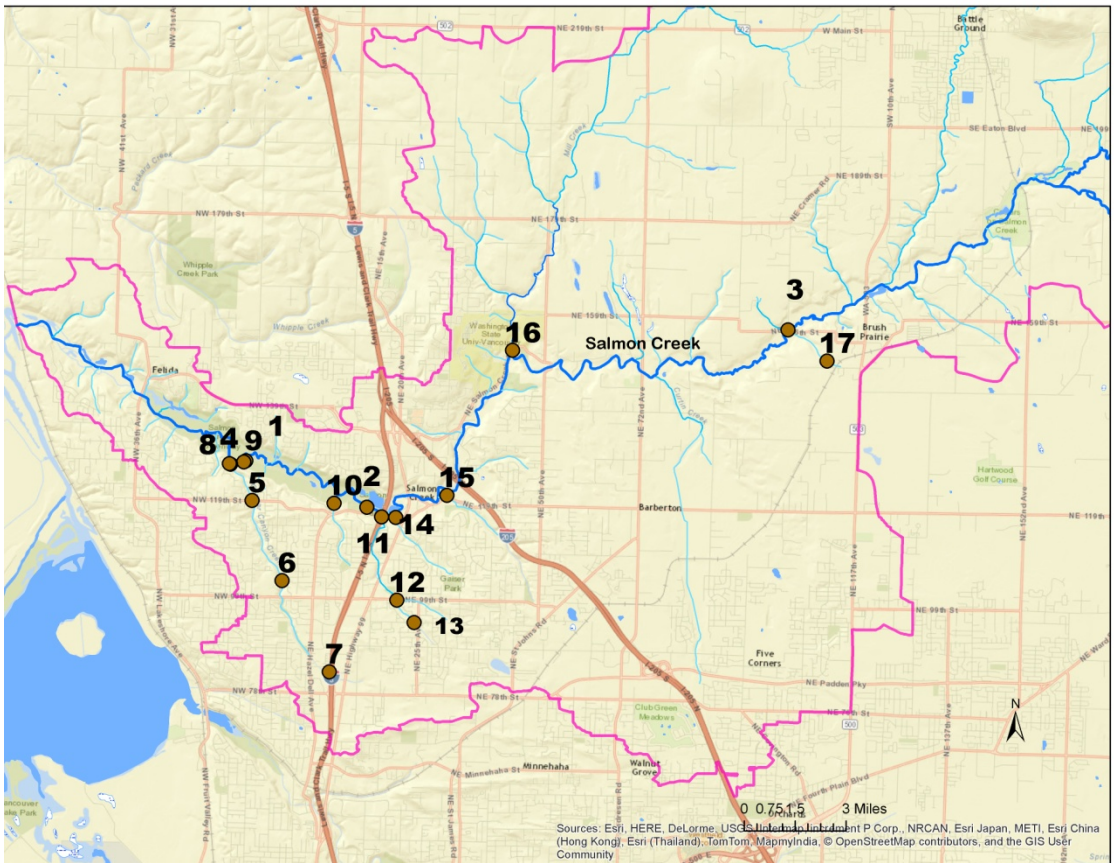

Figure 2. Fixed-network monitoring stations for this water quality project.

Table 5. Name and location of sites (Datum: NAD83 HARN).

