Quality Assurance Project Plan

Nonpoint Pollution Investigations in Western Washington

By

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For the

Water Quality Program

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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. This QAPP was approved to begin work in July 2021. It was finalized and approved for publication in September 2021.

Cover photo: Woodard Creek Estuary. Photo by Ecology Coastal Atlas staff.

Related Information

- Data for this project are available in Ecology's EIM Database[1].
- Federal Clean Water Act 1996 303(d) Listings addressed in this study. See Section 3.3.

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[1] www.ecology.wa.gov/eim
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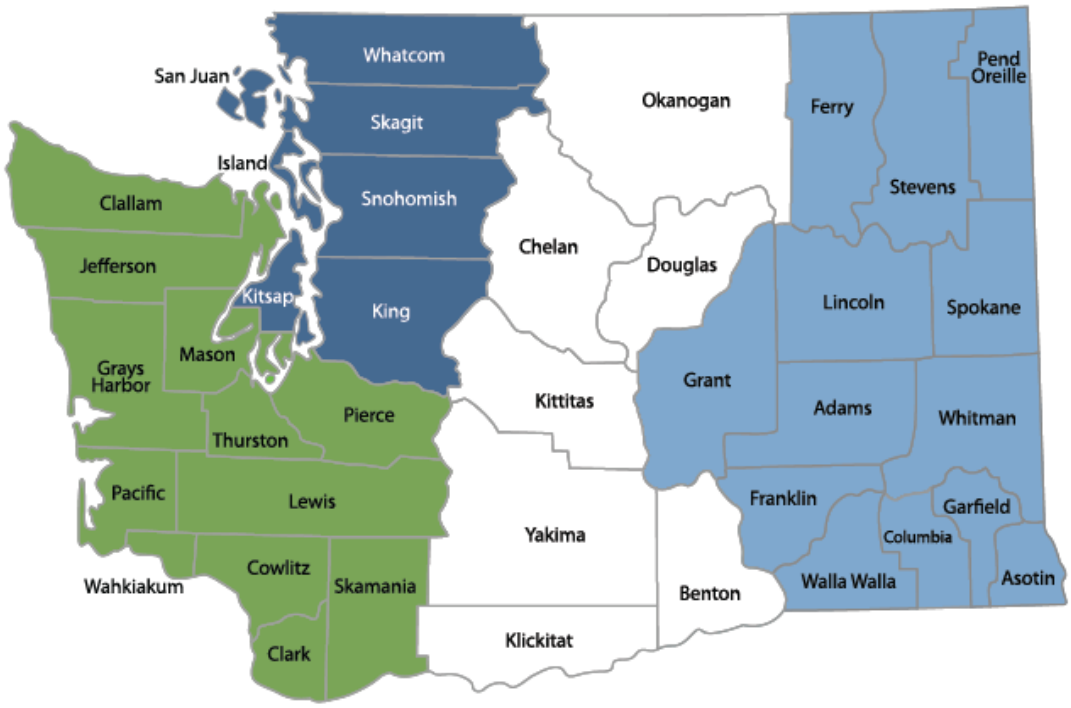
Department of Ecology's Regional Offices

Map of Counties Served



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1.0 Table of Contents

1.0 Table of Contents 5
List of Figures and Tables 7
Figures 7
Tables 7
2.0 Abstract 8
3.0 Background 8
3.1 Introduction and problem statement 8
3.2 Study area and surroundings 9
3.3 Water quality studies 17
4.0 Project Description 20
4.1 Project goals 20
4.2 Project objectives 20
4.3 Information needed and sources 20
4.4 Tasks required 21
4.5 Systematic planning process 21
5.0 Organization and Schedule 22
5.1 Key individuals and their responsibilities 22
5.2 Special training and certifications 23
5.3 Organization chart 23
5.4 Proposed project schedule 23
5.5 Budget and funding 24
6.0 Quality Objectives 25
6.1 Data quality objectives 25
6.2 Measurement quality objectives 25
6.3 Acceptance criteria for quality of existing data 30
7.0 Study Design 31
7.1 Study boundaries 31
7.2 Field data collection 31
7.3 Modeling and analysis design 34
7.4 Assumptions underlying design 34
7.5 Possible challenges and contingencies 34
8.0 Field Procedures 36
8.1 Invasive species evaluation 36
8.2 Measurement and sampling procedures 37
8.3 Containers, preservation methods, holding times 41
8.4 Equipment decontamination 43
8.5 Sample ID 43
8.6 Chain of custody 44
8.7 Field log requirements 44
8.8 Other activities 44
9.0 Laboratory Procedures 46

9.1 Lab procedures table 46
9.2 Sample preparation method(s) 47
9.3 Special method requirements 47
9.4 Laboratories accredited for methods 47
10.0 Quality Control Procedures 48
10.1 Table of field and laboratory quality control 49
10.2 Corrective action processes 49
11.0 Data Management Procedures 51
11.1 Data recording and reporting requirements 51
11.2 Laboratory data package requirements 51
11.3 Electronic transfer requirements 52
11.4 EIM/WQX data upload procedures 52
11.5 Model information management 52
12.0 Audits and Reports 53
12.1 Field, laboratory, and other audits 53
12.2 Responsible personnel 53
12.3 Frequency and distribution of reports 53
12.4 Responsibility for reports 53
13.0 Data Verification 54
13.1 Field data verification, requirements, and responsibilities 54
13.2 Laboratory data verification 55
13.3 Validation requirements, if necessary 55
13.4 Model quality assessment 55
14.0 Data Quality (Usability) Assessment 56
14.1 Process for determining project objectives were met 56
14.2 Treatment of non-detects 56
14.3 Data analysis and presentation methods 56
14.4 Sampling design evaluation 57
14.5 Documentation of assessment 57
15.0 References 58
16.0 Appendices 61
Appendix A. Regional Nonpoint Pollution Identification Projects 61
Appendix B. Glossaries, Acronyms, and Abbreviations 62

List of Figures and Tables

Figures

Figure 1. Map of Washington State showing Ecology regions and counties. 10

Figure 2. Aquatic Invasive Species Distribution in Washington State. 36

Figure 3. Bacteria water sampling equipment and sample bottles. 38

Tables

Table 1. Summary of water quality criteria for parameters assessed in this study. 15

Table 2. Organization of project staff and responsibilities. 22

Table 3. Schedule for completing field/laboratory work, data entry into EIM, and reports. 24

Table 4. MQOs for lab parameters. 26

Table 5. MQOs for parameters measured in the field. 28

Table 6. Laboratory analytes and field parameters. 34

Table 7. Sample containers, preservation method, and holding times. 42

Table 8. Measurement methods (laboratory). 46

Table 9. Rating of accuracy for field instruments. 48

Table 10. Quality control samples, type, and frequency. 49

2.0 Abstract

The Washington State Department of Ecology (Ecology) is required by Section 303(d) of the federal Clean Water Act (CWA) and U.S. Environmental Protection Agency (EPA) regulations to develop and implement Total Maximum Daily Loads (TMDLs) or alternative clean up plans for impaired waters. Ecology's Water Quality Program also investigates water quality in non-TMDL waters. These investigations include complaint-related studies recorded in the agency's Environmental Report Tracking System (ERTS), work related to Pollution Identification and Correction (PIC) programs, and basic characterization to determine compliance with state standards.

The purpose of this Quality Assurance Project Plan (QAPP) is to ensure that water quality investigations conducted in western Washington, by TMDL and Nonpoint staff from Ecology's Northwest Regional Office, Southwest Regional Office, and Field Offices, result in credible data. The EPA requires Ecology to prepare QAPPs for all EPA-funded projects that generate environmental data. Washington State's Water Quality Data Act (WQDA) also requires the generation and use of credible data in certain water quality-related actions as defined in Revised Code of Washington (RCW) 90.48.570 through 90.48.590. This QAPP describes a programmatic strategy and consistent methods for collecting credible water quality data and samples. It then details procedures for handling and analyzing those water samples and data.

This QAPP describes elements that are regularly used in the water quality investigation study process. It serves as the main reference for smaller water quality studies conducted by Nonpoint staff in different areas over time. The specific details for individual investigation projects are described in sections of Appendix A. Regional office staff will update these sections as prior projects are completed and plans are made to work on new watersheds or water bodies. Addendums to Appendix A will be prepared when proposing substantive changes, such as addition of new field or laboratory methods or parameters.

3.0 Background

3.1 Introduction and problem statement

Ecology Water Quality Program (WQP) staff routinely conduct water quality investigations, complaint-related studies (which are recorded in the agency's Environmental Report Tracking System (ERTS)) and may participate in pollution identification and correction (PIC) projects. Each year these projects characterize water quality in multiple watersheds of western Washington. This plan describes sampling methods and the analysis of the water samples that may be collected. Three levels of sampling with different purposes are described. Not all projects will require all three levels, but all three levels are described so they can be applied consistently when needed.

Excess bacteria is a common pollution problem in regional streams, lakes, and marine water. It indicates an increased risk of illness to the public, and affects beneficial uses such as swimming,

boating, fishing, wading, shellfish harvesting, and other water-related activities. Bacteria water quality criteria are set to protect people who work and play in and on the water from waterborne illnesses. In the Washington State Water Quality Standards, several types of bacteria are used as "indicator bacteria." Bacteria in the water "indicates" the presence of waste from humans and other warm-blooded animals. Warm-blooded animal waste is more likely to contain pathogens that will cause illness in humans than waste from cold-blooded animals. These bacteria criteria are set at levels that limit the risk of serious intestinal illness (gastroenteritis) in people.

There are three types of indicator bacteria included in this QAPP*; Escherichia coli* (*E. coli*), enterococci, and fecal coliform (FC). These bacteria are used to evaluate the risk to human health depending on different types of beneficial uses, as recommended in federal water quality standards. The levels of *E. coli* and enterococci strongly correlate with the incidence of gastrointestinal illnesses during water contact recreation. In streams and lakes, *E. coli* is used as the best indicator for fecal contamination. Enterococci is used to evaluate health risk in saltwater. FC bacteria are used for evaluating pollution levels in shellfish growing as required by the US Food and Drug Administration (FDA) and National Shellfish Sanitation Program (NSSP) guidelines. Regulatory standards for each of these bacteria are included in Table 1 as defined in Chapter 173-201A Washington Administrator Code (WAC), Water Quality Standards for Surface Waters of the State of Washington.

Other parameters may be investigated depending on the water quality problems identified in each watershed or project area. These parameters are described below in Section 3.2.3.

3.2 Study area and surroundings

The study area of this QAPP includes all of western Washington, although the geographic scale of individual water quality investigation projects ranges from small (for example, investigative sampling on a stretch of a stream or the impacts of a single pollution discharge) to large (for example, the watershed of an entire river and its tributaries).

The information in Appendix A describes the watersheds and sampling locations in western Washington where Ecology staff plan to conduct Nonpoint pollution investigations. Different sections of Appendix A describe the work done through each Regional or Field Office. Ecology staff will update these sections when new watersheds and sampling locations are chosen. This will usually be done annually based on mapping and review of existing water quality data in Ecology's Environmental Information Management (EIM) system, current listings of impaired water bodies under Section 303(d) of the CWA, and other factors relevant to water quality. Addendums will also be prepared when proposing substantive changes to the QAPP, such as new field or laboratory methods or parameters.

