DEPARTMENT OF ECOLOGY
State of Washington

Quality Assurance Project Plan

Lower Snohomish River Tributaries Fecal Coliform Bacteria Effectiveness Monitoring

May 2021

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Publication Information

Each study conducted by the Washington State Department of Ecology must have an approved Quality Assurance Project Plan (QAPP). 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.

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Federal Clean Water Act 1996 303(d) Listings Addressed in this Study. See Section 3.1.

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COVER PHOTO: Pilchuck River from the Old Snohomish Monroe Rd Bridge.
PHOTO BY NIAMH O'ROURKE, 2020.

Quality Assurance Project Plan

Lower Snohomish River Tributaries Fecal Coliform Bacteria Effectiveness Monitoring

by Scott Collyard and Niamh O'Rourke

May 2021

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Signatures are not available on the Internet version.
EAP: Environmental Assessment Program
WQP: Water Quality Program

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2.0 Abstract

In 2003, the Washington State Department of Ecology (Ecology) developed a fecal coliform bacteria (FC) Total Maximum Daily Load (TMDL) water cleanup plan for tributaries of the Lower Snohomish River. These include Allen Creek, French Creek, the Pilchuck River, the Marshlands, Quilceda Creek, and Woods Creek. The water cleanup plan documented the actions needed to reduce FC levels in the Lower Snohomish tributaries by 2009. Since development of the TMDL, numerous water cleanup projects have been implemented to reduce FC levels in the area. In addition, National Pollutant Discharge Elimination System (NPDES) stormwater permits were developed and implemented.

Ecology is evaluating the effectiveness of TMDL implementation. As part of this effort, Ecology is conducting bacteria monitoring as described in this Quality Assurance Project Plan (QAPP). The purpose of the monitoring is to (1) reassess current FC levels in the Lower Snohomish River tributaries and (2) characterize E coli concentrations due to a change in freshwater quality standards. The new bacteria data, as well as other credible ambient water quality data, will be evaluated. These data, along with a detailed compilation of bacteria pollution control actions taken, will provide subbasin managers and stakeholders the feedback needed for adaptive management purposes.

3.0 Background

3.1 Introduction and problem statement

The 2003 Lower Snohomish River Tributaries Fecal Coliform TMDL (Svrjcek, 2003) called for the reduction of bacteria concentrations to meet Washington State water quality standards by 2009. The TMDL detailed implementation plan documented specific actions for partners to take in order to make such reductions and called for an effectiveness monitoring study as described in this QAPP. This monitoring study will focus on six tributary watersheds (subbasins) to the Lower Snohomish River where water quality standards for bacteria have not been met and where implementation efforts have been prioritized: Allen Creek, French Creek, the Pilchuck River, the Marshlands, Quilceda Creek, and Woods Creek. The Snohomish River is within Water Resource Inventory Area (WRIA) 7 and flows into Possession Sound near the city of Everett.

Prior water quality testing by Snohomish County and the Washington State Department of Ecology (Ecology) confirmed that high FC levels existed in the tributary streams of the Snohomish River (Cusimano, 1997). Overall, the data suggested that the water quality in all six of the study subbasins was being adversely impacted by nonpoint pollution. The data showed that French Creek and the Marshlands had the poorest water quality of the subbasins. FC indicate the presence of fecal wastes from warm-blooded animals. Probable sources of bacteria include failing onsite septic systems, livestock manure, wildlife, and pet waste.

The high FC levels in many of the Snohomish tributaries increase the risk of people becoming ill when swimming (primary contact recreation), wading, fishing, or boating. Potential illnesses caused by contact with pathogen-contaminated recreational waters include gastrointestinal, respiratory, eye, ear, nose, throat, and skin diseases (EPA, 1986). Many of these polluted streams have ready access for adults and children to swim and wade.

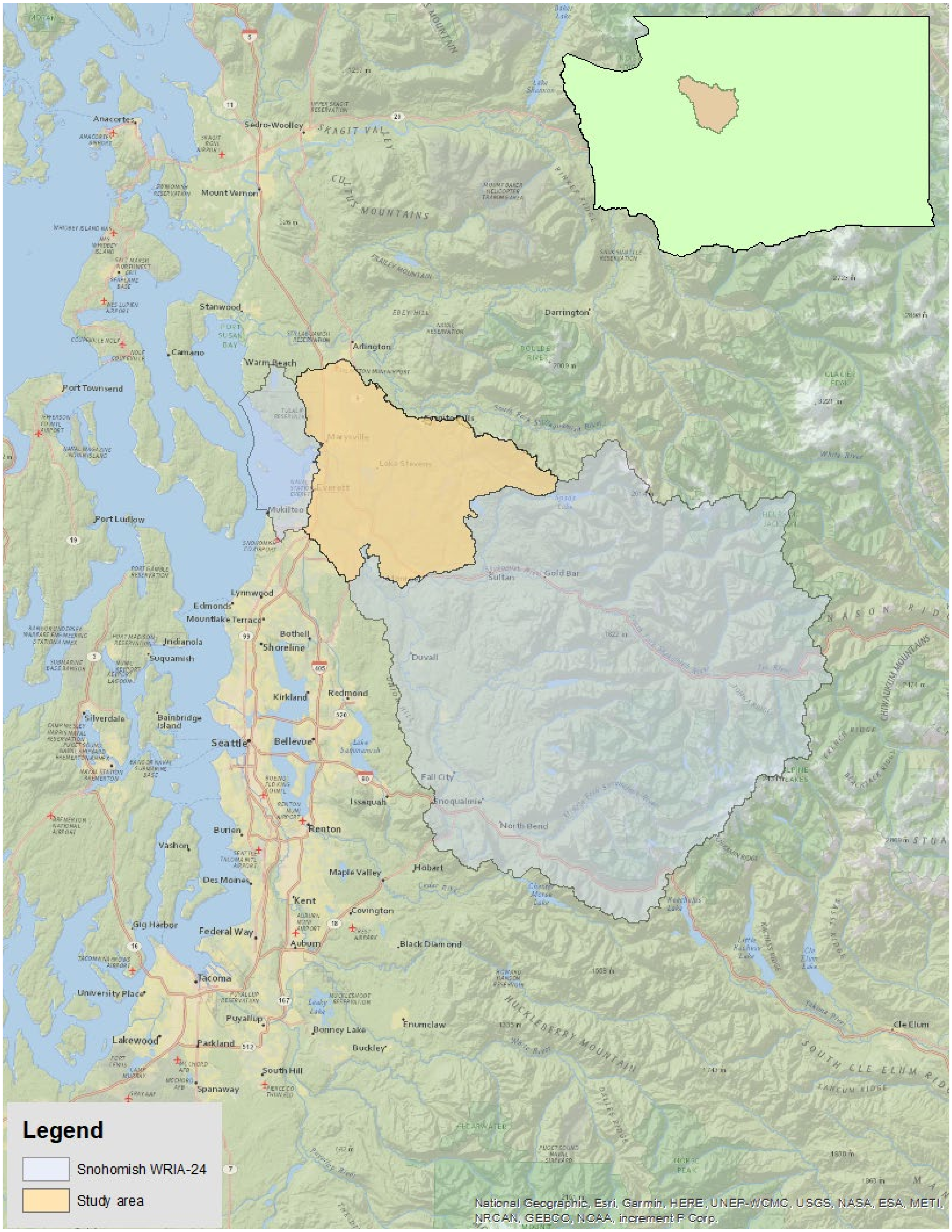

Figure 1. Map of larger study area in the Lower Snohomish River watershed

Table 1 summarizes the bacteria impairments from the 2012 Water Quality Assessment for each watershed (subbasin) this study plans to monitor (Ecology, 2012).

Table 1. 2012 Water Quality Assessment of bacteria impairments in the Lower Snohomish River tributaries.

Stream	Parameter	Impairment Category	Listing IDs
Allen Creek	Bacteria	4A	7258
Allen Creek	Bacteria	4A	7262
Allen Creek	Bacteria	4A	7264
Allen Creek	Bacteria	4A	45140
Allen Creek	Bacteria	4A	46925
French Creek	Bacteria	4A	7274
French Creek	Bacteria	4A	7279
French Creek	Bacteria	4A	7280
Marshlands	Bacteria	4A	9803
Marshlands	Bacteria	4A	9804
Pilchuck River	Bacteria	4A	9810
Pilchuck River	Bacteria	4A	46367
Quilceda Creek	Bacteria	4A	7304
Quilceda Creek	Bacteria	4A	7305
Quilceda Creek	Bacteria	4A	7306
Quilceda Creek	Bacteria	4A	46286
Quilceda Creek	Bacteria	4A	74317
Woods Creek	Bacteria	4A	7437
Woods Creek	Bacteria	4A	7440

3.2 Study area and surroundings

The Snohomish River basin (WRIA 7) encompasses 1,856 square miles draining to Puget Sound. The basin provides significant habitat for five salmon species, three trout species, and one char species. Over 1,730 tributary rivers, streams, and other waterways have been identified in the Snohomish River basin, totaling about 9,727 miles in length.

The Lower Snohomish tributaries study area encompasses seven distinct hydrologic unit code 12 (HUC-12) subbasins (Figure 2). The primary historical land uses in the study area were agriculture and forested lands, but the area has been rapidly developed for residential and commercial use. Increased urbanization and land development, riparian corridor alteration, conversion of forests, inadequate stormwater management, and impervious surfaces have been identified as impacting water quality in the basin (Cusimano and Coots 1997, Wright et al. 2001).