Map ID#	EIM Location ID	Location name	Description (more detailed)	Latitude	Longitude
1	28-SAL-3.3	Salmon Ck U/S Cougar Ck mouth	LB of river, at trail mile marker 1 1/2	45.71319	-122.68465
2	SMN020	Salmon Ck at Kleinline Pond	Immediately D/S of foot bridge	45.70684	-122.65801
3	28-SAL-12	Salmon Ck at NE 156th St	NE 156th St and NE 102nd Ave D/S side of road bridge	45.73528	-122.56823
9	28-TSAL-0.01	Trib to Salmon Ck LB	Tributary D/S of trail mile marker 1 1/2	45.71284	-122.68479
4	28-COU-0.01	Cougar Ck near mouth	Above the foot bridge	45.71317	-122.68794
5	28-COU-0.5	Cougar Ck D/S of 119th St	D/S of 119th St road and culvert	45.70739	-122.68283
6	CGR050	Cougar Ck at NW 99th St	Cougar Creek at Columbia River High School D/S of fish weir	45.69542	-122.67589
7	28-COU-2.6	Cougar Ck near NE 81st St	Upper reach of Cougar Creek behind Safeway store area	45.68184	-122.66517
8	28-TCOU-0.01	Trib at Cougar Ck near mouth LB	U/S of the foot bridge	45.71319	-122.68797
10	SUD020	Suds Cr D/S of 117th Street	Suds Creek at Salmon Creek Sports Complex	45.70729	-122.6651
11	TEN010	Tenny Ck at 117 St	South side of road	45.70535	-122.65524
12	TEN065	Tenny Ck at 99th	Above Swan Pond Park; South of 99th off 21st	45.69295	-122.65099
13	28-TEN-1.5	Tenny Ck at 94th St	D/S of road	45.68961	-122.64716
14	28-FOR-0.1	114th St Trib near mouth	At 117th U/S of foot bridge	45.7054	-122.65173
15	28-LAL-0.1	LaLonde Ck near Mouth	NE Salmon Creek Ave U/S of bridge	45.70896	-122.64068
16	MIL010	Mill Ck at Salmon Ck Ave	U/S of bridge near mouth	45.73107	-122.62752
17	28-CAS-0.5	CASEE Ck	At CASEE U/S of road crossing on campus	45.73019	-122.55792

The field sampling schedule is provided below in Table 6. These dates have been pre-arranged with MEL. Some dates may change due to unforeseen circumstances, however, any change will have to be approved by MEL and occur only on a Sunday through Wednesday based on MEL's analytical schedule.

Table 6. Sampling event dates.

2014		
Month	Date	
Oct	8	22
Nov	5	19
Dec	3	17
2015		
Jan	7	21
Feb	4	18
Mar	4	18
April	1	15
May	13	27
June	10	24
July	8	22
Aug	5	19
Sept	2	16

7.2 Maps or diagram

See Figures 1 and 2.

7.3 Assumptions underlying design

The assumption underlying this study design is that sources of fecal coliform bacteria will be able to be located by intensive investigative sampling and conducting bracketed sampling. We are assuming that the elevated concentration will be consistent enough to be traceable and not so variable that sources cannot be found.

7.4 Relation to objectives and site characteristics

See Section 7.1

7.5 Characteristics of existing data

The data for most of these smaller tributaries is lacking. The investigative source tracking will provide important information for implementation activities to reduce bacteria in the watershed.

8.0 Sampling Procedures

8.1 Field measurement and field sampling SOPs

Freshwater samples will be collected using Ecology SOPs EAP030 for bacteria (Ward and Mathieu, 2011) and EAP015 grab sampling (Joy, 2013). These SOPs can be found at the Ecology's QA Website (Ecology, 2009). Twenty percent of FC samples will be replicated in the field in a sequential manner to assess field and laboratory variability. Samples will be collected in a well-mixed flowing portion of the water body. A sampling pole will be used as possible to prevent sediment disturbance, which will occur if we enter the creek. A fecal coliform bridge-sampler will be used to sample from the bridges.

8.2 Containers, preservation methods, holding times

Table 7 shows the sample containers, preservation, and holding times required to meet the goals and objectives of this project.

Table 7. Sample container, preservation, and holding time.

Parameter	Matrix	Minimum Quantity Required	Container	Preservation	Holding Time
Fecal Coliform - MF	Water	250 mL	250 mL poly autoclaved	Cool to ≤6°C	24 hours

8.3 Invasive species evaluation

The Salmon Creek Watershed area is in Ecology's Lower Columbia Area of Extreme Concern. This area was specifically identified due to the presence, and concern for the spreading of, the New Zealand mud snail. Ecology field staff will follow EAP's SOP070 on minimizing the spread of invasive species (Parsons et al., 2012). www.ecy.wa.gov/programs/eap/InvasiveSpecies/AIS-PublicVersion.html).