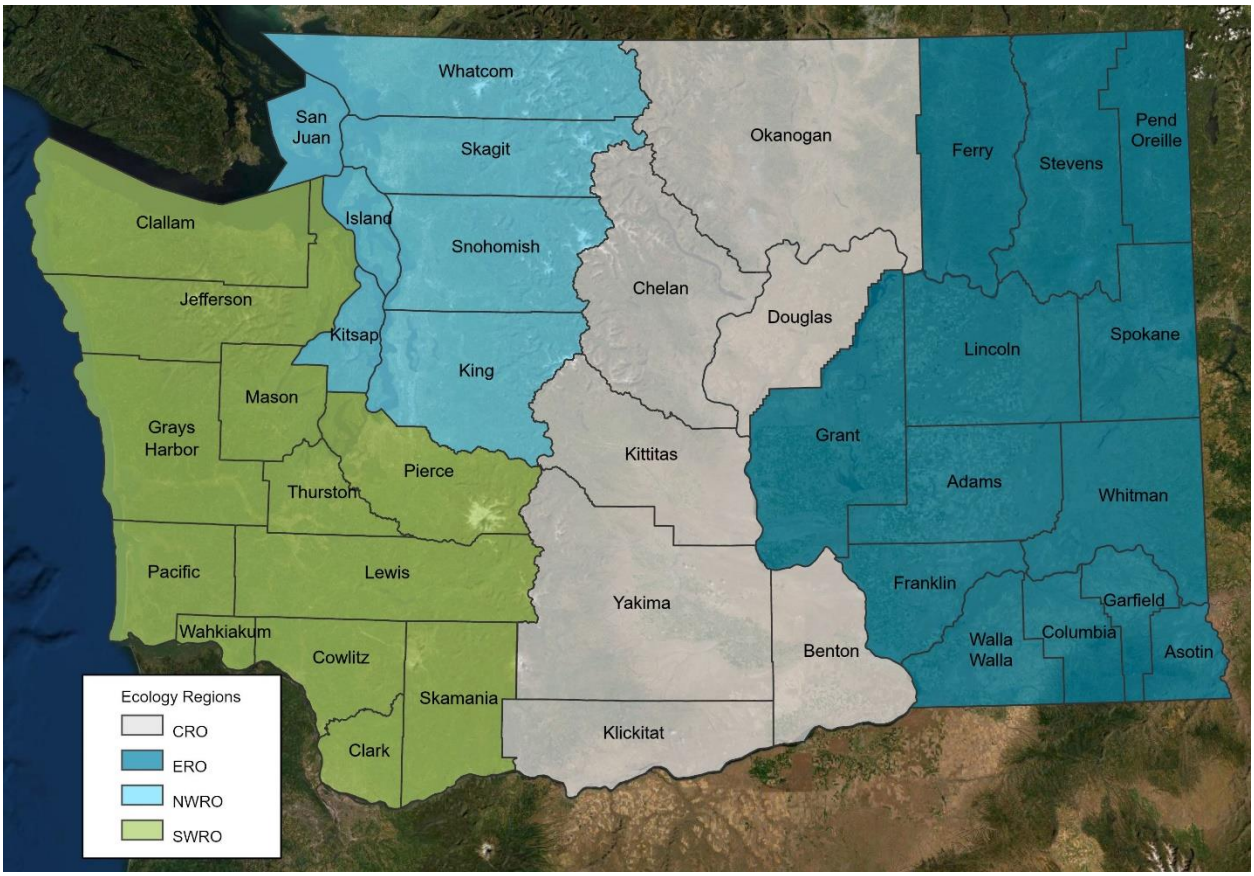

Figure 1. Map of Washington State showing Ecology regions and counties.

3.2.1 History of study area

This information is provided in Appendix A for each water quality investigation project.

3.2.2 Summary of previous studies and existing data

Current and historic water quality improvement projects in Washington listed by county can be found on Ecology's WQ Improvement Projects by County webpage[3].

Ecology's Environment Information Management (EIM) database contains data collected by Ecology and affiliates, such as local governments. EIM allows for the accessibility of discrete and time-series environmental data for air, water, soil, sediment, aquatic animals, and plants from water quality impairment studies and other studies (EIM Database[4]).

Information on previous studies and existing data for each water quality project area is provided in Appendix A as needed.

[3] https://ecology.wa.gov/Water-Shorelines/Water-quality/Water-improvement/Total-Maximum-Daily-Load-process/Directory-of-improvement-projects
[4] https://ecology.wa.gov/Research-Data/Data-resources/Environmental-Information-Management-database

3.2.3 Parameters of interest and potential sources

Projects conducted under this QAPP may address a variety of conventional parameters including bacteria, turbidity, pH, temperature, nutrients, and dissolved oxygen (DO). Source tracing may require the collection of additional parameters such as optical brighteners, genetic markers, and streamflow. See Appendix A for additional information about specific projects.

3.2.3.1 Bacteria

Bacteria indicators, such as *E. coli*, enterococci, and FC bacteria are used as indicators of fecal contamination and the presence of disease-causing (pathogenic) organisms from humans and 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. High bacteria concentrations in waterways may indicate an increased risk of infection from pathogens associated with fecal waste.

During sufficient precipitation events, rainwater washes the surface of the landscape and impervious surfaces, saturates soils, and raises water tables. Runoff from stormwater can accumulate and transport fecal matter. Stormwater runoff containing fecal matter may drain to receiving water bodies and potentially degrade water quality.

Potential sources of bacteria include:

- Waterfowl, rodents, and other warm-blooded wildlife.
- Range and pastured livestock with direct access to the river or stream.
- Livestock manure applied to fields, runoff of soil that receive manure applications, or manure leached from storage areas.
- Flooding of pastures and/or residential properties that mobilizes livestock and/or human waste.
- Resuspension of sediment colonized by fecal bacteria in the water column.
- Bacteria regrowth.
- Pet waste.
- Nuisance pest attractants such as uncovered dumpsters.
- Animal waste tracked by vehicle tires.
- Pulp and wood waste.
- Failing, poorly constructed or poorly maintained on-site sewage systems (OSS).
- Sanitary sewer overflows that reach surface waters directly and/or through formal and informal stormwater drainage systems (e.g., catch basins, pipes, ditches, swales).
- Combined sewer overflows.
- Improperly or inadequately treated sewage, including sporadic spills and/or illegal dumping of sewage.

3.2.3.2 Turbidity

Turbidity is a measure of light refraction in the water that indicates water quality based on the amount of sediment and suspended solids within the water column. The higher the intensity of

scattered light, the higher the turbidity. Turbidity is an indicator of suspended particles such as clay, silt, organic matter, and small organisms. Suspended solids in the water column and settled bottom sediments affect fish and other aquatic life.

Potential sources of increased turbidity include:

- Forestry, agricultural activities, and other land disturbance practices that expose soils to stormwater runoff.
- Range and pastured livestock with direct access to waterways.
- Eroding soil from construction sites, stream banks, and other areas with disturbed soils and a lack of erosion controls.
- Lack of riparian vegetation.
- Inadequate stormwater runoff flow controls that leads to stream bank erosion.
- Stormwater runoff from impervious surfaces that has mobilized surface particles such as street dirt, particles from air deposition, and dust.
- Flooding.

3.2.3.3 pH

The pH of natural waters is a measure of acid-base equilibrium achieved by the various dissolved compounds, salts, and gases. pH is an important factor in the chemical and biological systems of natural waters. pH both directly and indirectly affects the ability of waters to have healthy populations of fish and other aquatic species. Changes in pH affect the degree of dissociation of weak acids or bases and influence the toxicity of many compounds. While some compounds (e.g., cyanide) increase in toxicity at lower pH, others (e.g., ammonia) increase in toxicity at higher pH.

Human activity and development can raise or lower instream pH through many mechanisms and activities, which include:

- Mining activities.
- Industrial and domestic wastewater point-source discharges of acidic or basic substances to surface waters.
- Atmospheric deposition of sulfuric compounds emitted by industry.
- Reduced soil-buffering capacity with export of base cations (from the watershed) through forest harvest.
- Increased algal and plant photosynthesis due to eutrophication. Point source and Nonpoint source loading of nitrogen and phosphorus typically drive increased algal and plant growth and photosynthesis. When excess phosphorus or nitrogen is available, algae use it to build additional cell mass, obtaining carbon for new growth from carbon dioxide that is naturally present in river water. Because carbon dioxide affects the pH of the water, carbon uptake by algae causes the river to become less acidic and more basic. As a result, the pH of the river increases during daylight hours when photosynthesis occurs.

3.2.3.4 Temperature

Temperature affects the physiology and behavior of fish and other aquatic life. Temperature also affects the physical and biological properties of the water body, which can increase the harmful effects of other pollutants. For example, the warmer a stream is, the less oxygen it can hold for the organisms the stream supports. Therefore, temperature is an influential factor, which can limit the distribution and health of aquatic life.

Temperatures in waterbodies fluctuate over the day and year in response to changes in solar energy inputs, meteorological conditions, river flows, groundwater input, and other factors. Human activities can influence many of these factors that impair the health of the water by either increasing the temperature or by improving these conditions to promote cooler temperatures.

Potential sources of heat load that can increase water temperature include:

- Loss of riparian shade.
- Point source discharges of wastewater or stormwater.
- Loss of baseflow/groundwater from water withdrawals, or other physical changes in the watershed such as increasing impervious surfaces.
- Changes in the depth of stream channels from sediment loads.
- Loss of channel complexity/hyporheic exchange.

3.2.3.5 Nutrients

When an abundance of phosphorus or nitrogen is available, excessive algal growth can ultimately lead to higher pH and lower DO. Potential sources of anthropogenic nutrient loading include:

- Failing, poorly constructed or poorly maintained on-site sewage systems.
- Domestic wastewater (i.e., sewage).
- Poor livestock or pet manure management.
- Livestock with direct access to the waterways.
- Fertilization on agricultural lands and lawns.
- Bank erosion and leaching of soils from practices such as forest harvesting.
- Wildlife.
- De-icing activities at airports and roadways.
- Atmospheric deposition.
- Wet deposition in the form of precipitation or snow.

3.2.3.6 Dissolved Oxygen

Aquatic organisms are very sensitive to reductions in the level of DO in the water. The health of fish and other aquatic species depends on maintaining an adequate supply of oxygen dissolved in the water. DO levels affect growth rates, swimming ability, susceptibility to disease, and the relative ability to endure other environmental stressors and pollutants.

DO levels can fluctuate over the day and night in response to changes in climatic conditions as well as the respiratory requirements of aquatic plants and algae. The diurnal cycle of algal growth adds DO during the daylight hours as the plants perform photosynthesis, but reduces DO levels at night, reaching a minimum around daybreak, as respiration is predominant.

Changes in DO levels can be influenced by:

- High water temperatures that lower the ability of water to hold oxygen, causing warm water to hold less oxygen than cold water.
- Groundwater discharges affect DO levels and nutrient concentrations in streams. DO is often lower in groundwater.
- The combination of biological, biochemical, and chemical processes at the sediment-water interface, called sediment oxygen demand, consuming DO in the overlying water.
- Nutrient-containing discharges from wastewater or stormwater (point sources) or diffuse sources (Nonpoint sources) which influence biochemical oxygen demand (BOD).
- Increased algal and plant photosynthesis due to cultural eutrophication. Increased point and Nonpoint source loading of nitrogen and phosphorus drive plant and algal growth and photosynthesis, which increases the severity of the diurnal DO fluctuation. This can result in lower levels of DO than under natural conditions.

3.2.4 Regulatory criteria or standards

Ecology is responsible for setting limits on pollution by establishing water quality standards for surface waters in Washington. Ecology establishes standards to sustain public health and public enjoyment of lakes, streams, and marine water for swimming and fishing. The standards also help protect other beneficial uses such as the propagation and protection of fish, shellfish, and wildlife. The Water Quality Standards for Surface Waters of the State of Washington are found in WAC Chapter 173-201A, which may change over time.