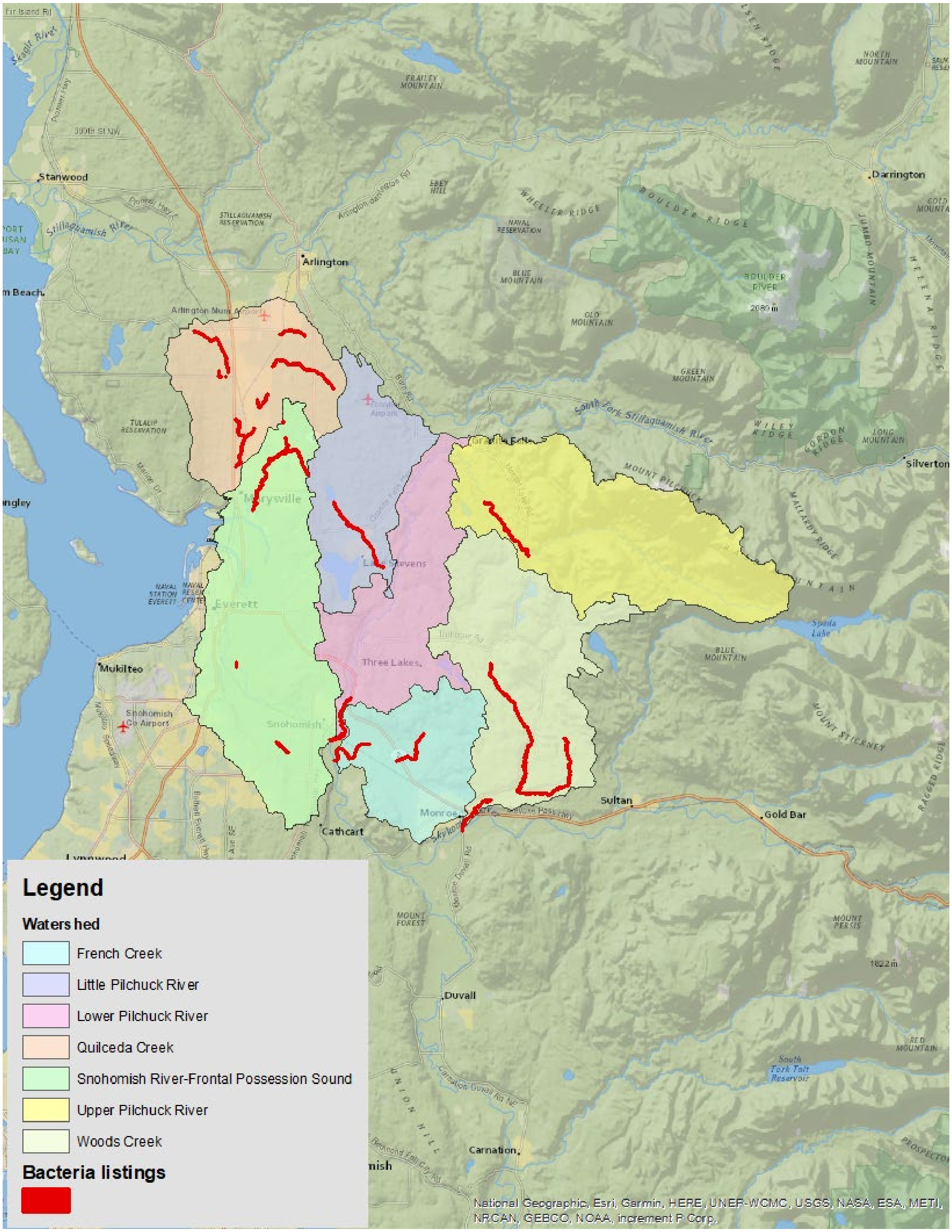

Figure 2. Study area and bacteria listings within Lower Snohomish River subbasins

Quilceda and Allen Creeks

Quilceda and Allen Creeks flow south through the city of Marysville. Quilceda Creek is contained within the Quilceda Creek HUC-12 while Allen Creek is within the Snohomish River-Frontal Possession Sound HUC-12 (Figure 3). The combined area of the two subbasins is about 49 square miles with Quilceda Creek draining about 38 square miles of land and Allen Creek about 11 square miles. Both streams enter the Snohomish River delta via Ebey Slough near Marysville. The upper portions of both the Quilceda and Allen subbasins have agricultural and rural land uses, while the lower subbasins are urbanized with increased amounts of residential and commercial development. About one-half of the city of Arlington contributes to the Quilceda subbasin, and due to the porous soils in the area, much of that stormwater is infiltrated and thus recharges groundwater supplies to feed Quilceda Creek (SCPW, 2015).

French Creek

French Creek flows westerly for about 11 miles and encompasses about 28 square miles (Figure 4). French Creek drains a portion of south-central Snohomish County north and west of the city of Monroe and southeast of the city of Snohomish, some of which is part of the Snohomish River floodplain. A small portion of the French Creek subbasin is located within the city of Monroe, with the majority of the basin within unincorporated Snohomish County.

Discharge of French Creek to the Snohomish River at about river mile 15 is controlled by a pumping station that is operated and maintained by the French Slough Flood Control District. The lower portion of the French Creek subbasin flows through the flat Snohomish River floodplain where much of the stream network has been straightened and channeled for agricultural purposes.

Agricultural practices and lack of stream buffers along the lower reaches of the creek were identified as causing water quality problems. Rural development in the upper subbasin has more recently become significant, increasing runoff from land clearing and residential development activities. The land uses in the upper reaches of the drainage are primarily a mix of residential development, small farms and pastures, forested areas, and equestrian centers. Commercial agriculture, dairies, and duck hunting preserves dominate the lower reaches.