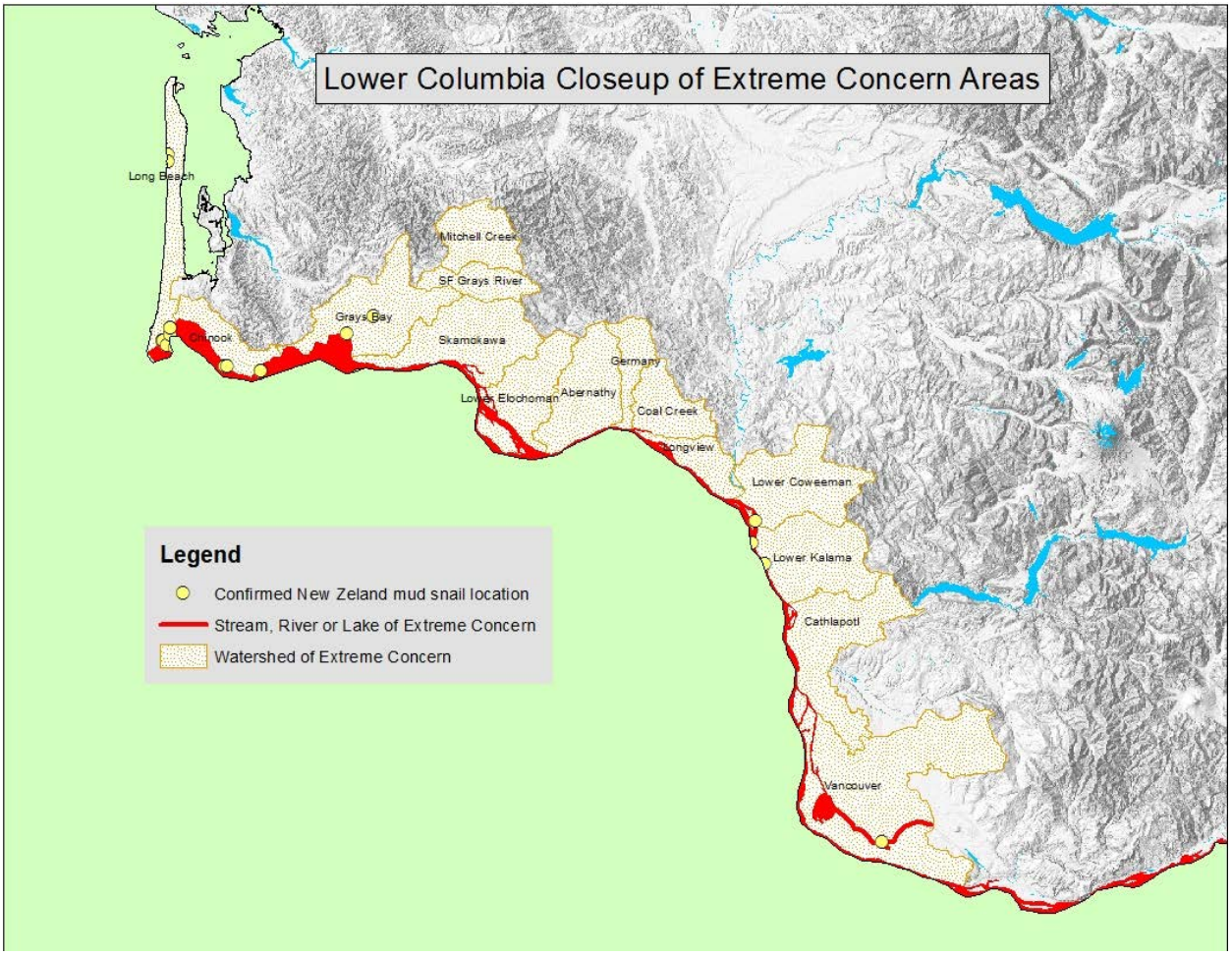

Figure 3. Lower Columbia area of extreme concern for the invasive New Zealand Mudsnail.