The standards include an anti-degradation policy that requires the protection and maintenance of existing uses. Different criteria may apply to areas depending on the beneficial uses present. Table 1 details Specific water quality criteria for some measured variables.

Ecology recently adopted amendments to Chapter 173-201A WAC to update the bacteria criteria for recreational use to align with the US EPA recommendations. *E. coli* is currently the primary indicator to protect water contact recreation in freshwater due to the strong correlation with illness from waterborne diseases. As of December 31, 2020, FC is no longer used to determine compliance with recreational use criteria. Current FC listings in freshwaters will remain in place until *E. coli* data is collected to update the listing. Section 14.3.1 provides more details on the process for determining compliance with the updated bacteria criteria.

Shellfish harvesting criteria for marine and brackish waters continues to be based on FC. Water contact recreation criteria is based on enterococci in marine and brackish waters. Studies such as TMDLs and effectiveness monitoring in marine and brackish waters that are designed to protect shellfish use are required to use the FC criteria specifically for shellfish use.

Additionally, studies in freshwater waterbodies that have potential impacts to downstream marine uses are also required to use the same FC criteria.

Studies in development that are designed to protect and regulate recreational uses in waterbodies with no downstream shellfish use should be based on *E. coli.* Studies such as FC TMDLs that were approved before December 31, 2020 remain unchanged. Yet, follow up effectiveness monitoring may involve E. coli analysis to determine compliance with recreational use criteria. Alternatively, dual parameter monitoring of FC and *E. coli* may be used to compare to past FC data and determine the compliance with recreational use criteria.

Programs such as local PIC programs that monitor for FC are not required to make changes as a result of the WAC change. Though not applicable as regulatory criteria in most freshwater settings, FC may still be used as an indicator to identify pollution sources, help prioritize areas or sites for clean-up efforts and communicate progress of water quality improvement. Ultimately, the selection of an appropriate bacteria indicator depends on whether the type of monitoring suitably meets the program's goals and objectives.

Other parameters may be investigated depending on the water quality problems identified in each watershed or project area as described in Appendix A.

Table 1. Summary of water quality criteria for parameters assessed in this study.

Parameter	Criteria
Escherichia coli (*E. coli*) Bacteria (fresh water)	*E. coli* organism 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.
Enterococci Bacteria (marine water)	Enterococci organism levels within an averaging period must not exceed a geometric mean value of 30 CFU or MPN per 100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample values exist) obtained within the averaging period exceeding 110 CFU or MPN per 100 mL.
Fecal coliform (shellfish growing areas)	Fecal coliform organism levels within an averaging period must not exceed a geometric mean value of 14 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 43 CFU or MPN per 100 mL.
Dissolved Oxygen	DO concentration must not fall below the criteria listed below for the specific aquatic life uses more than once ever ten years on average. When DO is lower than the criteria and due to natural conditions, human actions may not cause the DO to decrease more than 0.2 mg/L.

Parameter	Criteria
	• Char spawning and rearing: 9.5 mg/L. • Core summer salmonid habitat: 9.5 mg/L. • Salmonid spawning, rearing, and migration: 8.0 mg/L. • Salmonid rearing and migration only: 6.5 mg/L. • Non-anadromous interior redband trout: 8.0 mg/L. • Indigenous warm water species: 6.5 mg/L.
Temperature	7-day average of the daily maximum temperature (7-DADMax) must not exceed criteria listed below more than once every ten years on average. When temperature is warmer than the criteria and due to natural conditions, human actions may not cause temperature to increase more than 0.3°C. Some waterbodies also have more stringent supplemental criteria during parts of the year to further protect aquatic life uses (see subsection 173-201A-200 (1)(c)(B)(iv). • Char spawning and rearing: 12°C. • Core summer salmonid habitat: 16°C. • Salmonid spawning, rearing, and migration: 17.5°C. • Salmonid rearing and migration only: 17.5°C. • Non-anadromous interious redband trout: 18°C. • Indigenous warm water species: 20°C.
Turbidity	Turbidity shall not exceed 5 nephelometric turbidity units (NTU) over background when the background is 50 NTU or less or a 10% increase in turbidity when the background is more than 50 NTU.
pH	pH shall be within the range of 6.5 to 8.5 pH with human-caused variation within above range of less than 0.2 units for the following aquatic life uses: • Char spawning and rearing. • Core summer salmonid habitat. pH shall be within the range of 6.5 to 8.5 pH with human-caused variation within above range of less than 0.5 units for the following aquatic life uses: • Salmonid spawning, rearing, and migration. • Salmonid rearing and migration only. • Non-anadromous interior redband trout. • Indigenous warm water species.

CFU: Colony forming units
MPN: Most probable number

3.3 Water quality studies

This QAPP addresses elements that apply to different types of potential Nonpoint sampling and monitoring projects in Western Washington, which may include:

- Implementation of TMDL or water quality improvement plans.
- Source assessments.
- Straight-to-Implementation studies.
- Pre-project/reconnaissance fieldwork.
- Follow-up sampling.
- Investigative sampling.

These projects may also follow up on pollution source corrections and implementation activities resulting from TMDL or other efforts. Most monitoring done under this QAPP will be specified for each water quality investigation project in Appendix A.

3.3.1. TMDL studies

A TMDL is a numerical value representing the highest pollutant load a surface water body can receive and still meet Water Quality Standards. Any amount of pollution over the TMDL level needs to be reduced or eliminated to achieve clean water.

Federal Clean Water Act requirements

The CWA established a process to identify and clean up polluted waters. The CWA requires each state to have its own Water Quality Standards designed to protect, restore, and preserve water quality. Water Quality Standards consist of (1) designated uses for protection, such as cold water biota and drinking water supply, and (2) criteria, usually numeric criteria, to achieve those uses.

The Water Quality Assessment (WQA) and the 303(d) List and 305(b) Report

Every two years, states are required to prepare a list of water bodies that do not meet Water Quality Standards. This list is called the CWA Section 303(d) list. In Washington State, this list is part of the Water Quality Assessment (WQA) process.

To develop the WQA, the Washington State Department of Ecology (Ecology) compiles its own water quality data, along with data from local, state, and federal governments, tribes, industries, and citizen monitoring groups. All data in this WQA are reviewed to ensure that they were collected using appropriate scientific methods before they are used to develop the assessment. The list of waters that do not meet standards [the 303(d) list] is the Category 5 part of the larger assessment.

The WQA divides water bodies into five categories. Those not meeting standards are given a Category 5 designation, which collectively becomes the 303(d) list.

Category 1 – Waters that meet standards for parameter(s) for which they have been tested.
Category 2 – Waters of concern.
Category 3 – Waters with no data or insufficient data available.
Category 4 – Polluted waters that do not require a TMDL because they:
    4a – Have an approved TMDL being implemented.
    4b – Have a pollution-control program in place that should solve the problem.
    4c – Are impaired by a non-pollutant such as low water flow, dams, or culverts.
Category 5 – Polluted waters that require a TMDL, also known as the 303(d) list.

Both category 4 and category 5 waters are considered impaired. Further information is available at Ecology's Water Quality Assessment website[5].

3.3.2. Source Assessment

Source assessments are used when more information is needed about the extent of the impairment and the contributing sources, but resources or other obstacles prevent the development of a full TMDL. A source assessment is used to identify and prioritize sources of pollutants and are particularly useful for identifying Nonpoint sources of pollution. A source assessment study can serve as a standalone report, be used to justify particular compliance or permitting actions, or provide the foundation for a future TMDL, Straight-to-Implementation study, or other water quality cleanup plan.

3.3.3. Straight to Implementation Studies

Straight to implementation is a water quality improvement tool that may be completed in advance of a TMDL or water quality improvement plan. Straight to implementation can be useful when there is already data and pollutant sources have been identified. The straight to implementation report uses the data to guide future implementation activities and best management practices to address the identified pollution sources. Straight to implementation projects are typically not used in watersheds with wastewater treatment plants or other point source dischargers that need site-specific effluent limits informed by a TMDL process. Further information is available at Ecology's Straight to Implementation website[6].

3.3.4. Pre-project fieldwork

Pre-project fieldwork or reconnaissance may be necessary to gather more information about a location of interest. This work may initially begin as a standalone effort, or may be the foundation for a formal study such as a TMDL or source assessment. This pre-project/reconnaissance field works helps develop the study design and objectives and provides preliminary data to identify locations for future monitoring.

[5] https://ecology.wa.gov/Water-Shorelines/Water-quality/Water-improvement/Assessment-of-state-waters-303d
[6] https://ecology.wa.gov/Water-Shorelines/Water-quality/Water-improvement/Straight-to-implementation

3.3.5. Follow-up sampling

Follow-up sampling typically occurs following the original sampling or preliminary analysis of a study. This type of sampling is necessary when more information from the study area is needed to support the study goals and objectives.

3.3.6. Investigative sampling

Investigative samples help further characterize either identified problems from previous data collection or observed problems from documented complaints. This is also referred to as source tracing. For example, if previous results at a site show elevated bacteria concentrations, it may be necessary to take supplemental samples upstream of the site to help identify likely sources (e.g., malfunctioning on-site systems, livestock, wildlife, manure spreading, etc.) and bracket those pollution sources. Investigative samples may be collected at sites not previously included in the original project-specific QAPP in order to explore an area of concern.

Investigative samples may also be collected for complaint response purposes to address water quality concerns that require further investigation. Sampling during site inspection of complaint investigations is explained further in Section 7.2.1.3.

4.0 Project Description

This section of the QAPP describes the overall goal and objectives of conventional Nonpoint pollution investigation projects. Subsequent sections provide detailed procedures that Ecology staff will follow to achieve those objectives. Some sections of the QAPP, especially those related to laboratory analyses, contain technical terms, acronyms, and abbreviations that are defined in Appendix B. Specific information for each water quality investigation project is provided in Appendix A.

4.1 Project goals

The specific goals of the investigation projects conducted under this QAPP are to:

- Collect credible data of bacteria concentrations, turbidity, and other conventional pollutants in selected watersheds under various seasonal or hydrological conditions, including storm events.
- Assess the geographic range of significant contributors of pollution.
- Identify the pollution sources within the studied watersheds.
- Work with responsible parties to correct identified sources.
- Document water quality improvements to determine outcomes of source corrections and determine whether water bodies meet state water quality standards.

4.2 Project objectives

The results of the sampling projects will help Ecology and stakeholders focus efforts on priority pollution sources within each watershed. The objectives are:

- Collection of high quality data that is reliable for pollution source investigations and useful for measuring general stream quality.
- Public and stakeholder awareness on the level of pollution in local waters and where corrective actions are needed.
- Management of resources to control point and Nonpoint pollution.
- Attainment of Washington State surface water quality standards.

Specific project objectives will be outlined for each water quality investigation project in Appendix A.

4.3 Information needed and sources

Specific information for each water quality investigation project is provided in Appendix A. Examples of information that may be needed for individual projects include:

- A review of previous water quality studies.
- Status of shellfish growing areas within the project area.
- Current water quality conditions through samples and in situ monitoring.
- Stream flow data.
- Weather conditions and rainfall.

- Status and location of water quality improvement projects implemented by Ecology, our local partners, or other agencies and organizations.
- Stakeholder information, including information on land use, potential sources, local projects and monitoring results to be obtained from State, County, City, Tribal, and Conservation District partners, or through public websites, personal communication and direct collaboration.