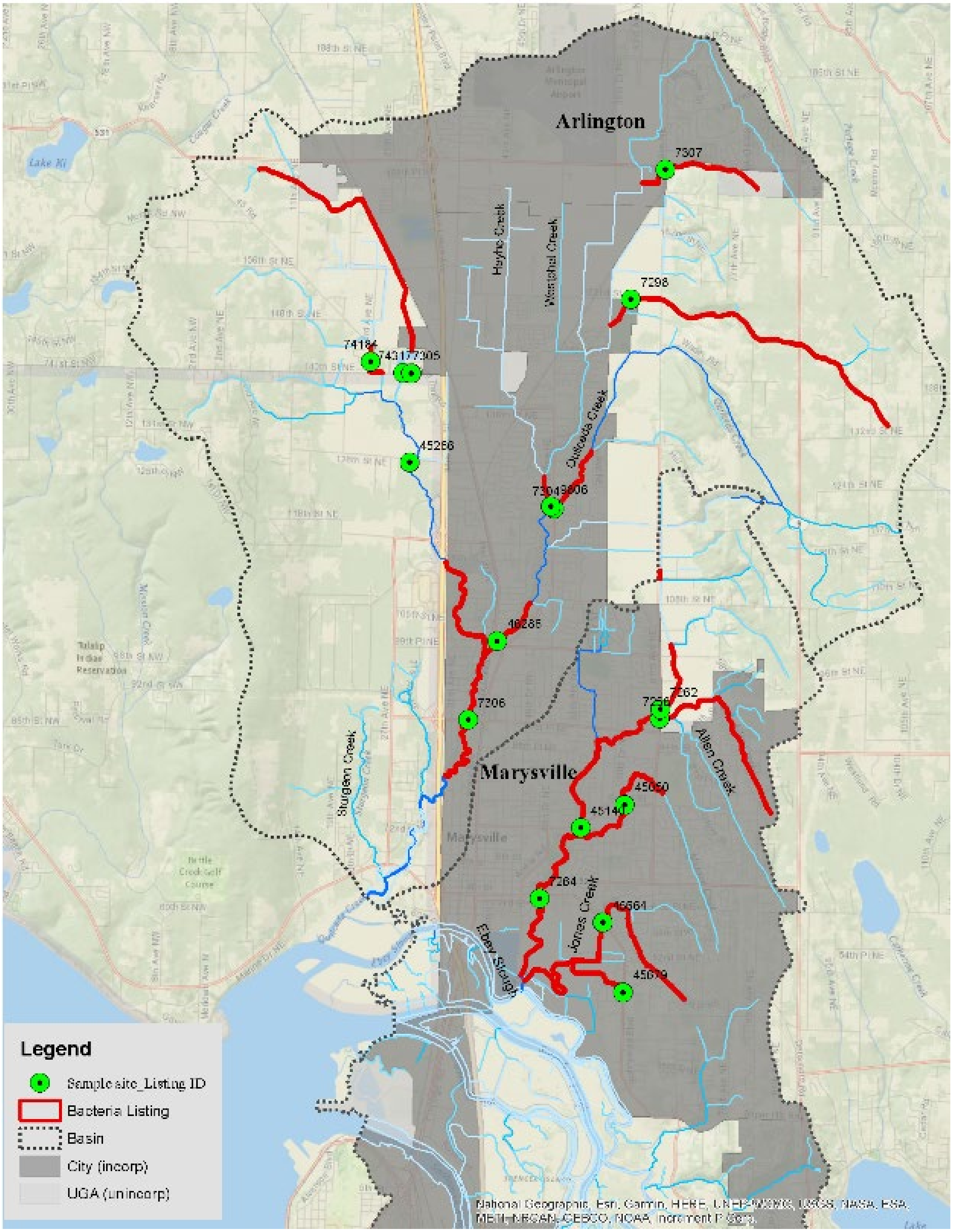

Figure 3. Quilceda and Allen Creek study area

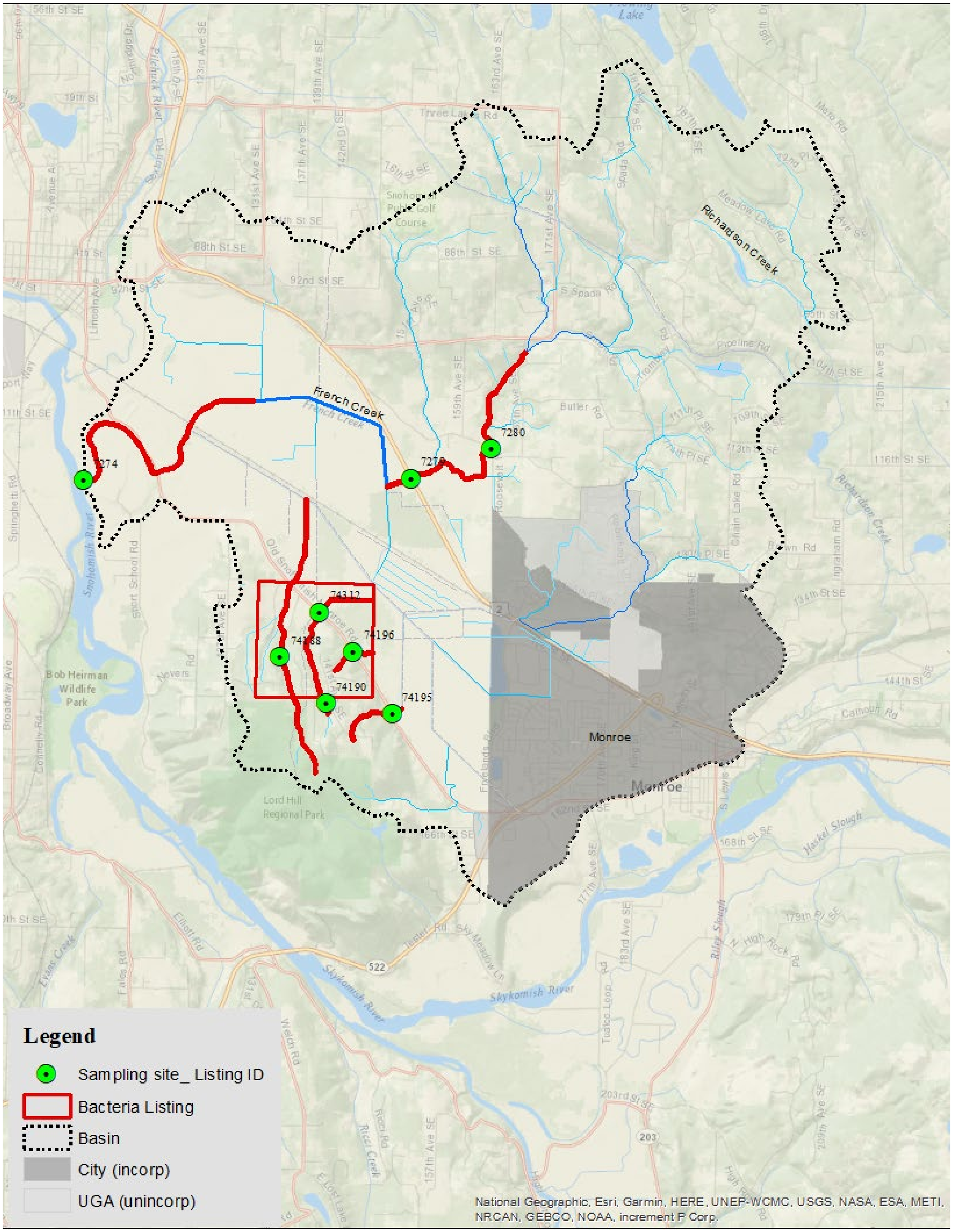

Figure 4. French Creek subbasin

Pilchuck River

The Pilchuck River flows 39 miles west and south from the western slopes of the Cascades to the Snohomish River and drains about 130 square miles of land (Figure 5). About 96% of the total Pilchuck subbasin lies within unincorporated Snohomish County. An average annual discharge of 364 cfs makes the Pilchuck River the largest tributary to the Snohomish River.

The city of Granite Falls operates a wastewater treatment plant (WWTP), which discharges secondary treated effluent to the river. The discharge from the Granite Falls WWTP is located more than 6 miles upstream from the upper-most segment of the Pilchuck River on the 303(d) list. The cities of Lake Stevens, Snohomish, and Granite Falls contribute stormwater to the Pilchuck River. Historically, the Pilchuck River has had well established riparian buffer. Low-density residential development and small farms dominate the land use in the basin. Urbanization is taking place around Lake Stevens, the city of Snohomish, and the town of Granite Falls.

Woods Creek

Woods Creek flows into the Skykomish River just upstream of the confluence with the Snoqualmie River (Figure 6). Draining about 62 square miles of land, Woods Creek flows southerly from near Lake Roesiger and enters the river at Monroe. Land use in the lower portion of the creek is mostly residential (around Monroe) and rural-residential with some small-scale, non-commercial farms and several equestrian centers. Land use in the upper portion of the drainage is low-density rural-residential, small farms, and tree farms.

Marshlands

The Marshland subbasin, contained within Snohomish River-Frontal Possession Sound HUC-12 and located southeast of the city of Everett and southwest of the city of Snohomish, consists of a number of small creeks (Figure 7). A large part of the Marshlands subbasin is a channeled irrigation and drainage ditch system. This drainage network and its tributaries include about 24 square miles of land primarily within the Snohomish River floodplain. The streams that drain to the Marshland originate in the residential areas of the ridge creating the south and west boundary of the floodplain. About 80% of the Marshlands subbasin is within unincorporated Snohomish County. The remainder is within the city of Everett.

Similar to the French Creek drainage, the lowland portion of the Marshland subbasin is in the floodplain of the Snohomish River where land use is dominated by commercial agriculture. The tributary subbasins on the hillsides above the Marshland agricultural area are primarily residential. After flowing through commercial agricultural land, discharge from Marshlands to the Snohomish River is controlled by a pumping station operated by the Marshlands Flood Control District.