8.4 Equipment decontamination

Ecology field staff will follow EAP's SOP070 on minimizing the spread of invasive species (Parsons et al., 2012; www.ecy.wa.gov/programs/eap/InvasiveSpecies/AIS-PublicVersion.html). In particular, we will use a sampling pole and bridge sampler when possible to eliminate entry into the water. No felt soled boots will be used. Rubber boots and sampling equipment will be decontaminated with 3% hydrogen peroxide if there is contact with the creek sediment.

8.5 Sample ID

MEL will provide the field lead with work order numbers for all scheduled sampling dates. The work order number will be combined with a field ID number that is given by the project manager. This combination of work order number and field ID number constitute the sample ID. All sample IDs will be recorded in field logs and in an electronic spreadsheet with the associated permanent field location name for tracking purposes.

8.6 Chain-of-custody, if required

Water quality samples will be stored in coolers in the sampling vehicle. The vehicle will be locked when field personnel are not in the vehicle. Upon return to the Chain of Custody room at Ecology's Headquarters building, the chain-of-custody portion of the Laboratory Analysis Required sheet will be filled out; red sealing tape will be applied over the cooler opening; and the secured coolers will be placed in the walk-in cooler. The door to the Chain of Custody room is always locked and only approved personnel have access with an electronic identification entry card. The MEL courier will pick up the samples the following morning and deliver them to MEL while retaining chain of custody.

8.7 Field log requirements

A field log will be maintained by the project manager and used during each sampling event. The following information will be recorded during each visit to each site:

- Name of Project
- Field staff for that day
- Environmental conditions
- Location site name
- Date, Time, Sample ID, identity of QC samples
- Pertinent observations and/or any problems with sampling

8.8 Other activities

Field staff will read the relevant Ecology SOPs used for sampling and sampling protocol will be discussed at the beginning of the field season. Field staff that are intermittent recruits will be asked to read the SOP but will not take samples.

A schedule of sampling events has been prearranged with MEL. This allows the lab to plan for the arrival of samples. All samples will be collected on Wednesday and delivered to MEL on Thursday via the laboratory Courier. The lab will be notified immediately if there are any deviations from the scheduled date of sampling. The field lead will also coordinate with the Courier for timely sample container delivery.

9.0 Measurement Methods

9.1 Field procedures table/field analysis table

Not Applicable - there will be no field measurements

9.2 Lab procedures table.

Table 8. Measurement methods (laboratory).

Analyte	Sample Matrix	Expected # of Samples	Expected Range of Results	Method	Method Detection Limit
Fecal Coliform - MF	Water	1000	1-30,000 cfu/100 mL	SM 9222 D	1 cfu/100 mL

9.3 Sample preparation method(s)

There are no sample preparation methods for this study

9.4 Special method requirements

There are no special methods for this study.

9.5 Lab(s) accredited for method(s)

All chemical analysis will be performed at MEL, which is accredited for the FC-MF method to be used.

10.0 Quality Control (QC) Procedures

10.1 Table of field and lab QC required

Table 9. Quality control information for field and laboratory.

Parameter	Field		Laboratory			
	Blanks	Replicates	Check Standards	Method Blanks	Analytical Duplicates	Matrix Spikes
Fecal Coliform - MF	N/A	20%	N/A	1/batch	1/20 samples	N/A

10.2 Corrective action processes

QC results may indicate problems with data during the course of the project. The lab will follow prescribed procedures to resolve the problems. Options for corrective actions may include:

- Modifying the analytical procedures.
- Qualifying results
- Retrieving missing information.
- Re-analyzing samples within holding time requirements.
- Requesting collection of additional samples or taking of additional field measurements.