4.4 Tasks required

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

Ecology staff may perform the following tasks to support the individual projects goals and objectives:

- Collect surface water samples for laboratory analysis.
- Collect surface water quality data including temperature, specific conductivity, DO, turbidity, and pH from each site when ample water is present. Ecology staff will use calibrated monitoring equipment to accomplish this task.
- Collect observational data for each sampling event and each site visit including weather conditions and any evidence of likely sources of pollution.
- Take photos to record observations, sampling locations and events.

Ecology staff also use various tools to accomplish the required tasks, which include:

- 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 and the project-specific information provided in Appendix A represent the systematic planning process and include these key elements:

- Description of the project, goals, and objectives (Section 4).
- Project organization, responsible personnel, and schedule (Sections 5 and 12).
- Study design to support the project goals/objectives and procurement of data (Sections 7, 8, and 9).
- Specification of QA and QC activities to assess the quality performance criteria (Sections 6, 10, and 11).
- Analysis of acquired data (Sections 13 and 14).

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

Table 2 provides a template that outlines the individuals involved in the project and designated responsibilities. The template should be used and completed for the specific projects added in Appendix A. Responsibilities may be shared across different titles depending on staff availability and project organization.

Table 2. Organization of project staff and responsibilities.

Staff	Title	Responsibilities
Name Program xx Regional Office Phone: xxx-xxx-xxxx	Client	Clarifies scope of the project. Provides internal review of the QAPP and approves the final QAPP.
Name xx Unit xx Section Phone: xxx-xxx-xxxx	Project Manager	Communicates and coordinates with client, project staff, managers and external entities. Keeps project on schedule. Manages budget, staff and other project resources.
Name xx Unit xx Section Phone: xxx-xxx-xxxx	Principal Investigator	Writes the QAPP. Oversees field sampling and transportation of samples to the laboratory. Conducts QA review of data, analyzes and interprets data, and enters data into EIM. Writes the draft report and final report. *Project Manager may assume Project Investigator role.*
Name xx Unit xx Section Phone: xxx-xxx-xxxx	Field Assistant	Helps collect samples and records field information.
Name xx Unit xx Section Phone: xxx-xxx-xxxx	Unit Supervisor for the Project Manager	Provides internal review of the QAPP, approves the budget, and approves the final QAPP.
Name xx Section Phone: xxx-xxx-xxxx	Section Manager for the Project Manager	Reviews the project scope and budget, tracks progress, reviews the draft QAPP, and approves the final QAPP.
Name xx Section Phone: xxx-xxx-xxxx	Section Manager for the Study Area	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.
Contract Laboratory	Project Manager	Reviews draft QAPP, coordinates with MEL QA Coordinator.

Staff	Title	Responsibilities
Chris Dudenhoeffer Water Quality Program Phone: 360-870-8409	Ecology Quality Assurance Officer	Reviews and approves the draft and final QAPP for Nonpoint studies.
Arati Kaza Environmental Assessment Program Phone: 360-407-6964	Ecology Quality Assurance Officer	Reviews and approves the draft and final QAPP for TMDL studies.

EAP: Environmental Assessment Program
EIM: Environmental Information Management database
QAPP: Quality Assurance Project Plan
TMDL: TMDL Studies

5.2 Special training and certifications

Ecology field staff are trained through education and experience. All field staff involved in water quality studies must have the relevant experience, be familiar with the required SOPs, or be trained by more senior field staff or the project manager who have the required experience. Any staff helping in the field who lack sufficient experience will always be paired with someone who has the necessary training and experience. The experienced staff will then lead the field data collection and oversee/mentor less experienced staff.

Any additional training or certifications required for work done under individual water quality investigation projects is described in Appendix A.

5.3 Organization chart

If applicable, this information is provided in Appendix A.

5.4 Proposed project schedule

Staff will investigate complaints as needed. The schedule for Nonpoint investigation projects is adaptively managed depending on the watersheds being monitored each year and status of other program efforts. Staff typically monitor selected watersheds for one year but sometimes monitor for a longer period of time.

Table 3 provides a template listing key activities, due dates, and lead staff for each project. This template should be used and completed in the project-specific QAPP addendum.

Table 3. Schedule for completing field/laboratory work, data entry into EIM, and reports.

Work type	Due date	Lead staff
Field work completed	month year	Name
Laboratory analyses completed	month year	Name
EIM data loaded [1]	month year	Name
EIM data entry review [2]	month year	Name
EIM complete [3]	month year	Name
Draft due to supervisor	month year	Name
Draft due to client/peer reviewer	month year	Name
Draft due to external reviewer(s)	month year	Name
Final (all reviews done) due to publications coordinator	month year	Name
Final report due on web	month year	Name

[1] All data entered into EIM by the lead person for this task.
[2] Data verified to be entered correctly by a different person; any data entry issues identified. Allow one month.
[3] All data entry issues identified in the previous step are fixed (usually by the original entry person); EIM Data Entry Review Form signed off and submitted to Melissa Peterson (who then enters the "EIM Completed" date into Activity Tracker). Allow one month for this step. Normally the final EIM completion date is no later than the final report publication date.

5.5 Budget and funding

Budgets for Nonpoint projects are provided in Appendix A. Additional costs for equipment, replacement, maintenance and calibrations may be included.

6.0 Quality Objectives

Quality objectives are statements of the precision, bias, and lower reporting limits necessary to meet project objectives. Precision and bias together express data accuracy. Other considerations of quality objectives include representativeness, completeness, and comparability.

6.1 Data quality objectives

The main data quality objectives (DQO) for Nonpoint investigation projects are to collect data of sufficient quantity and quality to characterize project area pollution levels and evaluate the effectiveness of pollution source correction efforts. These objectives will be met by using standard methods to achieve the measurement quality objectives (MQOs) described below 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. Precision and bias together express accuracy. Field measurements and laboratory analyses both have inherent data variability and as such, MQOs are equally important for both methods.

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 Tables 4 and 5 below.

6.2.1.1 Precision

Precision is a measure of variability between results of replicate measurements that is due to random error. 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.

Ecology staff will assess precision by analyzing duplicate field measurements or laboratory samples. Manchester Environmental Lab (MEL) will follow their standard quality control (QC) procedures to assess precision (MEL 2016). Precision will be expressed as percent relative standard deviation (% RSD) or absolute error. The MQOs for precision are defined in Table 4 for lab and field duplicates. 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). Table 5 presents MQOs for precision, as well as the manufacturer's stated accuracy, resolution, and range for field equipment that will be used in water quality studies.

6.2.1.2 Bias

Bias is the difference between the sample mean and the true value. 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.

Ecology staff assess field bias through frequent calibrations and sensor performance checks (see Section 10) and through appropriate sample collection procedures outlined in published SOPs. Bias will be evaluated for field measurements by reviewing the data and rating accuracy based on critiera in Table 9 (see Data Verification section). Lab bias will be addressed by laboratory instruments and by analyzing lab control samples, matrix spikes, and/or standard reference materials. Table 4 presents MQOs for lab parameters. Table 5 lists MQOs for field parameters

6.2.1.3 Sensitivity

Sensitivity is a measure of the capability of a field instrument or lab method to detect a substance or change in parameter. It is commonly described as a detection limit. Field instruments have a sensitivity typically reported by the manufacturer that is determined by its range, accuracy, and resolution. Sensitivity levels for all field sensors are detailed in Table 5. 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 4. MDLs for these parameters are listed in Section 9.1 (Table 8).

Table 4. MQOs for lab parameters.

Parameter	Analytical Method	Precision: Lab Duplicates (RPD)	Precision: Field Duplicates (RPD)[b]	Bias (% recovery): Matrix Spikes or SRMs	Bias (% recovery): Lab Control Samples	Bias (% recovery): Calibration Standards/ Blanks	Bias (% recovery): Method Blank Limit	Sensitivity: Method Lower Reporting Limit[a]
Ammonia-N	SM4500-NH3 H	20%	10% RSD	75-125%	80-120%	ICV/CCV: 90-110% ICB/CCB: <½ RL[c]	<½ RL[c]	0.01 mg/L
Nitrate + Nitrite-N	SM4500-NO3 I	20%	10% RSD	75-125%	80-120%	ICV/CCV: 90-110% ICB/CCB: <½ RL[c]	<½ RL[c]	0.01 mg/L
Total Persulfate Nitrogen	SM4500-N B	20%	10% RSD	75-125%	80-120%	ICV/CCV: 90-110% ICB/CCB: <½ RL[c]	<½ RL[c]	0.025 mg/L
Ortho-phosphate	SM4500-P G	20%	10% RSD	75-125%	80-120%	ICV/CCV: 90-110% ICB/CCB: <½ RL[c]	<½ RL[c]	0.003 mg/L

Parameter	Analytical Method	Precision: Lab Duplicates (RPD)	Precision: Field Duplicates (RPD)[b]	Bias (% recovery): Matrix Spikes or SRMs	Bias (% recovery): Lab Control Samples	Bias (% recovery): Calibration Standards/ Blanks	Bias (% recovery): Method Blank Limit	Sensitivity: Method Lower Reporting Limit[a]
Total Phosphorus	SM4500-P H	20%	10% RSD	75-125%	80-120%	ICV/CCV: 90-110% ICB/CCB: <½ RL[c]	<½ RL[c]	0.01 mg/L
E. coli - MF	EPA1103.[1] (mTEC2); EPA1603; SM9222G	40%	Footnote[d]	n/a	n/a	n/a	<MDL	1 cfu/100 mL
Fecal Coliform - MF	SM9222D	40%	Footnote[d]	n/a	n/a	n/a	<MDL	1 cfu/100 mL
Enterococci - MF[f]	EPA1600	40%	Footnote[d]	n/a	n/a	n/a	<MDL	1 cfu/100 mL
Fecal Coliform - MPN	SM9221E	40%	Footnote[e]	n/a	n/a	n/a	<MDL	1.8 MPN/ 100 mL
E. coli - MPN	SM9221F	40%	Footnote[e]	n/a	n/a	n/a	<MDL	1.8 MPN/ 100 mL
Enterococci – MPN[f]	SM9230B	40%	Footnote[e]	n/a	n/a	n/a	<MDL	1.8 MPN/ 100 mL
Klebsiella (%KES)[f]	MEL SOP	40%	Footnote[e]	n/a	n/a	n/a	<MDL	0%

RL: reporting limit; MDL: method detection limit; CCV: Continuing Calibration Verification; CCB: Continuing Calibration Blank;
ICV: Initial Calibration Verification; ICB: Initial Calibration Blank; RPD: Relative Percent Difference; SRM: Standard Reference Material; RSD: Relative Standard Deviation; MF: Membrane filtration; MPN: Most probable number

[a] reporting limit may vary depending on dilutions

[b] Field duplicate results with a mean of less than or equal to 5x the reporting limit will be evaluated separately

[c] or less than 10% of the lowest sample concentration for all samples in the batch

[d] 50% of replicate pairs < 20% RSD, and 90% of replicate pairs <50% RSD[b]

[e] 50% of replicate pairs < 50% RSD, and 90% of replicate pairs <100% RSD[b]

[f] MEL currently does not provide this analysis. Contract labs may have the capacity to do this analysis.

Table 5. MQOs for parameters measured in the field.