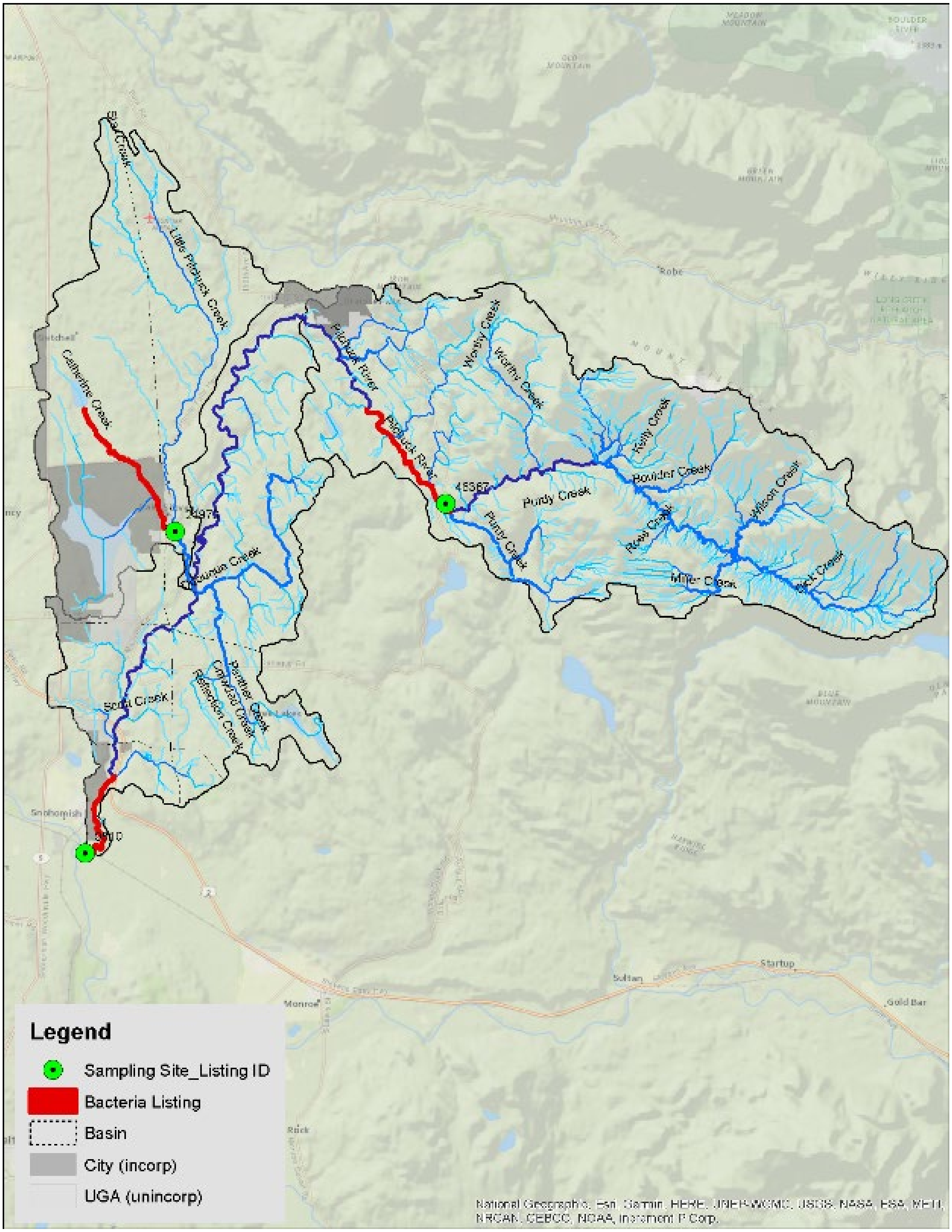

Figure 5. Pilchuck River study area

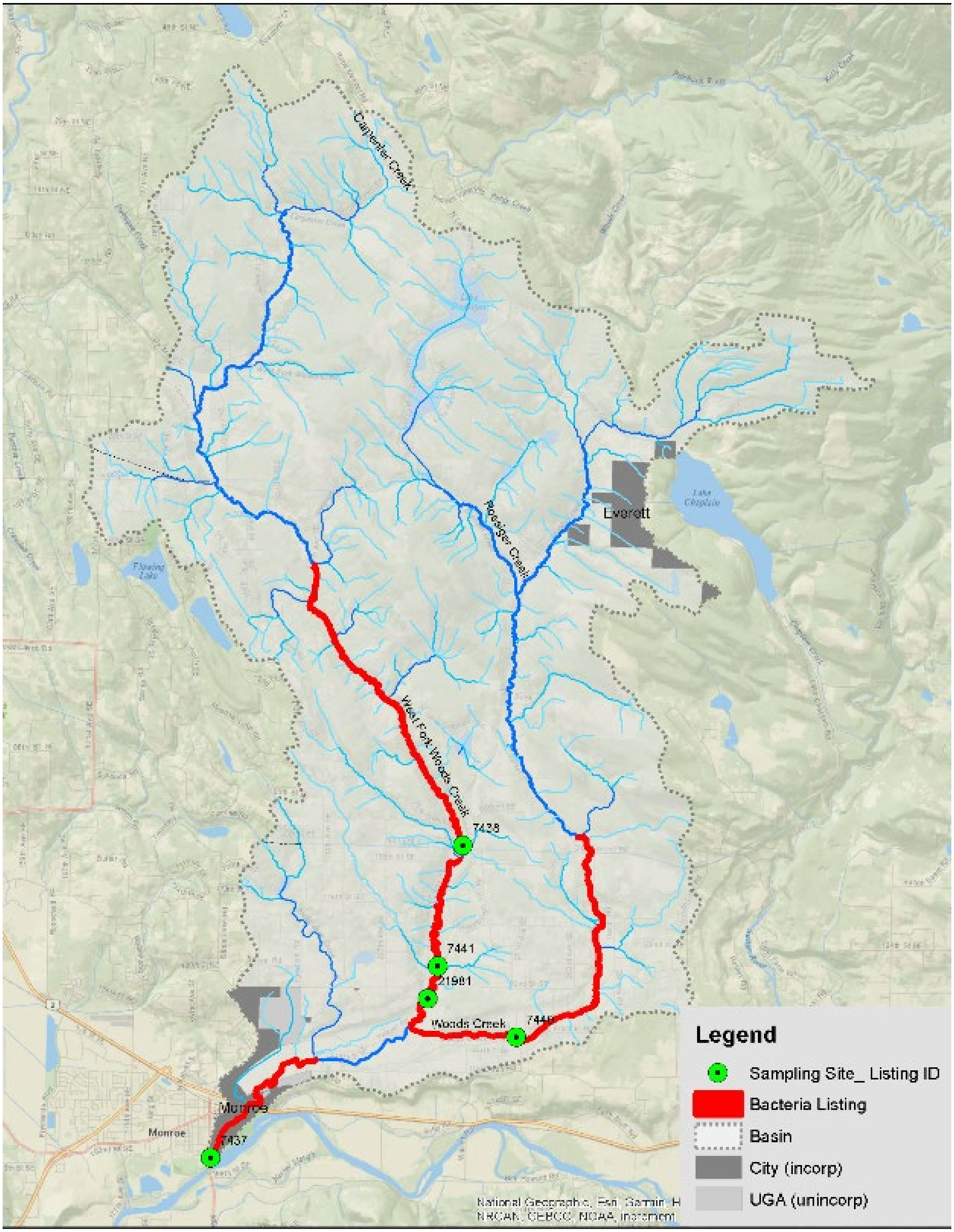

Figure 6. Woods Creek subbasin

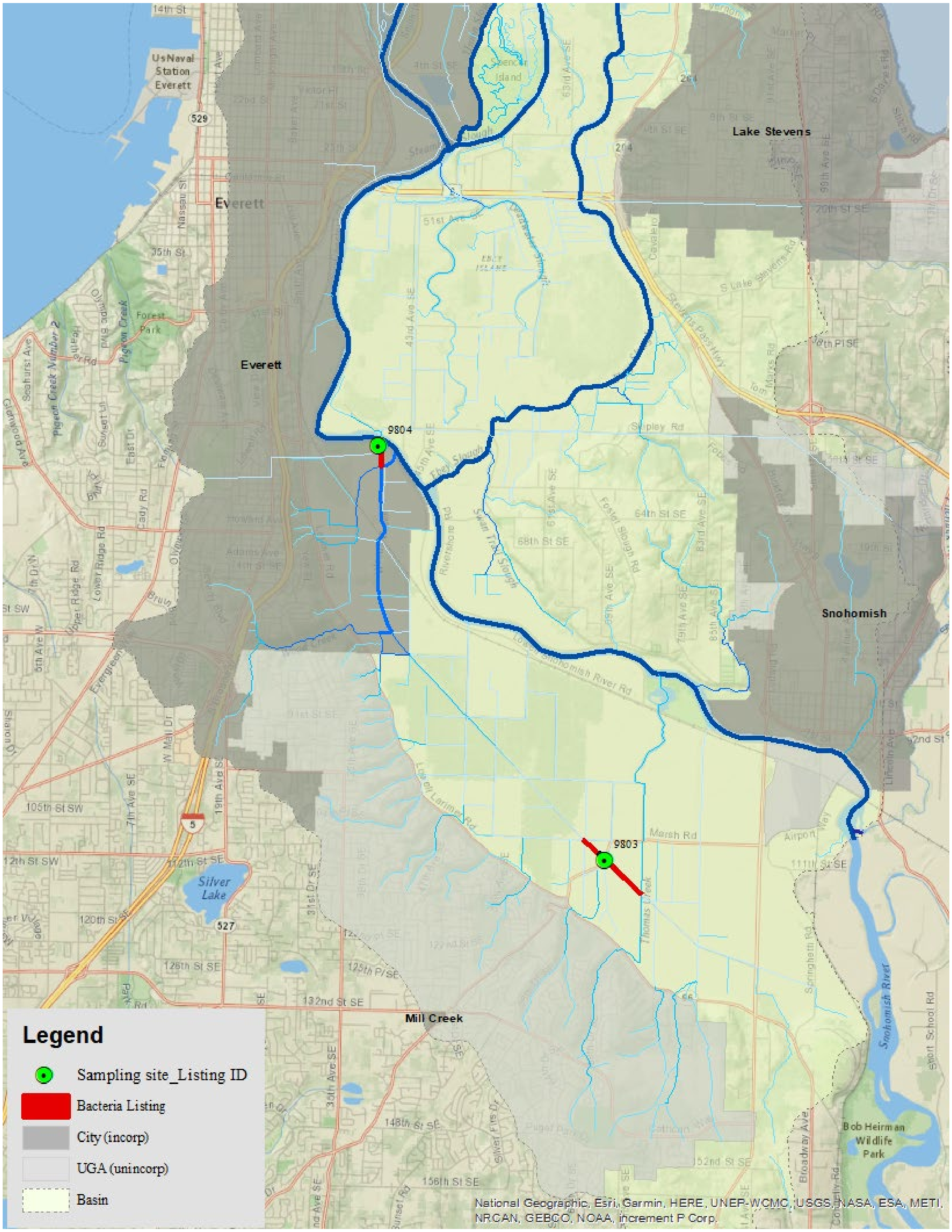

Figure 7. Marshlands study area

3.2.1 Parameters of interest and potential sources

Bacteria pollution in the Snohomish River tributaries originates from numerous diffuse sources. The predominant sources have been identified as coming from agriculture, septic systems, and stormwater runoff.

Agricultural inputs include animal waste from pasture and concentrated animal areas, waste storage facilities, land application, and stream access. Animals with access to the streams contribute both FC and oxygen-demanding organic matter. Data for FC and nutrients indicate that animal access is a major source of diffuse pollution caused by poor management practices.

Septic systems, when improperly located, poorly maintained, or failing, can contribute bacterial contamination to streams through surface or groundwater flows. Extensive areas of the Snohomish tributaries subbasins remain unsewered and, even though sewer service is provided in many areas, there may be a substantial number of homes that use on-site disposal systems, because hookup is not always required when a new sewer line is installed.

Stormwater runoff mobilizes pollutants and transports them to surface waters. In urbanized areas, bacteria sources to stormwater runoff include pet waste, sanitary sewer overflows into the stormwater system, and nuisance pest attractants such as uncovered dumpsters. Additional bacteria sources may include regrowth and sporadic spills and/or illegal dumping of sewage.

3.2.4 Regulatory criteria or standards

State law establishes water quality standards for surface waters throughout Washington. These standards protect human health and recreation as well as fish, shellfish, and wildlife. The standards include numeric and narrative criteria that must be met in order to protect the designated uses of water bodies throughout the state. Where water quality does not meet these criteria, local government and organizations implement pollution clean-up plans (TMDLs or TMDL alternatives) until water quality improves.

Freshwater bacteria concentrations in the Lower Snohomish River tributaries study area must meet both the water contact recreation bacteria criteria defined in the current state water quality standards (Table 2) and the target concentrations identified in the TMDL report.

Table 2. Water quality criteria for bacteria assessed in this study

Parameter	Criteria
Fecal coliform	Fecal coliform (FC) levels within an averaging period must not exceed a geometric mean value of 100 CFU or MPN per 100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained within an averaging period exceeding 200 CFU or MPN per 100 mL.
E. coli	*E. coli* levels within an averaging period must not exceed a geometric mean value of 100 CFU or MPN per 100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained within the averaging period exceeding 320 CFU or MPN per 100 mL.

The use of FC organism levels to determine compliance with state water quality standards expired December 31, 2020. *E. coli* levels are the primary basis for these standards moving forward. FC levels will still be used to determine changes over time with reference to established TMDL targets.

For assessing compliance with current state standards, geometric means and 10% exceedance values will be calculated for consecutive, rolling, three-month periods over the course of the water year (e.g., October-December, November-January).

For assessing compliance with TMDL targets, geometric means and 90th percentile values will be calculated for two seasons: dry (May - October) and wet (November - April). 90th percentile values were used in the TMDL in place of 10% exceedance values.