Corrective actions in the field may include:

- Increased staff training
- Modification of field procedures
- Specific comments provided to MEL staff regarding field conditions

11.0 Data Management Procedures

11.1 Data recording/reporting requirements

All field data will be recorded in a field notebook. Field notebooks will be checked for missing or improbable information before leaving each site. Missing or unusual data will be brought to the attention of the project manager.

Lab results will be checked for missing and/or improbable data. Data received from MEL through Ecology's Laboratory Information Management System (LIMS) will be checked for omissions against the "Request for Analysis" forms by the project manager. Data requiring additional qualifiers will be determined by the project manager.

Summary statistics for all data will be generated using MS Excel®. Data will be used to determine whether the data quality objectives and water quality criteria were met.

11.2 Laboratory data package requirements

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

11.3 Electronic transfer requirements

MEL has a protocol in place to provide all data electronically to the project manager through the LIMS to EIM data feed system.

11.4 Acceptance criteria for existing data

Not Applicable. No special criteria are necessary to assess the usability of existing data.

11.5 EIM/STORET data upload procedures

All FC data will be entered into EIM following all existing Ecology business rules and the EIM User's Manual for loading, data quality checks, and editing. Data from this project is not required to be uploaded to STORET.

12.0 Audits and Reports

12.1 Number, frequency, type, and schedule of audits

There is not a need for a formal audit for this study. However, field staff will monitor each other to maintain consistency with SOPs.

12.2 Responsible personnel

No formal audits will be performed.

12.3 Frequency and distribution of report

The project manager will inform the Lower Columbia Water Quality Management Area TMDL Coordinator of samples over 100 cfu/100mL upon receiving the data from MEL. The TMDL Coordinator will determine the appropriate local jurisdiction/s to notify.

12.4 Responsibility for reports

Betsy Dickes will be responsible for the final report.

13.0 Data Verification

13.1 Field data verification, requirements, and responsibilities

Not Applicable - there will not be any field data collected.

13.2 Lab data verification

MEL staff will perform the laboratory verification following standard laboratory practices. After the laboratory verification, a secondary verification of *each data* package will be performed by the project manager. This secondary verification will entail a detailed review of all parts of the laboratory data package with special attention being paid to laboratory QC results. If any issues are discovered, the project manager will take steps toward clarification/ resolution with appropriate MEL staff.

13.3 Validation requirements, if necessary

All laboratory data that have been verified by MEL staff will be validated by the project manager. After data entry and data validation tasks are completed, all data will be entered into the EIM system.

14.0 Data Quality (Usability) Assessment

14.1 Process for determining whether project objectives have been met

After all laboratory and field data are verified, a detailed examination of the data package using statistics and professional judgment will be performed, by the project manager, to determine if MQOs have been meet. The project manager will examine the entire data package to determine if all the criteria for MQOs, completeness, representativeness, and comparability have been met. If the criteria have not been met, the project manager will decide if affected data should be qualified or rejected based upon the criteria from the QA Project Plan. The project manager will decide how any qualified data will be used in the technical analysis.

14.2 Data analysis and presentation methods

Summary statistics for all data will be generated using MS Excel®. These summary statistics will be presented in tables.

14.3 Treatment of non-detects

Non-detects will be included in data analysis. The non-detect will be reported at the reporting limit and qualified as "U" in EIM.

14.4 Sampling design evaluation

If the project manager determines that the data package meets the MQOs, criteria for completeness, representativeness, and comparability then the sampling design will be considered effective.

14.5 Documentation of assessment

The project manager will include a section in the technical report summarizing the findings of the data quality assessment.

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16.0 Appendix A. Glossaries, Acronyms, and Abbreviations

Glossary of general terms

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

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

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

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.