Parameter	Equipment	Duplicate Measurements: Precision	Equipment Information: Accuracy	Equipment Information: Resolution	Equipment Information: Range	Expected Range
Water Temperature	YSI ProDSS	± 0.2°C	± 0.2°C	0.1°C	-5 - 70°C	0-30°C
Specific Conductivity	YSI ProDSS	5% RSD	±0.5% of reading or 1 µS/cm, w.i.g.[a]	1 µS/cm[b]	0 – 200,000 µS/cm	20 – 1,000 µS/cm
Dissolved Oxygen	YSI ProDSS	5% RSD	± 0.1 mg/L or ± 1% of reading, w.i.g.[c]	0.01 or 0.1 mg/L (auto-scaling)	0 - 50 mg/L	0.1 - 15 mg/L
pH	YSI ProDSS	± 0.2 s.u.	± 0.2 s.u.	0.01 s.u.	0 - 14 s.u.	6 - 10 s.u.
Turbidity	YSI ProDSS	15% RSD	0 – 399.99 NTU: ± 2% of reading; 400 – 1600 NTU: ±4% of reading	0.01 NTU	0 – 1,600 NTU	0 - 500 NTU
Streamflow	SOP EAP024	10% RSD	n/a	n/a	n/a	0.01 - 2,000 cfs
Velocity	SonTek FlowTracker Handheld ADV®	5% RSD	±1%	0.01 ft/s	0.0003 - 13 ft/s	0.01 - 10 ft/s
Velocity	OTT MF Pro	5% RSD	±2.0% or ±0.05 ft/s, w.i.g.	0.003 ft/s	0 to +10 ft/s	0.01 - 10 ft/s

w.i.g.: whichever is greater.
a: for 1,4 m cables; for 10 m, 20 m, 30 m cables: ±2.0% of the reading or 1.0 uS/cm, whichever is greater.
b: range dependent, for 501 to 50,000 µS/cm: 0.01; for 50,001 to 200,000 µS/cm: 0.1.
c: accuracy is diminished outside of range.

6.2.2 Targets for comparability, representativeness, and completeness

6.2.2.1 Comparability

Comparability is a qualitative parameter expressing the confidence with which one data set can be compared to another. This goal is achieved through use of standard techniques to collect and analyze representative samples, along with standardized data verification and reporting procedures. Ecology Northwest and Southwest Regional Office staff may sample some of the

same sites sampled by local municipalities as well as additional sites. Ecology does not need to combine data from both agencies to make decisions about investigation projects but may compare data to ensure similar concentrations and trends exist in both datasets for the same sampling station.

If the datasets are not similar, Ecology will further investigate for possible reasons for the discrepancy. Variation in results derived from different analytical methods will be considered in data comparability analyses where the two different methods are used.

Ecology will achieve comparability of study results to previously collected data through following Ecology's protocols and published Ecology 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 QC procedures. When applicable, Nonpoint pollution investigations 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 2019).
- Guidance for Effectiveness Monitoring of Total Maximum Daily Loads in Surface Water (Collyard and Onwumere 2013).
- Standard Operation Procedure for Hydrolab®, DataSonde®, MiniSonde® and HL4 Multiprobes (Anderson 2020).
- Standard Operating Procedure for Measuring Streamflow for Water Quality Studies (Mathieu 2016).

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 watershed in a manner designed to meet study objectives.

Pollution investigation projects are designed to have enough sampling sites and sufficient sampling frequency to meet study objectives. However, natural spatial and temporal variability can contribute greatly to overall variability in the parameter value. For example, bacteria values are known to be highly variable over time and space. Additionally, resources limit the number of samples that staff can take at one site spatially or over various intervals of time.

Ecology staff can somewhat control spatial and temporal variability by performing the following:

- Strictly follow relevant standard operating procedures.
- Collect QC samples to assess variability.

- Sample and/or measure in well-mixed rivers and streams along the main channel in the thalweg or predominant flow.
- Avoid sampling in extreme conditions (e.g. extreme flows) if the study objective is to represent average conditions.
- Ensure there are no tributaries, outfalls or groundwater seepage immediately upstream.

6.2.2.3 Completeness

Completeness is a measure of the amount of valid data required to meet project objectives. The goal for these studies are 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 95% may be considered acceptable. If equipment fails or samples are damaged, Ecology staff may 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 a project does not meet its completeness targets, 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.

Investigative samples may not meet the minimum requirements for statistical or other data analysis, but may still be useful for source location identification, recommendations, or other analyses**.** Investigative samples may be combined with data from another project to meet sample number requirements.

6.3 Acceptance criteria for quality of existing data

In addition to collecting new environmental data, Nonpoint pollution investigations may use data collected by others, including counties, cities, conservation districts, Native American tribes and others. All data from outside Ecology will be reviewed to assess comparability.

The primary sources of historical data will be Ecology's EIM database and project files for Ecology-sponsored studies. Ecology staff may access analytical results and observational data through its EIM system and review project files to gather more information such as site-specific sampling locations and method descriptions.

7.0 Study Design

7.1 Study boundaries

The boundaries of individual water quality investigation projects are described in Appendix A.

7.2 Field data collection

Ecology staff use a variety of sampling strategies specifically chosen to answer the water quality question at hand. Examples of sampling strategies include random, stratified random, subjective, before-after-control-impact (BACI), nested paired, and spot sampling. Larger characterization projects discussed in the Appendices should list all target sampling locations and potential alternate locations as accurately as possible. If staff cannot identify sampling locations in advance of sampling, staff will describe the factors they will use to choose locations when in the field. Project descriptions should describe as accurately as possible how often and when staff will collect samples, or how staff will determine the timing of sample collection (e.g., within 4 hours of storm > 0.1" of precipitation).

Long-term ambient sampling stations are used to monitor the overall health of large watersheds (e.g., on the scale of 12- digit Hydrologic Unit Codes) over multiple years. If long-term monitoring results indicate poor water quality, Ecology may select one or more focus watersheds for pollution source investigation. Long-term ambient monitoring is described in a separate QAPP (Ecology 2003).

This QAPP defines three additional levels of sampling that may be employed, described in detail below. (1) Short-term ambient stations have a similar purpose as the long-term stations. They are used to characterize smaller water bodies to help identify sources. (2) If short-term stations do not provide sufficient resolution to identify sources, additional source identification samples may be taken. Source identification sampling typically involves more intensive bracketed sampling, which involves collecting samples upstream and downstream of an area with known water quality issues. (3) Compliance samples may be taken to verify functionality of best management practices (BMPs) or as part of site inspections.

Ecology may conduct sampling for storm events in some studies or investigations. The following section briefly describes options for this approach. If studies include storm event sampling, individual project plans in Appendix A will provide details.

7.2.1 Sampling locations and frequency

Sampling locations and frequency will vary for each project. This information is described in Appendix A. Ecology staff select sampling locations and frequency based on project budget, historical site locations, previous data, accessibility, safety, ease of access, and adequate project area coverage.

Nonpoint sampling and investigations may include a variety of conventional parameters, as described in section 7.2.2. One of the most commonly measured parameters is bacteria, which is discussed in detail below.

7.2.1.1 Short-term ambient stations

Ecology will choose short-term ambient station locations to identify the highest pollution concentrations under different flow regimes. Ecology may then use the data to prioritize smaller areas for further sampling work if necessary and to inform cleanup activities.

Ecology may sample and characterize short-term ambient stations frequently during both wet and dry seasons before identifying priority areas for pollution correction actions. Budgets ultimately influence sampling frequency, yet the typical frequency should be at least 1-2 monthly samples for at least a 1-year period. Within each month, the sampling interval should be random, but may end up being based on a fixed frequency.

Short-term (and long-term) ambient sampling stations may also be sampled by other entities. For example, the Washington State Department of Health may contract with a county to collect data at a short-term ambient station as part of a PIC program grant. If so, the data should be collected under an approved QAPP consistent with Ecology guidance.

Water quality data collected at these short-term ambient stations may be used to determine compliance with water quality criteria if there is an established water quality standard (see Section 3.2.4). Procedures for comparing results to water quality standards are defined in Ecology's Water Quality Program Policy 1-11[7].

7.2.1.2 Source identification stations

If short-term station results show water quality issues, source identification samples can be used to further investigate the area and help identify the likely sources (e.g., malfunctioning on-site systems, livestock, wildlife, manure spreading, etc.). Source identification samples are typically collected at stations that bracket areas with known water quality issues until the source is found. If necessary, Ecology staff will choose supplemental source identification stations to sample after considering relevant information such as nearby land use, parcel ownership, other local government records, streamside structures, observed overland flows and seeps, and shoreline vegetation.

Compared to short-term ambient sampling, source identification may not require sampling on a routine basis or fixed frequency. Source identification samples may involve sampling once or multiple times depending on the whether a source has been successfully identified.

[7] https://ecology.wa.gov/Water-Shorelines/Water-quality/Water-improvement/Assessment-of-state-waters-303d/Assessment-policy-1-11

7.2.1.3 Sampling during site inspections or complaint investigations

For this QAPP, a specific location or station where staff collect a sample during an inspection or site visit, or merely where staff suspect a potential significant bacteria source is located, will be termed a *confirmation station*. Staff will identify a confirmation station in field notes as being representative of receiving water, representative of a discharge to receiving waters, or representative of water with a potential to discharge to receiving waters. Samples strongly suspected of having high concentrations of bacteria or other types of pollution should be labeled or otherwise noted as such, and the laboratory should be notified to ensure appropriate dilutions are analyzed.

7.2.1.4 Storm event sampling

Ecology staff may determine whether a study or investigation should include storm event sampling. During its planning process, Ecology staff will check if others conduct storm event sampling in the project area or have established protocols. Based on recommendations from local jurisdictions or Ecology staff with storm sampling experience, Ecology may base its storm sampling triggers on a combination of predicted rainfall totals and projected river rise, or a precipitation volume (>0.25" or >0.5").

Projects may use a combination of predicted rainfall, river stage (elevation) rise, and antecedent conditions to determine storm event sampling triggers. Staff may consult resources such as the WSU's AgWeatherNet map[8] to observe current precipitation amounts, the Northwest River Forecast Center (NWRFC) website[9], or the National Weather Service, Advanced Hydrologic Prediction Service, Seattle[10] to observe current and predicted streamflow conditions.

The NWRFC site provides 10-day predictions for the state. Ecology staff may use the general information for planning up to a week in advance.

Ecology staff may adjust the sample criteria based on the hydrologic response time of the system and/or the antecedent conditions. Some individual stream reaches may experience a more rapid increase in flow, with a shorter high flow duration (a hydrologically "flashy" system), which creates a very narrow sample window for storm events. Staff may use field observations to estimate if the stream flow is on the rising or falling limb of the hydrograph.

7.2.2 Field parameters and laboratory analytes to be measured

Ecology may observe, count, measure or analyze the following parameters depending on the focus and intent of different Nonpoint projects. See Appendix A for the parameters included in each project.

[8] https://weather.wsu.edu/
[9] https://www.nwrfc.noaa.gov/rfc/
[10] https://water.weather.gov/ahps2/forecasts.php?wfo=sew

Table 6. Laboratory analytes and field parameters.

Laboratory Analytes	Field Parameters
Ammonia	Water Temperature
Nitrate/Nitrite	Specific Conductivity
Nitrate	Dissolved Oxygen
Nitrite	pH
Nitrogen - Total Persulfate (TPN)	Turbidity
Orthophosphate (OP)	Streamflow
Total Phosphorus (TP)	Velocity
pH	
Turbidity	
E. coli	
Fecal Coliform	
Enterococci [a]	
% Klebsiella KES [a]	

[a] MEL currently does not provide this analysis. Contract labs may have the capacity to do this analysis.

7.3 Modeling and analysis design

Modeling is not applicable for the projects developed under this QAPP. However data collected under this QAPP may be considered for use in a modeling project as described in a separate modeling QAPP.

7.4 Assumptions underlying design

Assumptions that underlie the project design include:

- Funding and resources will continue for the duration of the long-term effectiveness monitoring to assess the efficacy of TMDL implementation efforts.
- Water quality management actions will reduce pollutant loading to the watersheds and will result in higher water quality over time.
- The project design including site selection and sample frequency will adequately represent the watersheds. It will also sufficiently monitor the effectiveness of TMDL implementation efforts and aid in source tracing of new pollutants.