The TMDL authors used the statistical rollback method to set load allocations for FC in the form of target values and required percent reduction in concentration for each site (Cusimano and Coots, 1997). This method produced target values for the geometric mean that should be low enough to ensure that each site meets both the geometric mean criterion and the 10% exceedance criterion of the state standards (Svrjcek, 2003). By assessing compliance with both these TMDL load allocations and the state standard criteria, we will gain insight into the effectiveness of using the statistical rollback method to ensure compliance with both components of the state standard.

3.3 Effectiveness monitoring studies

Effectiveness monitoring is a vital part of TMDL implementation efforts. In addition to assessing if water quality criteria for bacteria are being met, this study will also measure the extent to which bacteria levels in six subbasins – Allen Creek, French Creek, the Pilchuck River, the Marshlands, Quilceda Creek, and Woods Creek – have improved.

The TMDL effectiveness evaluation should provide the following information to facilitate adaptive management needs:

- A measure of progress toward implementation of recommendations (i.e., how much watershed restoration has been achieved and how much more effort is required).
- More efficient allocation of funding and optimization in planning and decision-making.
- Technical feedback to refine the initial TMDL model, best management practices, nonpoint source plans, and permits.

4.0 Project Description

This Quality Assurance Project Plan (QAPP) serves jointly with the following documents:

- Programmatic QAPP for Water Quality Impairment Studies (McCarthy and Mathieu, 2017).
- Standard Operating Procedures for the Collection, Processing, and Analysis of Stream Samples (Ward, 2016).
- Guidance for Effectiveness Monitoring of Total Maximum Daily Loads in Surface Water (Collyard and Onwumere, 2013).

The above documents address elements that apply to all water quality impairment projects, while this QAPP addresses elements specific to this project.

4.1 Project goals

The main goals of this effectiveness monitoring study are to:

- Determine compliance with existing water quality standards for E. coli.
- Compare past and current FC results to assess trends over time.
- Provide the information feedback needed for adaptive management purposes.

4.2 Project objective

The study objective is to collect bacteria (FC and E. coli) water samples twice a month at locations where water quality targets have been established.

4.3 Information needed and sources

Additional information to support the TMDL effectiveness evaluation includes a comprehensive list of pollution control measures implemented to protect or restore water quality. This information will be needed from participating organizations identified in the TMDL detailed implementation plan (Ecology, 2003). Also required are historical and current bacteria data from regional monitoring programs, to assess trends over time.

4.4 Tasks required

A general overview of the tasks required to meet the project goals for this effort are discussed below and in Section 4.2. Additional detail on the technical approach and field and lab tasks are described in Section 7.

The following tasks will be performed to support the goals and objectives of this study:

- Collect surface water samples from Snohomish River tributaries for bacteria analysis.
- Collect observational data at each site visit including any evidence of likely sources of bacterial pollution. Take photos as necessary.

This project also uses various tools to accomplish the required tasks, such as:

- Standard Operating Procedures (SOPs) for field and calibration activities.
- Checklists for field supplies and calibrations.
- Paper and digital logs for calibration activities.
- Chain of Custody forms for all lab samples.

- Sample collection gear such as personal protective equipment, poles, boots, and coolers.
- Computer programs for compiling, storing, organizing, analyzing, and reporting of information such as field and laboratory sample data.

4.5 Systematic planning process

This QAPP, in combination with the *Programmatic QAPP for Water Quality Impairment Studies*, represent the systematic planning process.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

Table 3 shows the responsibilities of those who will be involved in this project.

Table 3. Organization of project staff and responsibilities

Staff[1]	Title	Responsibilities
Heather Khan Water Quality Program Northwest Regional Office Phone: 425-649-7003	EAP Client	Clarifies scope of the project. Provides internal review of the QAPP and approves the final QAPP. Informs decisions on bracketed sampling as necessary.
Tricia Shoblom Water Quality Program Northwest Regional Office Phone: 425-649-7288	Non-point Source Project Manager	Provides internal review of the QAPP and approves the final QAPP.
Niamh O'Rourke Watershed Health and Effectiveness Monitoring Unit Statewide Coordination Section Phone: 360-407-7614	Project Manager / Principal Investigator	Co-writes the QAPP and provides internal review of co-authored sections. Oversees field sampling and data entry into EIM. Conducts QA review of data and analyzes and interprets data. Creates project web content. Writes the draft final reports.
Alyssa Peter Watershed Health and Effectiveness Monitoring Unit Statewide Coordination Section Phone: 360-407-6690	Field Assistant	Provides data management and field support. Creates project web content.
Scott Collyard Watershed Health and Effectiveness Monitoring Unit Statewide Coordination Section Phone: 360-407-6455	Unit Supervisor for the Project Manager	Co-writes the QAPP and provides internal review of co-authored sections. Approves the budget and the final QAPP.
Jessica Archer Statewide Coordination Section Phone: 360-407-6698	Section Manager for the Project Manager	Reviews the project scope and budget, tracks progress, reviews the draft QAPP, and approves the final QAPP.
Alan Rue Manchester Environmental Laboratory Phone: 360-871-8801	Manchester Lab Director	Reviews and approves the final QAPP.
Arati Kaza Phone: 360-407-6964	Ecology Quality Assurance Officer	Reviews and approves the draft QAPP and the final QAPP.

[1]All staff except the client are from EAP.
EAP: Environmental Assessment Program
EIM: Environmental Information Management database
QAPP: Quality Assurance Project Plan

5.2 Special training and certifications

Ecology field staff are trained through education and experience. Field staff are required to (1) be familiar with all study related SOPs and (2) adhere to task-specific procedures documented in Ecology's Environmental Assessment Program (EAP) and Water Quality Program (WQP) Safety Plans. Field staff certify review of these procedures every two years. Key personnel involved in the collection of water quality data and interpretation of results for this study have extensive experience in similar efforts.

5.3 Organization chart

Table 4 lists the Ecology staff involved in this study.

5.4 Proposed project schedule

Sampling for this study will be conducted over one year beginning in October 2020 to correspond with water year 2021. Water quality monitoring will occur twice monthly at all sites. Bracketed monitoring to further characterize polluted reaches will occur as feasible and deemed necessary by WQP specialists working in the watershed or by the need to follow-up on pollution sources found during the study.

Tables 4, 5, and 6 list key activities, due dates, and lead staff for this project.

Table 4. Schedule for completing field and laboratory work

Task	Due date	Lead staff
Field work	Oct 2021	Niamh O'Rourke
Laboratory analyses	Oct 2021	Edlin Nuss

Table 5. Schedule for data entry

Task	Due date	Lead staff
EIM data loaded	Nov 2021	Niamh O'Rourke
EIM QA	Dec 2021	Jenny Wolfe
EIM complete	Jan 2022	Niamh O'Rourke

EIM Project ID: EFF_LSRT
EIM: Environmental Information Management database

Table 6. Schedule for final report

Task	Due date	Lead staff
Draft to supervisor	3/31/2022	Niamh O'Rourke
Draft to client/ peer reviewer	4/31/2022	Niamh O'Rourke
Draft to external reviewers	5/31/2022	Niamh O'Rourke
Final draft to publications team	6/31/2022	Niamh O'Rourke
Final report due on web	7/30/2022	Niamh O'Rourke

5.5 Budget and funding

The project budget is divided between lab and field costs. All lab samples will be analyzed at Ecology's accredited Manchester Environmental Laboratory (MEL). The estimated lab budget is detailed in Table 7.

Table 7. Laboratory budget details

Parameter	Number of Samples	Number of QA Samples	Total Number of Samples	Cost Per Sample ($)	Lab Subtotal ($)
Fecal coliform & *E. coli* (MF)	864	87	951	42	39,942

6.0 Quality Objectives

6.1 Data quality objectives

The main data quality objective (DQO) for this study is to collect data of sufficient quantity and quality for effectiveness monitoring of TMDL implementation efforts. This objective will be met by using standard methods that meet the measurement quality objectives (MQOs) that are described below and that are comparable to previous study results.

6.2 Measurement quality objectives

MQOs are performance or acceptance criteria for data quality indicators including precision, bias, sensitivity, representativeness, comparability, and completeness. Field measurements and laboratory analyses both have inherent data variability and as such, MQOs are equally important for both methods. For a measurement of data accuracy, precision and bias are addressed.

6.2.1 Targets for precision, bias, and sensitivity

The MQOs for project results, expressed in terms of acceptable precision, bias, and sensitivity, are described in this section and summarized in Table 8 below.

6.2.1.1 Precision

Precision is a measure of variability between results of replicate measurements that is due to random error. It will be assessed by analyzing duplicate samples. Random error can occur from the environment, field procedures, and/or lab methods. Common sources of random error include field sampling procedures, sample handling, sample transportation, lab sample preparation and analysis, and data handling. Field precision will be addressed by collecting replicate samples. Lab precision will be assessed by MEL and will follow their standard quality control procedures (MEL, 2016). Precision will be expressed as percent relative standard deviation (% RSD) or absolute error and assessed using the MQOs defined in Table 8. The targets for precision of field duplicates are based on historical performance by MEL for environmental samples taken around the state by EAP (Mathieu, 2006).

6.2.1.2 Bias

Bias is the difference between the sample mean and the true value. Bias will be addressed by calibrating laboratory instruments, and by analyzing lab control samples, matrix spikes, and/or standard reference materials. Bias can originate from instrument sensor drift or improper calibration, sample instability during transportation or storage, sample or equipment contamination, or the inability of analytical methods to detect all forms of the parameter. Field bias will be assessed through following appropriate sample collection procedures outlined in published SOPs. Lab bias will be assessed by MEL through the use of blanks and spiked samples. MQOs are listed in Table 8.

6.2.1.3 Sensitivity

Sensitivity is a measure of the capability of a field instrument or lab method to detect a substance. It is commonly described as a detection limit. For lab data, the method detection limit (MDL) is usually used to describe sensitivity. The method reporting limit (MRL) is typically a little higher than the MDL and is used to represent sensitivity for lab parameters listed in Table 8.