Pollution: Contamination or other alteration of the physical, chemical, or biological properties of any waters of the state. This includes change in temperature, taste, color, turbidity, or odor of the waters. It also includes discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state. This definition assumes that these changes will, or are likely to, create a nuisance or render such waters harmful, detrimental, or injurious to

(1) public health, safety, or welfare, or (2) domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or (3) livestock, wild animals, birds, fish, or other aquatic life.

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

Reach: A specific portion or segment of a stream.

Riparian: Relating to the banks along a natural course of water.

Salmonid: Fish that belong to the family *Salmonidae*. Any species of salmon, trout, or char.

Sediment: Soil and organic matter that is covered with water (for example, river or lake bottom).

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 snowmelt. Stormwater can also come from hard or saturated grass surfaces such as lawns, pastures, playfields, and from gravel roads and parking lots.

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

Total Maximum Daily Load (TMDL): A distribution of a substance in a water body designed to protect it from not meeting (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, requiring 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: An estimated portion of a sample population based on a statistical determination of distribution characteristics. The 90th percentile value is a statistically derived estimate of the division between 90% of samples, which should be less than the value, and 10% of samples, which are expected to exceed the value.

Acronyms and abbreviations

Following are acronyms and abbreviations used frequently in this report.

BMP	Best management practice
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
MEL	Manchester Environmental Laboratory
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
WRIA	Water Resource Inventory Area

Units of Measurement

cfu	colony forming units
mL	milliliter

Quality assurance glossary

Accreditation: A certification process for laboratories, designed to evaluate and document a lab's ability to perform analytical methods and produce acceptable data. For Ecology, it is "Formal recognition by (Ecology)…that an environmental laboratory is capable of producing accurate analytical data." [WAC 173-50-040] (Kammin, 2010)

Accuracy: The degree to which a measured value agrees with the true value of the measured property. USEPA recommends that this term not be used, and that the terms precision and bias be used to convey the information associated with the term accuracy. (USGS, 1998)

Analyte: An element, ion, compound, or chemical moiety (pH, alkalinity) which is to be determined. The definition can be expanded to include organisms, e.g., fecal coliform, Klebsiella. (Kammin, 2010)

Bias: The difference between the population mean and the true value. Bias usually describes a systematic difference reproducible over time, and is characteristic of both the measurement system, and the analyte(s) being measured. Bias is a commonly used data quality indicator (DQI). (Kammin, 2010; Ecology, 2004)

Blank: A synthetic sample, free of the analyte(s) of interest. For example, in water analysis, pure water is used for the blank. In chemical analysis, a blank is used to estimate the analytical response to all factors other than the analyte in the sample. In general, blanks are used to assess possible contamination or inadvertent introduction of analyte during various stages of the sampling and analytical process. (USGS, 1998)

Calibration: The process of establishing the relationship between the response of a measurement system and the concentration of the parameter being measured. (Ecology, 2004)

Check standard: A substance or reference material obtained from a source independent from the source of the calibration standard; used to assess bias for an analytical method. This is an obsolete term, and its use is highly discouraged. See Calibration Verification Standards, Lab Control Samples (LCS), Certified Reference Materials (CRM), and/or spiked blanks. These are all check standards, but should be referred to by their actual designator, e.g., CRM, LCS. (Kammin, 2010; Ecology, 2004)

Comparability: The degree to which different methods, data sets, and/or decisions agree or can be represented as similar; a data quality indicator. (USEPA, 1997)

Completeness: The amount of valid data obtained from a project compared to the planned amount. Usually expressed as a percentage. A data quality indicator. (USEPA, 1997)

Continuing Calibration Verification Standard (CCV): A QC sample analyzed with samples to check for acceptable bias in the measurement system. The CCV is usually a midpoint calibration standard that is re-run at an established frequency during the course of an analytical run. (Kammin, 2010)

Control chart: A graphical representation of quality control results demonstrating the performance of an aspect of a measurement system. (Kammin, 2010; Ecology 2004)