7.5 Possible challenges and contingencies

7.5.1 Logistical problems

Logistical problems that interfere with sampling can include:

- Denial of access to private property: At most sampling locations, samples can be collected from a bridge or public right of way, but occasionally access to private property is necessary. If permission to access private property is denied, staff will attempt to find a nearby alternate sampling location.

- Changes in stream flows: Some seasonal streams may stop flowing during the late summer, or during longer drought periods. Heavy rain or snowmelt may cause deep water, high flow velocity, or flooding. In these situations, personnel safety will always be the first consideration.
- Safe access to sampling locations: Vegetation can grow rapidly during the spring and summer, requiring clearing to maintain access to sampling sites. If a site becomes inaccessible due to road changes, erosion, etc., staff will consider adding new sites based on the needs of the project objectives.
- Sample holding times and transport: Numerous logistical issues can arise when transporting/shipping samples and attempting to meet holding times including:
    - Bacteria samples collected before 10 AM cannot be shipped/courier transported to the MEL overnight and meet the 24-hour holding time. These samples must be delivered directly to the lab by 3 PM on the day of collection.
    - Inclement weather can cancel or delay commercial shipping vehicles. Attempts should be made to reschedule sampling events impacted by inclement weather.
    - Overnight shipping drop-off times for commercial shipping options is usually between 3 and 4:30 PM. Delays in sampling or driving can result in missing the drop-off deadline.

Seasonal considerations, sampling around low tide schedule, tide gates, irregular operation of pump stations, sample bottle delivery errors, vehicle and equipment problems, site access issues, traffic conditions, road safety, and limited availability of personnel or equipment: Any missed samples or events typically will be revisited at the next most convenient time dependent on staff priorities and lab availability.

Staff will note and discuss in the final report any circumstance that interferes with data collection.

7.5.2 Practical constraints

Practical constraints for projects conducted under this QAPP may include unforeseen budget cuts and staff reductions or vacancies, required protocols during public health emergencies such as a pandemic, changes in program priorities or agency policies. Contingencies could include reductions in sampling sites, analytical parameters, sample frequency, and/or sampling events.

7.5.3 Schedule limitations

Project schedules could be affected by the various factors listed above. Ecology staff will try to ensure the sampling schedule stays consistent with the project plan. These efforts may include ensuring all sampling equipment is properly maintained and calibrated prior to sampling, re-prioritizing budget needs within the program, or collaborating with other partners.

8.0 Field Procedures

8.1 Invasive species evaluation

Depending on the presence of invasive species in different watersheds, field staff will follow SOP EAP070 to minimize spread of invasive species (Parsons et al. 2021). Ecology staff will specify these actions within individual project plans.

Two problem species have been tentatively or definitively identified in western Washington watersheds. These include *Didymosphenia geminata* (Didymo) and New Zealand Mud Snail (*Potamopyrgus* sp.).

Ecology currently defines problem invasive species areas into two categories: Areas of Extreme Concern and Areas of Moderate Concern. Watersheds with New Zealand Mud Snails are Extreme Concern Areas while those with Didymo are Moderate Concern Areas. Staff must follow Ecology's standard operating procedures EAP070 (Parsons et al. 2021).

8.1.1 New Zealand Mud Snails

New Zealand Mud Snails have been found in numerous areas of Washington State, where they can potentially cause tremendous environmental and economic impacts. These areas are now considered to be of Extreme Concern. Figure 2 displays Washington State's documented Extreme Areas of Concern as of 2020.

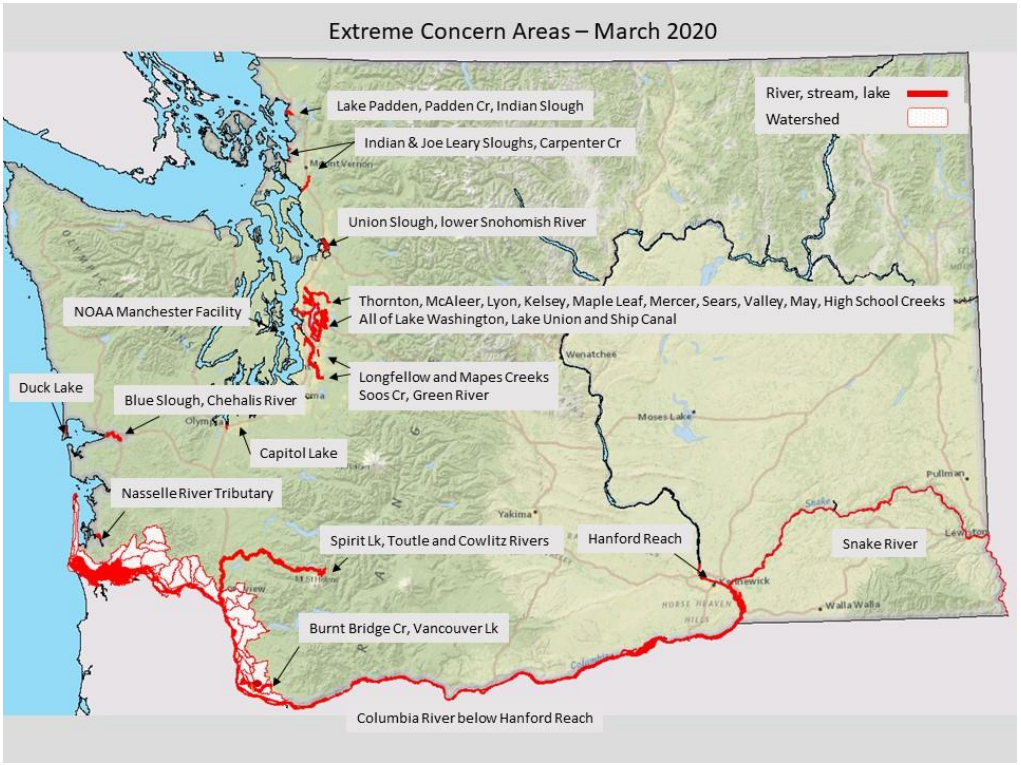

Figure 2. Aquatic Invasive Species Distribution in Washington State.

Staff will consult Ecology's Invasive Species webpage for the most recent information when designing sampling studies. Staff designing studies in the greater Puget Sound watershed will evaluate potential sampling sites for the likely presence of mud snails (see Ecology's Invasive Species webpage[11] and the USGS Nonindigenous Aquatic Species webpage[12]) and contact Jesse Shultz (Washington Department of Fish and Wildlife Invasive Aquatic Species Unit) or Jenifer Parsons (EAP Central Regional Office) with questions that arise.

Staff will follow decontamination procedures when sampling in Areas of Extreme Concern (Parsons et. al. 2021). Sampling will be done in these watersheds using a pole, if feasible, and avoiding contact with wet streamside soils. Sampling will proceed from upstream to downstream. Between sampling sites, boots that have contacted stream water or wet streamside soils during sample collection will undergo decontamination procedures using chemicals or heat, especially when cold treatment (4hrs at -4°C) or drying (48 hrs. to fully dry) cannot be completed in time. Wearing short rubber boots will simplify decontamination, while wearing felt-soled boots will make decontamination more difficult.

8.1.2 Didymo

The Didymo diatom is a single-celled alga that can thrive in cold water and grow to cover streambeds in thick gelatinous mats. These mats can smother various stream organisms and reduce the availability of food to juvenile salmonids.

Ecology staff sampling in areas of the Stillaguamish River Watershed where Didymo may be present will use sample poles wherever feasible and follow the decontamination procedures for Areas of Moderate Concern (Parsons et al. 2021) if not wearing felt-soled boots. Staff wearing felt-soled boots will use an upstream-to-downstream sampling sequence and follow decontamination procedures for Areas of Extreme Concern. Staff will decontaminate all sampling gear using chemicals or heat prior to same-day sampling in uncontaminated watersheds, especially when cold treatment (4hrs at -40°C) or drying (48 hrs. to fully dry) cannot be completed in time.

8.2 Measurement and sampling procedures

All water samples will be collected using Ecology's Standard Operating Procedures (SOPs) for the Collection, Processing, and Analysis of Stream Samples (Ward 2019). Any water quality data collected by multi-parameter sondes will follow guidance from Ecology's SOP for Hydrolab® DataSonde®, MiniSonde®, and HL4 Multiprobes (Anderson 2020), or the manufacturers as applicable. Any streamflow measurements will be conducted following Ecology's SOP for Measuring Streamflow for Water Quality Studies (Mathieu 2016).

[11] www.ecy.wa.gov/programs/eap/InvasiveSpecies/AIS-PublicVersion.html
[12] https://nas.er.usgs.gov/

Individual projects may also include continuous monitoring, auto-sampling, or other sampling methods. Any sampling procedures or methods used must follow established SOPs or equipment manufacturer instructions. Plans may also refer to other SOPs from Ecology's QA Website that address specific sampling and field analytical techniques, or other procedural details of the project. New sampling sites should be documented with a location description, latitude and longitude in decimal degrees, nearest street address if relevant, and a photo of the location.

Field staff will first confirm the correct order of sampling stations in each watershed. Downstream stations will generally be sampled first to avoid disturbing sediments thereby potentially affecting other samples, or a sampling pole will be used at upstream stations. If invasive species are present in the watershed, the sampling strategy should follow the SOP and resources discussed in Section 8.1.

8.2.1 Equipment & supplies

The normal container for bacteria sampling is a 250 mL or 500 mL sterile polypropylene bottle and cap as shown in Figure 1. The sample bottle normally comes from the MEL with aluminum foil wrapped over the cap to preserve sterility. If working with an accredited laboratory other than MEL they may provide other sterile sealed bottles.

Figure 3. Bacteria water sampling equipment and sample bottles.

Left: Specialized bridge sampler with bottle. Center: 250 mL polypropylene and glass sample bottles. Right: Sampling extension pole.

Typical supplies needed for bacteria water sampling include but are not limited to:

- 250 mL or 500 mL sterile polypropylene bottles or other bottles provided by an accredited lab and sealed to prevent contamination.
- Disposable pipettes (sterile, individually wrapped) or 50 mL sterile syringe for very shallow water bodies or discharges.
- Latex or nitrile gloves (for sites where bacteria level is known or suspected to be high).

- Anti-bacterial hand sanitizer or soap.
- Cooler(s).
- Ice (Regular or blue ice blocks).
- Distilled water (for rinsing equipment) and Tap water (for hand washing).
- Sample tags with work order numbers assigned by MEL, or labels suitable for other accredited laboratories.
- Lab Analysis Request (LAR) forms, or other chain of custody forms for use with accredited laboratory.
- Hip boots or waders (if applicable).
- Sampling extension pole.
- Specialized bridge sampler and rope (if applicable).
- Foam spacers to secure bottles.
- Field book, pencils, Sharpie marker.
- Camera, work cell phone, communication device for remote areas, and car chargers.

8.2.2 Grab sampling

Samples to characterize loading will be collected only from flowing water and not from pools or ditches that are stagnant. Samples to characterize potential discharges or conditions in a lake may be sampled from stagnant water. Care will be taken not to disturb bottom sediment or let the bottle touch the streambed, particularly in slow moving or stagnant water. For slow moving streams with easily disturbed sediment, samples will be collected from the stream bank using a sampling extension pole (Figure 3). Sample containers will be filled only once and not pre-rinsed with sample water. The bottle will not be rinsed or filled from another non-sterilized container.