Table 8. Measurement quality objectives

Parameter	Lab Duplicate (RPD)	Field Duplicate (RPD)	Matrix Spike Duplicate (RPD)	Lab Control Standard (% Recovery)	Matrix Spike (% Recovery)	Internal Standard Recovery (% Recovery)	Lowest Concentrations of Interest
Fecal coliform + *E. coli* (MF)	40%	≤ 20% RSD & 90% of replicate pairs ≤ 50% RSD[a]	n/a	n/a	n/a	n/a	1 cfu / 100 mL

[a] field duplicate results with a mean of less than or equal to 5x the reporting limit will be evaluated separately.
RPD: relative percent difference. RSD: relative standard deviation.

6.2.2 Targets for comparability, representativeness, and completeness

6.2.2.1 Comparability

The comparability of study results to previously collected data will be achieved through following Ecology's strict protocols and by following published EAP SOPs. Many factors can affect comparability including quality assurance documents such as QAPPs and SOPs, staff training, sample locations, seasonality and weather conditions, lab methods, calibration practices, equipment maintenance, and data entry quality control procedures. This study will adhere to the following Ecology SOPs and refer to equipment manuals for instrument-specific quality procedures:

- Programmatic QAPP for Water Quality Impairment Studies (McCarthy and Mathieu, 2017)
- Standard Operating Procedures for the Collection, Processing, and Analysis of Stream Samples (Ward, 2016)
- Guidance for Effectiveness Monitoring of Total Maximum Daily Loads in Surface Water (Collyard and Onwumere, 2013)

6.2.2.2 Representativeness

Representativeness is mainly a function of individual study design. Each study is designed to collect sufficient data, meet study-specific objectives, and assess spatial and temporal variability of the measured parameters throughout the study area. Sampling locations are distributed throughout each subbasin in a manner designed to meet study objectives. Sampling will be conducted throughout the year, capturing both dry and wet seasons which was also designed to meet study objectives.

6.2.2.3 Completeness

Completeness is a measure of the amount of valid data required to meet project objectives. The goal for this effectiveness monitoring study is to collect and analyze 100% of the samples or measurements when proper water levels allow. Due to unforeseen problems that may arise from site access problems, weather conditions, or equipment malfunction, a completeness of 80% will be acceptable. If equipment fails or samples are damaged, Ecology will attempt to recollect the data under similar conditions, such as the following day, if possible. In general, each project should be designed to accommodate some data loss and still meet project goals and objectives.

If completeness targets are not met, the study report will analyze the effect of the incomplete data on meeting the study objectives, account for data completeness (or incompleteness) in any data analyses, and document data completeness and its consequences in any study reports.

Investigative samples may not meet the minimum requirements for statistical or other data analysis, but will still be useful for source location identification, recommendations, or other analyses.

6.3 Acceptance criteria for quality of existing data

This study will likely use data collected through monitoring efforts conducted by others, including Ecology, Snohomish County, Snohomish Conservation District, and other stakeholder groups. The primary source of historical data will be Ecology's EIM database and project files for Ecology-sponsored studies. EIM will be used to access all analytical results and observational data, whereas project files will be used to gather more detailed information such as site-specific sampling locations and method descriptions. These data and all data from outside Ecology will be reviewed to assess comparability with this study.

6.4 Model quality objectives

NA

7.0 Study Design

7.1 Study boundaries

All field samples will be collected within six subbasins of the Snohomish River: the Pilchuck River, the Marshlands, and Allen, French, Quilceda, and Woods Creeks. See Figures 1-7 for additional maps of these subbasins. Figures 3-7 show sampling locations within each subbasin. Additional sampling locations could be added to assess the extent of bacteria pollution or if sites become inaccessible over the duration of the project. Sites could also be abandoned or moved due to accessibility during the study.

7.2 Field data collection

7.2.1 Sampling locations and frequency

Sampling locations are listed in Table 9. These were selected because they are the same locations used in the original TMDL study and associated original impairment listings. Fieldwork began October 2020 and will continue through September 2021. All sites will be visited twice a month, about every 2 weeks. Due to the length of time required by MEL for processing bacteria samples, site visits will be conducted on Mondays and Tuesdays whenever possible.

Table 9. Latitude and longitude of all planned sample sites

Site*	Stream	Latitude	Longitude	EIM Location ID	Listing ID
FR00.1	French Creek	47.8887	-122.0873	07-FRE-0.1	7274
FR01.3	French Creek	47.8898	-122.0741	07R050	7274
FR04.4	French Creek	47.8897	-122.0275	07-FRE-4.4	7279
FR05.4	French Creek	47.8935	-122.0130	FR05.4	7280
FT02.0	Unnamed Creek (Trib to French Creek)	47.8762	-122.0491	LORD_HILL_6	74188
FT02.7	Unnamed Creek (Trib to French Creek)	47.8730	-122.0438	LORD_HILL_5	74190
FT02.6	Unnamed Creek (Trib to French Creek)	47.8694	-122.0386	LORD_HILL_3	74312
FT02.8	Unnamed Creek (Trib to French Creek)	47.8683	-122.0375	LORD_HILL_2	74196
FT03.3	Unnamed Creek (Trib to French Creek)	47.8607	-122.0301	LORD_HILL_1	74195
PI00.2	Pilchuck River	47.9018	-122.0875	PRDN	9810
PI25.5	Pilchuck River	48.0186	-121.9149	07B150	46367
CA00.0	Catherine Creek	48.0078	-122.0468	CCDN	21973
QU03.4	Quilceda Creek	48.0757	-122.1790	QCLD	7306
QU04.4	Quilceda Creek	48.0866	-122.1733	QU04.4	46286
QU06.0	Quilceda Creek	48.1049	-122.1621	QUILCEDA3	7304
QM00.0	Quilceda Creek, M.F.	48.1051	-122.1629	MFQUILCEDA5	9806
QM02.4	Quilceda Creek, M.F.	48.1337	-122.1472	QM02.4	7298
QT02.4	Quilceda Creek, M.F. (Trib) AKA Edgecomb Creek	48.1515	-122.1406	Edge/67	7307

Site*	Stream	Latitude	Longitude	EIM Location ID	Listing ID
QW02.4	Quilceda Creek, W.F.	48.1109	-122.1919	QCWF	45266
QD00.1	Quilceda Creek, W.F. (Trib)	48.1230	-122.1919	QA 140TH E	74317
QT00.3	Quilceda Creek, W.F. (Trib)	48.1231	-122.1936	QA 140TH W	7305
QW03.7	Quilceda Creek, W.F.	48.1246	-122.2002	QA 23RD	74184
MA00.1	Marshlands	47.9471	-122.1801	MLDN	9803
MA04.3	Marshlands	47.8969	-122.1375	MLUP	9804
JT00.7	Unnamed Creek (Trib to Ebey Slough) AKA Trib to Jones Cr.	48.0388	-122.1464	UNNAMED (SS3)	45679
JO01.7	Unnamed Creek (Trib to Ebey Slough) AKA Jones Creek	48.0483	-122.1508	UNNAMED (SS2)	45664
AL01.1	Allen Creek	48.0514	-122.1638	ACLD	7264
AL02.1	Allen Creek	48.0612	-122.1556	ACMS	45140
MU00.6	Munson Cr. (Trib to Allen Cr.)	48.0645	-122.1467	ACMC	45050
AL03.8	Allen Creek	48.0763	-122.1399	ACSF1	7258
AT00.1	Allen Creek (Trib)	48.0776	-122.1397	AT00.1	7262
WO00.1	Woods Creek	47.8484	-121.9703	WCDN	7437
WO05.0	Woods Creek	47.8698	-121.8934	WCFA_SNOCO	7440
WW00.5	Woods Creek, W.F.	47.8762	-121.9161	WCWF	21981
WW01.1	Woods Creek, W.F.	47.8816	-121.9137	WW01.1	7441
WW03.1	Woods Creek, W.F.	47.9022	-121.9079	SNOCO_WOODS298	7438

* Existing EIM location IDs will be used where available to align with EIM guidelines and allow for ease of historical data analysis. Due to the varied format of existing IDs, corresponding study-specific location IDs (site aliases) have been created for the purposes of this effectiveness monitoring study. These aliases reference the waterbody and river mile (e.g. AL01.1 is Allen Creek at river mile 1.1).

7.2.2 Field parameters and laboratory analytes to be measured

Fecal coliform (FC) and E. coli samples are required to meet the data needs of the study. Parameters may be added or removed from the study design as the project advances if needed to further characterize polluted stream reaches. Model quality objectives and other quality standards will be implemented for any parameters added to the study.

7.3 Modeling and analysis design

NA

7.4 Assumptions underlying design

Assumptions that underlie the project design include:

- The project design, including site selection and sample frequency, will adequately represent the subbasins.
- The project design will sufficiently monitor the effectiveness of TMDL implementation efforts and aid in assessing the extent of bacterial pollution.

7.5 Possible challenges and contingencies

7.5.1 Logistical problems

Due to the long duration of this effectiveness monitoring study, site accessibility could become a possible challenge. If a site becomes inaccessible due to road changes, erosion, etc., the addition of a new site will be considered based on the needs of the project objectives. In addition, the ephemeral nature some of the waterways could present challenges for sample collection if adequate water levels are not present or if weather patterns are conducive to longer drought periods. These events will be documented throughout the project. If equipment failure occurs during a sampling event, troubleshooting will be attempted in the field. If troubleshooting fails, any missed sites will be revisited at the next most convenient time dependent on staff priorities and lab availability.

7.5.2 Practical constraints

Practical constraints to this study may include unforeseen budget cuts and staff reductions or vacancies. Contingencies would include site or parameter reductions, a reduction in sample frequency, and/or sampling postponement.

7.5.3 Schedule limitations

The project schedule could be affected by the various factors listed above. Strong efforts will be made to ensure the sampling schedule stays consistent with the project plan. These efforts may include re-prioritizing budget needs within the program, collaborating with other work groups, and ensuring all sampling equipment is properly maintained and calibrated prior to sampling.