Control limits: Statistical warning and action limits calculated based on control charts. Warning limits are generally set at +/- 2 standard deviations from the mean, action limits at +/- 3 standard deviations from the mean. (Kammin, 2010)

Data Integrity: A qualitative DQI that evaluates the extent to which a data set contains data that is misrepresented, falsified, or deliberately misleading. (Kammin, 2010)

Data Quality Indicators (DQI): Data Quality Indicators (DQIs) are commonly used measures of acceptability for environmental data. The principal DQIs are precision, bias, representativeness, comparability, completeness, sensitivity, and integrity. (USEPA, 2006)

Data Quality Objectives (DQO): Data Quality Objectives are qualitative and quantitative statements derived from systematic planning processes that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions. (USEPA, 2006)

Data set: A grouping of samples organized by date, time, analyte, etc. (Kammin, 2010)

Data validation: An analyte-specific and sample-specific process that extends the evaluation of data beyond data verification to determine the usability of a specific data set. It involves a detailed examination of the data package, using both professional judgment, and objective criteria, to determine whether the MQOs for precision, bias, and sensitivity have been met. It may also include an assessment of completeness, representativeness, comparability, and integrity, as these criteria relate to the usability of the data set. Ecology considers four key criteria to determine if data validation has actually occurred. These are:

- Use of raw or instrument data for evaluation.
- Use of third-party assessors.
- Data set is complex.
- Use of EPA Functional Guidelines or equivalent for review.

Examples of data types commonly validated would be:

- Gas Chromatography (GC).
- Gas Chromatography-Mass Spectrometry (GC-MS).
- Inductively Coupled Plasma (ICP).

The end result of a formal validation process is a determination of usability that assigns qualifiers to indicate usability status for every measurement result. These qualifiers include:

- No qualifier, data is usable for intended purposes.
- J (or a J variant), data is estimated, may be usable, may be biased high or low.
- REJ, data is rejected, cannot be used for intended purposes (Kammin, 2010; Ecology, 2004).

Data verification: Examination of a data set for errors or omissions, and assessment of the Data Quality Indicators related to that data set for compliance with acceptance criteria (MQOs). Verification is a detailed quality review of a data set. (Ecology, 2004)

Detection limit (limit of detection)**:** The concentration or amount of an analyte that can be determined to a specified level of certainty to be greater than zero. (Ecology, 2004)

Duplicate samples: Two samples taken from and representative of the same population, and carried through and steps of the sampling and analytical procedures in an identical manner. Duplicate samples are used to assess variability of all method activities including sampling and analysis. (USEPA, 1997)

Field blank: A blank used to obtain information on contamination introduced during sample collection, storage, and transport. (Ecology, 2004)

Initial Calibration Verification Standard (ICV): A QC sample prepared independently of calibration standards and analyzed along with the samples to check for acceptable bias in the measurement system. The ICV is analyzed prior to the analysis of any samples. (Kammin, 2010)

Laboratory Control Sample (LCS): A sample of known composition prepared using contaminant-free water or an inert solid that is spiked with analytes of interest at the midpoint of the calibration curve or at the level of concern. It is prepared and analyzed in the same batch of regular samples using the same sample preparation method, reagents, and analytical methods employed for regular samples. (USEPA, 1997)

Matrix spike: A QC sample prepared by adding a known amount of the target analyte(s) to an aliquot of a sample to check for bias due to interference or matrix effects. (Ecology, 2004)

Measurement QualityObjectives (MQOs)**:** Performance or acceptance criteria for individual data quality indicators, usually including precision, bias, sensitivity, completeness, comparability, and representativeness. (USEPA, 2006)

Measurement result: A value obtained by performing the procedure described in a method. (Ecology, 2004)

Method: A formalized group of procedures and techniques for performing an activity (e.g., sampling, chemical analysis, data analysis), systematically presented in the order in which they are to be executed. (EPA, 1997)