Remove stopper/lid from bottle just before sampling, leaving the aluminum foil over stopper/lid. Be careful not to contaminate the cork (glass bottle), cap (plastic bottle) or the inside of the bottle with fingers, coughing, dirt particles, dripping water from bridges, or other sources of contamination. The sample is collected from the stream thalweg or predominant flow avoiding back eddies and side channels. While facing upstream, hold the bottle near its base and plunge it (mouth down) below the surface, avoiding oversampling the top micro-layer where bacteria tend to concentrate. Collect sample at approximately 40 to 60 percent of the water's depth in wadable water. In lakes, collect the sample from approximately 25 cm depth. While under water, turn the bottle into the current and away from you, the shore, and the side of the sampling platform or boat. If sampling in a lake, move bottle away from you, mouth first to create a small artificial current from mouth to hand. In shallow depths, collect sample from surface if unavoidable and record in field notes.

Fill the sample bottle to the appropriate level, being careful to pull the bottle out of the water as it reaches the point where it is filled to or near the shoulder of the bottle. If the bottle is filled above this level, immediately pour out (downstream of sampler) enough of sample so that the water level is at or near the shoulder of the bottle. This will allow enough air space above the sample for proper mixing and processing for analysis at the lab.

After filling the bottle to the appropriate level, securely replace the aluminum-covered stopper/lid on sample bottle. Rinse any large amount of dirt or debris from the outside of the container.

8.2.3 Specialized sampling devices

The following specialized sampling devices are frequently used for taking bacteria, turbidity, and nutrient samples in the field. Consult EAP staff if a bridge sampler is needed for DO analyses.

Extension Pole

A sampling extension pole such as the one shown in Figure 3 may be used to collect stream samples where feasible. Use of the sampling pole can reduce overall disturbance of the stream and riparian zone, help prevent the spread of New Zealand mud snails, and help ensure a representative sample is collected where wading would be dangerous. The use of a sampling pole can also speed up sample collection times and increase overall staff safety. When using a sampling pole, caution should be taken to prevent the pole from collecting water internally and spilling into the sample bottle. Similarly, if the previous sampling site is suspected to have very high bacteria levels, the end of the pole should be rinsed prior to taking a sample at the next location to avoid contamination.

Bridge Sampler

If sample collection using the sampling pole is not feasible, samples may be collected using a bridge sampler such as shown in Figure 3. Select a location where the bridge sampler can be lowered into the water near the center of the current, and away from overhanging branches or other obstructions. Insert the sample bottle into the bridge sampler, and if necessary use a foam spacer to secure the bottle in the sampler cup. Carefully remove the lid from the sterile sample bottle and hold the lid via the aluminum foil, or set it somewhere free of dirt or other sources of contamination and out of the wind so it is not disturbed. Lower the sampler so as not to contaminate the open bottle with dirt or dripping water on the way down. Lower the base of the sampler to the water surface and raise it up to clean the bottom of the sampler. Lower the sampler about 15 cm and allow sampler to orient into the current. After the sampler is oriented with the bottle upstream of the fin, continue lowering. When the top of the bottle approaches the water surface, drop the sampler quickly through the surface to a depth of 25 cm to 50 cm to avoid oversampling the top micro-layer. Keep the bottle submerged just long enough for the bottle to fill (or 1-2 inches below the top).

Pull up the sampler and bottle, careful not to contaminate the sample with dirt or water from either the rope, bridge, or other sources of contamination. Pour out excess water to allow for the air space needed for proper mixing at the lab. Securely replace the aluminum-covered lid. Rinse any dirt or debris from the outside of the container.

Pipette or Syringe

Where water bodies or discharges to surface water are very shallow, a sterile disposable pipette or 50 mL sterile syringe can be used to prevent the introduction of sediments into the sample. The syringe should be filled and emptied into the sample bottle enough times to ensure an adequate volume of water/wastewater is sampled. It is preferable to use a new pipette or syringe at each location. If an adequate number of pipettes or syringes are not available then the reused item should be flushed at least 3 times at each site and annotations on the use of a reused syringe should be logged in the field notes.

8.3 Containers, preservation methods, holding times

Depending on the project area, staff may have samples analyzed by Ecology's MEL or another accredited laboratory. This will be specified for each project in Appendix B.

If MEL will analyze samples

Field staff will collect discrete samples directly into pre-cleaned or sterilized containers supplied by MEL and described in their Lab User's Manual (MEL 2016). Table 7 lists the sample parameters, containers, volumes, preservation requirements, and holding times for all lab samples.

After collecting the sample, the string or elastic band attached to the sample tag will be looped over stopper/lid until secure. For bacteria samples, make sure to attach sample tag beneath, not on top of, the aluminum foil cover, as the covers can be easily separated from the sample bottle during transport and handling. The date and time each station was sampled will be recorded on the sample tag and in the field notes. The filled and labeled sample bottle will be immediately placed in an iced cooler. It is important to cool to ≤4°C immediately and store in a dark cooler, as bacteria samples are sensitive to light.

Samples will be packed in regular cubed or crushed ice. Lab Analysis Requested (LAR) forms will be left on the ice chest for pick-up and transport to lab. LAR forms at minimum will contain the project name, station names, sample numbers, date, times, and parameters requested. Field staff will store samples for laboratory analysis on ice in a walk-in cooler and arrange for sample pick-up via MEL staff. Sample pick-up should be arranged with the lab in advance of the field sampling or samples may be transported to the lab by regional staff early the next day.

MEL follows standard analytical methods outlined in their Lab User's Manual (MEL 2016). Standard Methods (APHA et al. 1998) recommends a maximum holding time of eight hours for microbiological samples (six hours transit and two hours laboratory processing) for non-potable water tested for compliance purposes. For environmental samples, Standard Methods recommends a holding time of no more than 24 hours. MEL has a maximum holding time for environmental microbiological samples of 24 hours (MEL 2016). Microbiological samples analyzed beyond the 24-hour holding time are qualified with a "J" qualifier code, indicating an estimated sample result.

If another accredited laboratory will analyze samples

After collecting the sample, staff will confirm the sample label contains the correct station, date time and analysis required. The date and time each station was sampled will be recorded in the field notes. The filled and labeled sample bottle will be immediately placed in an iced cooler. It is important to cool to 4°C immediately and store in dark cooler, as bacteria samples are sensitive to light.

Samples will be packed in coolers as soon as possible after collection. Temperature will be maintained ≤4°C by ice or blue ice. Chain of custody forms will be completed. Sample labels will be verified with log books and chain of custody/lab analysis request forms at the end of each sampling event.

Table 7. Sample containers, preservation method, and holding times.

Parameter	Matrix	Recommended Quantity	Container	Holding Time	Preservation Method
Ammonia	Water	125 mL[6]	125 mL clear w/m poly bottle[2]	28 days	1:1 H_2SO_4 to pH <2; Cool to ≤6°C
Nitrate/Nitrite	Water	125 mL[6]	125 mL clear w/m poly bottle[2]	28 days	1:1 H_2SO_4 to pH <2; Cool to ≤6°C
Nitrate	Water	(2) 125 mL[6]	(1) 125 mL amber and (1) 125 mL clear w/m poly bottle	48 hours	Cool to ≤6°C; H_2SO_4 to pH <2 for clear bottle
Nitrite	Water	125 mL[6]	125 mL amber w/m poly bottle	48 hours	Cool to ≤6°C
Nitrogen - Total Persulfate (TPN)	Water	125 mL[6]	125 mL clear w/m poly bottle[2] 0.45 µm pore size filters for dissolved TPN	28 days	H_2SO_4 to pH <2; Cool to ≤6°C
Orthophosphate (OP)	Water	125 mL[5]	125 mL amber w/m poly bottle[7] 0.45 µm pore size filters for dissolved OP	48 hours	Filter in field with 0.45 µm pore size filter; Cool to ≤6°C
Total Phosphorus (TP)	Water	60 mL	125 mL clear n/m poly bottle[2]	28 days	1:1 HCl to pH <2; Cool to ≤6°C
pH	Water	Fill jar - NO headspace	500 mL w/m poly bottle	15 minutes*	Cool to ≤6°C; Fill bottle completely
Turbidity	Water	500 mL	500 mL w/m poly bottle[1, 5]	48 hours	Cool to ≤6°C
E. coli	Water	250 mL, 500 for QC	250 mL glass/polypropylen	24 hours	Fill the bottle to the shoulder; Cool to ≤4°C

Parameter	Matrix	Recommended Quantity	Container	Holding Time	Preservation Method
			e autoclaved bottle[3, 4]		
Fecal Coliform	Water	250 mL, 500 for QC	250 mL glass/polypropylene autoclaved bottle[3, 4]	24 hours	Fill the bottle to the shoulder; Cool to ≤4°C
Enterococci [9]	Water	250 mL, 500 for QC	250 mL glass/polypropylene autoclaved bottle[3, 4]	24 hours	Fill the bottle to the shoulder; Cool to ≤4°C
% Klebsiella KES [9]	Water	250 mL, 500 for QC	250 mL glass/polypropylene autoclaved bottle[3, 4]	24 hours	Fill the bottle to the shoulder; Cool to ≤4°C

w/m, wide mouth
poly, polyethylene
* pH analysis may not be used for regulatory compliance under the CWA when the sample cannot be analyzed immediately (within 15 minutes) upon collection.
[1] Do not combine alkalinity with parameters that must be shaken (e.g. turbidity and other solids tests).
[2] Container is sent by lab with preservative in it.
[3] Microbiology: Submit 1 500 mL bottle if 2 tests are requested, and 250 mL for each additional test. Bottles are not guaranteed sterile after 6 months. Return all unused bottles to lab for autoclaving.
[4] If chlorine is suspected in sample, then request bottle with thiosulfate preservative in it.
[5] May be able to analyze several general chemistry parameters from the same container, such as conductivity and pH – NO headspace when sampling for pH; fill jar completely. DO NOT combine alkalinity with turbidity, solids, or any other test that requires vigorous shaking.
[6] May be able to analyze several nutrient parameters from the same container.

- For 125 mL – unpreserved: Orthophosphate, Nitrite only, Nitrate only.
- For 125 mL – preserved: Nitrate/Nitrite, Total Persulfate Nitrogen (TPN), Ammonia

[7] Filter in field.
Do not combine Total Kjeldahl Nitrogen(TKN) with any other nutrient, since this analysis is not performed by MEL and will be sub-contracted to an alternate laboratory. Do not combine BOD, TOC, or Chlorophyll with any other parameter.
[8] MEL currently does not provide this analysis. Contract labs may have the capacity to do this analysis.

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.

When data results are received from MEL, COC forms are reconciled with data to ensure complete delivery and correct invoicing for all results. If discrepancies exist, research and investigation of the discrepancy is conducted in coordination with MEL until the problem is resolved.

8.7 Field log requirements

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

- Field personnel.
- Site, date and time at which samples or data are collected.
- Observational environmental conditions (flow, weather, water color, etc.).
- Field measurement results.
- Deviations from the sampling plan, or factors that might affect interpretation of results.
- Notes of potential sources of pollution.

Field measurements collected with a multi-parameter sonde will be recorded both internally within the data logger and handwritten into the field log. These recordings will be verified for uniformity once data are uploaded. Photos may also be taken to record observations, sampling locations and events. These photos may 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 fieldwork include sensor and 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 the following:

- Conducting all pre-sampling sensor calibrations.
- Prepping all field gear including sampling poles, gloves, filters, etc.
- Ensuring adequate supply of sample bottles.
- Cancelling or rescheduling the event 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.