8.0 Field Procedures

8.1 Invasive species evaluation

Field staff will follow SOP EAP070 on minimizing the spread of invasive species (Parsons et al., 2018). Areas of extreme concern have, or may have invasive species like New Zealand mud snails that are particularly hard to clean off equipment and are especially disruptive to native ecological communities. For more information, please see Ecology's website on minimizing the spread of invasive species at
www.ecy.wa.gov/programs/eap/InvasiveSpecies/AIS-PublicVersion.html.

8.2 Measurement and sampling procedures

All water samples will be collected using Ecology's SOP for the Collection, Processing, and Analysis of Stream Samples (Ward, 2016).

8.3 Containers, preservation methods, holding times

Field staff will collect discrete samples directly into pre-cleaned or sterilized containers supplied by MEL and described in their *Lab Users Manual* (MEL, 2016). Table 10 lists the sample parameters, containers, volumes, preservation requirements, and holding times for all lab samples. Field staff will store samples for laboratory analysis on ice in a walk-in cooler and arrange for sample pick-up via MEL staff. MEL follows standard analytical methods outlined in their *Lab Users Manual* (MEL, 2016).

Table 10. Sample containers, preservation, and holding times

Parameter	Matrix	Minimum Quantity Required	Container	Preservation	Holding Time
Fecal coliform + *E. coli* (MF)	Water	250 mL	250 mL clear w/m poly autoclaved bottle	Fill the bottle to the shoulder; Cool to ≤10°C	24 hours

8.4 Equipment decontamination

Staff will follow all recommended protocols from instrument manufacturers for cleaning, maintaining, and calibrating sensors.

8.5 Sample ID

All samples will be labeled with station, date, time, parameter, sample identification number, and work order number, which are recorded in the field log and on the chain of custody (COC) form. Each lab sample is automatically given a unique identification number once loaded into the database. This number is transferred to analyses logs for internal lab samples. All sample bottles are reconciled against forms to verify completeness as samples move through the analytical process, described in the Quality Control section of this QAPP.

8.6 Chain of custody

Based on field log data, COC forms will be created and filled out for each sample event. COC logs are delivered to the lab with the corresponding samples for management of sample counts, scheduling, and tracking. Once the samples are delivered, lab personnel log in each sample and assign a lab number to each, using the sample label number and date. Each laboratory sample number must correspond to a particular date, station, and depth.

8.7 Field log requirements

Field logs will consist of pre-printed templates that will include the following information:

- Field personnel
- Site, date and time of which data is collected
- Observational data (e.g., flow, weather, water color)
- Any deviation from the sampling plan that might affect interpretation of results
- Notes of potential sources of pollution

Field Photos will also be taken as necessary to record observations and events. These photos will be used to document each sampling event and for the creation of reports, procedures, and other documents. Digital copies of all field and sample logs (COCs) will be stored for future reference on a shared, secure, and frequently backed up network server.

8.8 Other activities

Other activities related to field work include equipment maintenance, correspondence with MEL personnel for sample delivery and bottle ordering, budget tracking, and field staff training.

The project manager or field lead for each sample event is responsible for:

- Prepping all field gear (e.g., sampling poles, gloves, filters).
- Ensuring adequate supply of sample bottles.
- Cancelling assessments if conditions warrant.
- Complying with field and safety procedures.
- Knowledge of use and location of the safety equipment.
- Sample handling and processing, including chemical safety protocols.
- Emergency procedures.

9.0 Laboratory Procedures

9.1 Lab procedures table

Ecology's Manchester Environmental Laboratory (MEL) conducts laboratory analyses and procedures following Standard Operating Procedures (SOPs) and other guidance documents. Analytical methods and lower reporting limits are listed in Table 11.

Table 11. Measurement methods (laboratory)

Analyte	Sample Matrix	Samples (Number/ Arrival Date)	Expected Range of Results	Detection or Reporting Limit	Sample Prep Method	Analytical (Instrumental) Method
Fecal coliform (MF)	Water	792	1-15,000 cfu/100 mL	1 cfu/100 mL (RL)	n/a	SM9222 D
E. coli (MF)	Water	792	1-15,000 cfu/100 mL	1 cfu/100 mL (RL)	n/a	SM9222 G

9.2 Sample preparation method(s)

Sample preparation methods are listed in standard operating procedures for lab analyses or in analytical methods.

9.3 Special method requirements

NA

9.4 Laboratories accredited for methods

All chemical analysis will be performed at MEL, which is accredited for all methods.

10.0 Quality Control Procedures

Implementing quality control (QC) procedures provides the information needed to assess the quality of the data that is collected. These procedures also help identify problems or issues associated with data collection and/or data analysis while the project is underway.

10.1 Table of field and laboratory quality control

The primary types of QC samples used to evaluate and control the accuracy of laboratory analyses are check standards, duplicates, spikes, and blanks (MEL, 2016). Check standards serve as an independent check on the calibration of the analytical system and can be used to evaluate bias. MEL routinely duplicates sample analyses in the laboratory to determine laboratory precision. Matrix spikes are used to check for matrix interference with detection of the analyte and can be used to evaluate bias as it relates to matrix effects. Blanks are used to check for sample contamination in the laboratory process. Laboratory and field QC procedures are presented in Table 12.

Table 12. Quality control samples, types, and frequency

Parameter	Field Blanks	Field Replicates	Laboratory Check Standards	Laboratory Method Blanks	Analytical Duplicates	Laboratory Matrix Spikes
Fecal coliform (MF)	n/a	10-30%	n/a	n/a	1/batch	n/a
E. coli	n/a	10-30%	n/a	n/a	1/batch	n/a

10.2 Corrective action processes

QC results may indicate problems with data during the course of the project. Corrective action processes will be used if activities are found to be inconsistent with this QAPP, if results do not meet MQOs or performance expectations, or if some other unforeseen problems arise. Options for corrective actions might include:

- Retrieving missing information.
- Re-analyzing samples within holding time requirements.
- Modifying the analytical procedures.
- Requesting additional sample collection.
- Qualifying results.

11.0 Data Management Procedures

11.1 Data recording and reporting requirements

The Environmental Information System (EIM) Study ID for this project is EFF_LSRT.

Staff will record all field data in a field notebook. Before leaving each site, staff will check field notebooks for missing or improbable measurements. Staff will enter field-generated data into EIM as soon as is practical after they return from the field. Data entry will be checked against the field notebook data for errors and omissions.

Lab results will be checked for missing and/or improbable data. MEL will send data through Ecology's Laboratory Information Management System (LIMS). Data will be checked for completeness and reviewed for any additional required qualifiers.

The project web page (https://ecology.wa.gov/Research-Data/Monitoring-assessment/Water-quality-improvement-effectiveness-monitoring/Lower-Snohomish-River-Tributaries) will host a story map that will include the following:

- Map of monitoring locations
- Map of TMDL implementation work (e.g. stream restoration projects)
- Data visualizations of water quality results, updated as we receive them from the lab
- Map of stream reaches meeting or exceeding water quality standards based on sampling data
- Data visualization of progress toward TMDL targets

Data summaries and web maps will be presented in free form on Ecology's Effectiveness Monitoring web page: https://ecology.wa.gov/Research-Data/Monitoring-assessment/Water-quality-improvement-effectiveness-monitoring.

11.2 Laboratory data package requirements

Laboratory-generated data reduction, review, and reporting will follow procedures outlined in MEL's *Lab Users Manual* (MEL, 2016). Variability in lab duplicates will also be quantified using procedures in this 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 will provide all data electronically to the project manager through the LIMS to EIM data feed. There is already a protocol in place for how and what MEL transfers to EIM through LIMS.

11.4 EIM/STORET data upload procedures

All water quality 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.

11.5 Model information management

NA

12.0 Audits and Reports

12.1 Field, laboratory, and other audits

Audits will be conducted at the end of the project on all EIM data to check for missing values, extreme outliers, negative values, and duplicates. Any errors found will be investigated and corrected if possible. Audits of field procedures and sample processing are not planned for this study.

12.2 Responsible personnel

The project manager is responsible for the final report. The project manager is also responsible for communicating with TMDL and non-point staff about status and trends throughout the study period. This may be in the form of various products and presentations of results.

12.3 Frequency and distribution of reports

A peer-reviewed technical report or water quality improvement report will be completed and published to Ecology's website. The final report will also be distributed to all managers, clients, tribes, municipalities, and other stakeholders involved or interested in the study. Ecology has specific publication guidelines depending on the type of final report that describe the exact requirements necessary for publication.

12.4 Responsibility for reports

The project manager is responsible for the final report. The project manager is also responsible for communicating with TMDL and non-point staff about status and trends throughout the study period. This may be in the form of various products and presentations of results.

13.0 Data Verification

Data verification and review is conducted by the project manager by examining all field and laboratory-generated data to ensure:

- Specified methods and protocols were followed.
- Data are consistent, correct, and complete, with no errors or omissions.
- Data specified in the *Sampling Process Design* section were obtained.
- Results for QC samples, as specified in the *Measurement Quality Objectives* and *Quality Control*, accompany the sample results.
- Established criteria for QC results were met.
- Data qualifiers (QC codes) are properly assigned.

13.1 Field data verification, requirements, and responsibilities

Throughout field sampling, the field staff are responsible for carrying out station positioning, sample collection, and field measurement procedures as specified in the QAPP and SOPs. Additionally, staff systematically review all field documents (such as field logs, COCs, and sample labels) to ensure data entries are consistent, correct, and complete, with no errors or omissions.

13.2 Laboratory data verification

MEL staff will perform laboratory verification following standard laboratory practices (MEL, 2016). After the lab verification, the project manager will perform a secondary verification of the data. This secondary verification will entail a detailed review of all parts of the lab data with special attention to lab QC results. After data entry and data validation tasks are completed, all field and laboratory data will be entered into the EIM system. EIM data will be independently reviewed by staff for errors at an initial 10% frequency. If significant entry errors are discovered, a more intensive review will be undertaken.