Method blank: A blank prepared to represent the sample matrix, prepared and analyzed with a batch of samples. A method blank will contain all reagents used in the preparation of a sample, and the same preparation process is used for the method blank and samples. (Ecology, 2004; Kammin, 2010)

Method Detection Limit (MDL): This definition for detection was first formally advanced in 40CFR 136, October 26, 1984 edition. MDL is defined there as the minimum concentration of

an analyte that, in a given matrix and with a specific method, has a 99% probability of being identified, and reported to be greater than zero. (Federal Register, October 26, 1984)

Percent Relative Standard Deviation (%RSD): A statistic used to evaluate precision in environmental analysis. It is determined in the following manner:

$$\%RSD = (100 * s)/x$$

where s is the sample standard deviation and x is the mean of results from more than two replicate samples (Kammin, 2010)

Parameter: A specified characteristic of a population or sample. Also, an analyte or grouping of analytes. Benzene and nitrate + nitrite are all "parameters." (Kammin, 2010; Ecology, 2004)

Population: The hypothetical set of all possible observations of the type being investigated. (Ecology, 2004)

Precision: The extent of random variability among replicate measurements of the same property; a data quality indicator. (USGS, 1998)

Quality Assurance (QA): A set of activities designed to establish and document the reliability and usability of measurement data. (Kammin, 2010)

Quality Assurance Project Plan (QAPP): A document that describes the objectives of a project, and the processes and activities necessary to develop data that will support those objectives. (Kammin, 2010; Ecology, 2004)

Quality Control (QC): The routine application of measurement and statistical procedures to assess the accuracy of measurement data. (Ecology, 2004)

Relative Percent Difference (RPD): RPD is commonly used to evaluate precision. The following formula is used:

$$[Abs(a-b)/((a + b)/2)] * 100$$

where "Abs()" is absolute value and a and b are results for the two replicate samples. RPD can be used only with 2 values. Percent Relative Standard Deviation is (%RSD) is used if there are results for more than 2 replicate samples (Ecology, 2004).

Replicate samples: Two or more samples taken from the environment at the same time and place, using the same protocols. Replicates are used to estimate the random variability of the material sampled. (USGS, 1998)

Representativeness: The degree to which a sample reflects the population from which it is taken; a data quality indicator. (USGS, 1998)

Sample (field): A portion of a population (environmental entity) that is measured and assumed to represent the entire population. (USGS, 1998)

Sample (statistical): A finite part or subset of a statistical population. (USEPA, 1997)

Sensitivity: In general, denotes the rate at which the analytical response (e.g., absorbance, volume, meter reading) varies with the concentration of the parameter being determined. In a specialized sense, it has the same meaning as the detection limit. (Ecology, 2004)

Spiked blank: A specified amount of reagent blank fortified with a known mass of the target analyte(s); usually used to assess the recovery efficiency of the method. (USEPA, 1997)

Spiked sample: A sample prepared by adding a known mass of target analyte(s) to a specified amount of matrix sample for which an independent estimate of target analyte(s) concentration is available. Spiked samples can be used to determine the effect of the matrix on a method's recovery efficiency. (USEPA, 1997)

Split sample: The term split sample denotes when a discrete sample is further subdivided into portions, usually duplicates. (Kammin, 2010)

Standard Operating Procedure (SOP): A document tha describes in detail a reproducible and repeatable organized activity. (Kammin, 2010)

Surrogate: For environmental chemistry, a surrogate is a substance with properties similar to those of the target analyte(s). Surrogates are unlikely to be native to environmental samples. They are added to environmental samples for quality control purposes, to track extraction efficiency and/or measure analyte recovery. Deuterated organic compounds are examples of surrogates commonly used in organic compound analysis. (Kammin, 2010)

Systematic planning: A step-wise process which develops a clear description of the goals and objectives of a project, and produces decisions on the type, quantity, and quality of data that will be needed to meet those goals and objectives. The DQO process is a specialized type of systematic planning. (USEPA, 2006)

References for QA glossary

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