13.3 Validation requirements, if necessary

NA

13.4 Model quality assessment

NA

14.0 Data Quality (Usability) Assessment

14.1 Process for determining project objectives were met

After all laboratory and field data are verified and validated, the project manager will thoroughly examine the data, using statistics and professional judgment, to determine if MQOs have been met for completeness, representativeness, and comparability. If the MQOs in the QAPP have not been met, the project manager will assess the degree to which affected data deviate from the MQOs and decide whether to qualify or reject the data. The project manager will decide how any qualified data will be used in the technical analysis.

14.2 Treatment of non-detects

Any non-detects will be included in the study analysis. For bacteria values below the detection limit, a conservative value of the detection limit minus one significant digit will be used (Sargent and Lowe, 2014). For bacteria values above the detection limit, the upper detection limit plus one significant digit will be used.

14.3 Data analysis and presentation methods

Data analysis consists of comparing results to water quality standards and detecting changes in monitoring parameters over time. Procedures comparing results to water quality standards are defined in the following:

- Ecology's Water Quality Program Policy 1-11: https://ecology.wa.gov/Water-Shorelines/Water-quality/Water-improvement/Assessment-of-state-waters-303d/Assessment-policy-1-11
- Guidance for Effectiveness Monitoring of Total Maximum Daily Loads in Surface Waters (Collyard and Onwumere, 2013)
- Programmatic QAPP for Water Quality Impairment Studies (McCarthy and Mathieu, 2017)

14.4 Sampling design evaluation

The project manager will decide whether data meet the MQOs, criteria for completeness, representativeness, and comparability, and whether meaningful conclusions (with enough statistical power) can be drawn from the results and analysis. If so, the sampling design will be considered effective. The sampling design will be considered successful if project objectives are met.

14.5 Documentation of assessment

In the technical report, the project manager will include a summary of the data quality assessment findings. This summary will be included in the data quality section of the report.

15.0 References

APHA, AWWA, and WEF, 1998. Standard Methods for the Examination of Water and Wastewater 20th Edition. American Public Health Association, Washington, D.C.

Collyard, S. and Onwumere, G., 2013. Guidance for Effectiveness Monitoring of Total Maximum Daily Loads in Surface Water. Washington State Department of Ecology, Olympia, WA. Publication 13-03-024. https://apps.ecology.wa.gov/publications/SummaryPages/1303024.html

Cusimano, Robert F. and Randy Coots, 1997. Water Quality Assessment of Tributaries to the Snohomish River and Nonpoint Source Pollution TMDL Study. Publication 97-334. Washington Department of Ecology Water Quality Program Olympia, WA. 52 pps plus appendices. https://apps.ecology.wa.gov/publications/SummaryPages/97334.html

Ecology, 2019a. Permits – Point Source Pollution. Water Quality Program, Washington State Department of Ecology, Olympia, WA. https://ecology.wa.gov/Water-Shorelines/Water-quality/Water-quality-permits

Ecology, 2019b. River and Stream Water Quality Monitoring. Environmental Assessment Program, Washington State Department of Ecology, Olympia, WA. https://ecology.wa.gov/Research-Data/Monitoring-assessment/River-stream-monitoring.

Ecology, 2019c. Quality Assurance at Ecology. Environmental Assessment Program, Washington State Department of Ecology, Olympia. https://ecology.wa.gov/About-us/How-we-operate/Scientific-services/Quality-assurance.

Ecology, 2019d. Water Quality Data Quality Assessment. Water Quality Program, Washington State Department of Ecology, Olympia, WA. https://ecology.wa.gov/Research-Data/Monitoring-assessment/River-stream-monitoring/Water-quality-monitoring/River-stream-monitoring-methods

Ecology, 2012. Washington State Water Quality Assessment. Water Quality Program, Washington State Department of Ecology, Olympia, WA. https://ecology.wa.gov/Water-Shorelines/Water-quality/Water-improvement/Assessment-of-state-waters-303d

Lombard, S. and C. Kirchmer, 2004. Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies. Washington State Department of Ecology, Olympia, WA. Publication 04-03-030. https://apps.ecology.wa.gov/publications/SummaryPages/0403030.html

Mathieu, N., 2006. Replicate Precision for 12 Total Maximum Daily Load (TMDL) Studies and Recommendations for Precision Measurement Quality Objectives for Water Quality Parameters. Washington State Department of Ecology, Olympia, WA. Publication 06-03-044. https://apps.ecology.wa.gov/publications/SummaryPages/0603044.html

MEL, 2016. Manchester Environmental Laboratory *Lab Users Manual*, Ninth Edition. Manchester Environmental Laboratory, Washington State Department of Ecology, Manchester, WA.

Ott, W., 1995. Environmental Statistics and Data Analysis. Lewis Publishers, New York, NY.

Snohomish County Public Works, 2015. Snohomish County Total Maximum Daily Load Monitoring Quality Assurance Project Plan. Snohomish River Tributaries, Stillaguamish Basin, North, Swamp and Little Bear Creek TMDL Coverage Areas 2015 – 2018. Snohomish County Public Works. Snohomish County, WA.

Svrjcek. R., 2003. Lower Snohomish River Tributaries Fecal Coliform Bacteria Total Maximum Daily Load: Detailed Implementation Plan. Washington State Department of Ecology, Bellevue, WA. Publication 03-10-031. https://apps.ecology.wa.gov/publications/publications/0310031.pdf

WAC 173-201A. Water Quality Standards for Surface Waters in the State of Washington. Washington State Department of Ecology, Olympia, WA. http://app.leg.wa.gov/WAC/default.aspx?cite=173

Ward, W.J., 2007. Collection, Processing, and Analysis of Stream Samples, Version 1.3. Washington State Department of Ecology, Olympia, WA. SOP EAP034. https://www.ecology.wa.gov/About-us/How-we-operate/Scientific-services/Quality-assurance

Wright, R.J., Coots, R., and Cusimano R.F. 2001. Snohomish River Tributaries Fecal Coliform Total Maximum Daily Load. Submittal Report. Washington State Department of Ecology, Olympia, WA. Publication 00-10-087. https://apps.ecology.wa.gov/publications/SummaryPages/0010087.html

16.0 Appendix. Glossaries, Acronyms, and Abbreviations

Glossary of General Terms

Char: Fish of genus *Salvelinus* distinguished from trout and salmon by the absence of teeth in the roof of the mouth, presence of light-colored spots on a dark background, absence of spots on the dorsal fin, small scales, and differences in the structure of their skeleton. (Trout and salmon have dark spots on a lighter background.)

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

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

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

Effluent: An outflowing of water from a natural body of water or from a human-made structure. For example, the treated outflow from a wastewater treatment plant.

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.

Load allocation: The portion of a receiving water's loading capacity attributed to one or more of its existing or future sources of nonpoint pollution or to natural background sources.

Loading capacity: The greatest amount of a substance that a water body can receive and still meet water quality standards.

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

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

National Pollutant Discharge Elimination System (NPDES): National program for issuing, modifying, revoking and reissuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements under the Clean Water Act. The NPDES program regulates discharges from wastewater treatment plants, large factories, and other facilities that use, process, and discharge water back into lakes, streams, rivers, bays, and oceans.

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

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

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

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

Point source: Source of pollution that discharges at a specific location from pipes, outfalls, and conveyance channels to a surface water and is subject to regulation under the NPDES program.

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*. Species of salmon, trout, or char.

Stormwater: That portion of precipitation that does not naturally percolate into the ground or evaporate, but flows via overland flow, interflow, pipes and other features of a stormwater drainage system into a defined surface waterbody, or a constructed infiltration facility.

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

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

Wasteload allocation: The portion of a receiving water's loading capacity allocated to existing or future point sources of pollution. Wasteload allocations constitute one type of water quality-based effluent limitation.

Watershed (Basin): 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

DO	(see Glossary above)
EAP	Environmental Assessment Program
e.g.	For example
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
et al.	And others
FC	(see Glossary above)
GIS	Geographic Information System software
MEL	Manchester Environmental Laboratory
MQO	Measurement quality objective
NPDES	(See Glossary above)
QA	Quality assurance

QAPP	Quality Assurance Project Plan
QC	Quality control
RPD	Relative percent difference
RSD	Relative standard deviation
SOP	Standard operating procedure
TMDL	(see Glossary above)
USGS	United States Geological Survey
WAC	Washington Administrative Code
WQP	Water Quality Program
WRIA	Water Resource Inventory Area
WWTP	Wastewater treatment plant

Units of Measurement

°C	degrees centigrade
Cfs	cubic feet per second
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 sample 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).

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): 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): 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 are usable for intended purposes.
- J (or a J variant) – data are estimated, may be usable, may be biased high or low.
- REJ – data are 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 which 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).

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 Quality Objectives (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:

$$[\text{Abs}(a-b)/((a + b)/2)] * 100$$

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).

Standard Operating Procedure (SOP): A document which 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

Ecology, 2004. Guidance for the Preparation of Quality Assurance Project Plans for Environmental Studies. Washington State Department of Ecology, Olympia, WA. https://apps.ecology.wa.gov/publications/SummaryPages/0403030.html.

Kammin, B., 2010. Definition developed or extensively edited by William Kammin, 2010. Washington State Department of Ecology, Olympia, WA.

USEPA, 2006. Guidance on Systematic Planning Using the Data Quality Objectives Process EPA QA/G-4. http://www.epa.gov/quality/qs-docs/g4-final.pdf.

USGS, 1998. Principles and Practices for Quality Assurance and Quality Control. Open-File Report 98-636. U.S. Geological Survey. http://ma.water.usgs.gov/fhwa/products/ofr98-636.pdf.