Safety

Gloves should be worn to avoid exposure to water contaminants. If gloves are not worn, hands and anything they touch will be assumed to be contaminated after sampling. In such cases, hands will be cleaned using anti-bacterial soap or hand sanitizer after completing work at each sampling station or, at a minimum, after completing work at sampling stations with known high bacteria counts and before ingesting food or drink. Further field health and safety measures are available in the *Environmental Assessment Program (EAP) Safety Manual* (Ecology 2019).

When field staff are working in areas outside cell phone coverage, they should use another type of communication device, follow a check-in procedure, or coordinate with their Supervisor to ensure communication and timely response when necessary.

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 8.

The type of analytes and number of samples will vary by project. See Appendix A for more information.

Table 8. Measurement methods (laboratory).

Analyte	Matrix	Expected Range of Results	Method	Method Detection Limit
Ammonia-N	Water	<0.01 – 30 mg/L	SM4500-NH3 H	0.002 mg/L
Nitrate	Water	<0.01 – 30 mg/L	SM 4500-NO3 I	0.0025 mg/L
Nitrite	Water	<0.01 – 30 mg/L	SM 4500-NO3 I	0.0025 mg/L
Nitrate + Nitrite-N	Water	<0.01 – 30 mg/L	SM4500-NO3 I	0.0025 mg/L
Total Persulfate Nitrogen (TPN)	Water	0.5 – 50 mg/L	SM4500-N B	0.013 mg/L
Orthophosphate (OP)	Water	0.01 – 5.0 mg/L	SM4500-P G	0.0017 mg/L
Total Phosphorus (TP)	Water	0.01 – 10 mg/L	SM4500-P H	0.006 mg/L
pH	Water		SM 4500-H+ B	
Turbidity	Water	0 – 1,000 NTU	SM 2130 B	0.01 NTU
Fecal coliform (MF)	Water	1 – 15,000 cfu/100 mL	SM9222 D	1.0 cfu/100 mL (RL)
E. coli (MF)	Water	1 –15,000 cfu/100 mL	SM9222 G	1.0 cfu/100 mL (RL)
Enterococci [1]	Water	1 – 1,200 cfu/100mL	MF – EPA 1600 MPN – ASTM D6503	1.0 cfu/100mL (RL)
%Klebsiella KES [1]	Water	1 – 1,200 cfu/100mL	MEL 710001	1.0 cfu/100mL (RL)

RL: Reporting Limit
[1] MEL currently does not provide this analysis. Contract labs may have the capacity to do this analysis.

9.2 Sample preparation method(s)

Collection and preservation of samples analyzed at Ecology's Manchester Environmental Laboratory (MEL) will be prepared according to their internal SOPs. Other sample preparation methods are listed in standard operating procedures for lab analyses or in applicable analytical methods.

9.3 Special method requirements

This QAPP contains lab procedures for common analytes. Any special method requirements should be addressed within individual project plans in Appendix A.

9.4 Laboratories accredited for methods

The analyses completed for water quality projects covered by this QAPP may be performed at MEL, which is accredited for all the methods listed in Table 8. When using an alternative laboratory, the laboratory must be accredited by Ecology's Lab Accreditation Unit (LAU) for each method performed.

10.0 Quality Control Procedures

Implementing 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.

For field instruments, the following QC procedures will be performed:

- Pre check: Prior to each sample event, all sensors will be checked and if necessary, calibrated, following recommendations by the manufacturer.
- Post check: At the conclusion of each sample event, all sensors will be checked again to assess for any potential bias from instrument drift, fouling, or interference.
- The YSI ProDSS, a multi-parameter probe used for all field measurements, requires periodic calibrations for all sensors excluding temperature to maintain accurate measurements. According the manufacturer, temperature calibration is not available nor required for accurate temperature measurements.
- Pre and post checks for each sensor will be conducted as following:
    - For specific conductivity, pH, and turbidity, using certified standards specific to each parameter.
    - For DO, checking the probe against 100% water saturated air or in a 100% air saturated water bath.
    - For temperature, checking the probe's temperature readings using a NIST-certified thermometer.
    - Each field instrument will be assigned an accuracy rating based on the pre and post check results by using the criteria in Table 9.
- If a pre-check falls below the excellent accuracy rating, the sensor will be re-calibrated or sent to a manufacturer to be re-calibrated.
- If a post-check falls below the good accuracy rating, the data will be investigated and potentially flagged with a qualifier.

Table 9. Rating of accuracy for field instruments.

Measured Field Parameter	Excellent	Good	Fair	Poor
Water Temperature	≤ ± 0.2°C	> ± 0.2 – 0.5°C	> ± 0.5 – 0.8°C	> ± 0.8°C
Specific Conductivity	≤ ± 3%	> ± 3 – 10%	> ± 10 – 15%	> ± 15%
Dissolved Oxygen	≤ ± 0.3 mg/L or ≤ ± 5%%, whichever is greater	> ± 0.3 – 0.5 mg/L or > ± 5 – 10%, whichever is greater	> ±0.5 – 0.8 mg/L or > ± 10 – 15%, whichever is greater	> ± 0.8 mg/L or > ± 15%, whichever is greater
pH	≤ ± 0.2 units	> ± 0.2 – 0.5 units	> ± 0.5 – 0.8 units	> ± 0.8 units

Measured Field Parameter	Excellent	Good	Fair	Poor
Turbidity	≤ ± 0.5 NTU or ≤ ± 5%, whichever is greater	> ± 0.5 – 1.0 NTU or > ± 5 – 10%, whichever is greater	> ±1.0 – 2.0 NTU or > ± 10 – 20%, whichever is greater	> ± 2.0 NTU or > ± 20%, whichever is greater

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 can be used 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 check for matrix interference with detection of the analyte and can be used to evaluate bias related to matrix effects. Blanks are used to check for sample contamination in the laboratory process. QC procedures are summarized in Table 10.

Table 10. Quality control samples, type, and frequency.

Parameter	Field Replicates	Field Blanks	Lab Check Standards	Lab Method Blanks	Lab Analytical Duplicates	Lab Matrix Spikes
Ammonia-N	20-30%	10%	1/batch	1/batch	1/batch	1/batch
Nitrate + Nitrite-N	20-30%	10%	1/batch	1/batch	1/batch	1/batch
Total Persulfate Nitrogen	20-30%	10%	1/batch	1/batch	1/batch	1/batch
Orthophosphate	20-30%	10%	1/batch	1/batch	1/batch	1/batch
Total Phosphorus	20-30%	10%	1/batch	1/batch	1/batch	1/batch
Fecal coliform	10-30%	n/a	n/a	1/batch	1/batch	n/a
E. coli	10-30%	n/a	n/a	1/batch	1/batch	n/a
Enterococci	10-30%	n/a	n/a	1/batch	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 field instruments yield unusual results, if results do not meet MQOs or performance expectations, or if some other unforeseen problems arise. There may be cause for field instruments to be recalibrated, following SOPs, while still on site. Options for corrective actions might include:

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

11.0 Data Management Procedures

11.1 Data recording and reporting requirements

The Environmental Information System (EIM) Study ID for projects conducted under this QAPP will be listed with the project specific details in Appendix A.

Staff will record all field data in a water-resistant field notebook or an equivalent electronic collection platform. Before leaving each site, staff will check field notebooks for missing or improbable measurements. Staff will enter field-generated data into Microsoft (MS) Excel® spreadsheets or EIM as soon as is practical after they return from the field. For data collected electronically, data will be backed up on Ecology servers when staff return from the field. Data entry will be checked against the field notebook data for errors and omissions.

All final spreadsheet files, paper field notes, and final products created as part of the data collection and data QA process will be kept with the project data files and will be retained following the agency's document retention guidelines and schedule.

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.

In addition, data summaries and web maps will be either presented in free form on Ecology's Effectiveness Monitoring web page[13], or Ecology's EIM database[14].

Field notebooks will be checked for missing or improbable measurements before leaving each site. Field-generated data will be entered into spreadsheets or online database as soon as practical after returning from the field. The spreadsheet will be labeled "DRAFT" until data verification are completed. Data entry will be checked by the field assistant against the field notebook data for errors and omissions. Missing or unusual data will be brought to the attention of the project manager for consultation. Verified data will be moved to a separate file labeled "FINAL."

11.2 Laboratory data package requirements

Laboratory-generated data reduction, review, and reporting will follow procedures outlined in MEL's Lab User's Manual (MEL 2016). Variability in lab duplicates will be quantified, also 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.

[13] https://ecology.wa.gov/Research-Data/Monitoring-assessment/Water-quality-improvement-effectiveness-monitoring

[14] https://ecology.wa.gov/Research-Data/Data-resources/Environmental-Information-Management-database

If data are received from an accredited laboratory other than MEL, confirm that the laboratory report includes QA/QC verification. Enter data from laboratory report into Excel spreadsheet or other file system.

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. Other accredited laboratories may have their own methods of providing electronic data.

11.4 EIM/WQX data upload procedures

Ecology's water quality data will be entered into EIM, following existing Ecology business rules and procedures. Depending on program and individual job responsibilities, staff involved in EIM data submission should undergo EIM training.

Detailed EIM procedures are outlined on the EIM Help Center webpage[15]. This webpage provides help documents and EIM templates, which are preformatted Excel spreadsheets used to submit data to EIM. The templates provide specific data-entry requirements and are designed to be filled out and submitted online. The basic elements for EIM data entry are as follows:

- Establish a Study in EIM using the online form in EIM. A Study is considered an organized activity or set of monitoring activities with specific objectives and quality assurance goals described in a QAPP. A new EIM Study should be entered for monitoring projects with a project-specific QAPP. The EIM Data coordinator should be contacted when a new EIM Study is created.
- Enter Study Locations to EIM online or using the approved EIM Location template. All locations require general location information and metadata (i.e. coordinates). A new location does not have to be entered if the sampling location already exists in EIM and the location information and metadata are applicable.
- Enter Results directly to EIM online or using the approved EIM Results template. The results must reside under a Study and Study Location and meet the requirements specified in the guides and templates.
- Review of data entries in EIM by a project technical lead or other staff to detect and correct potential data entry errors.

Other databases may be used as storage for Ecology data depending on the study and funding sources.

11.5 Model information management

Not Applicable.

[15] https://apps.ecology.wa.gov/eim/help/HelpDocuments

12.0 Audits and Reports

12.1 Field, laboratory, and other audits

Audits will be conducted 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. Any audits of field procedures and sample processing will be specified in the project plans included in Appendix A.

12.2 Responsible personnel

The project manager conducts any data audits and works with field sampling staff and lab technicians to complete reviews.

12.3 Frequency and distribution of reports

Depending on the scope and nature of various projects, a summary report or water quality improvement report may be completed and published to Ecology's website. Any reports will also typically 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 any reporting. The project manager is also responsible for communicating with TMDL and Nonpoint 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 is the process of evaluating the completeness, correctness, and conformance/compliance of a specific data set against the method, procedural, or contractual requirements (EPA, QA/G-8, 2002).

Data verification and review is conducted by the project manager or designated staff 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 study design section (Section 7) 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. Field notebooks will be checked for missing or improbable measurements, and initial data will be verified before leaving each site. This process involves checking the data sheet for omissions or outliers. If measurement data are missing or a measurement is determined to be an outlier, the measurement will be flagged in the data sheet and repeated if possible.

Upon returning from the field, data are both manually entered and downloaded from instruments and then uploaded into the appropriate database or project folder (see Data Management Section). If errors or omissions are found, the source of the data (e.g., field crew, instruments) will be consulted to determine the correct value or form of the data in question.

Following data entry verification, raw field measurement data will undergo the following quality analysis verification process to evaluate the performance of the sensors:

- Review discrete field QC checks.
- Review post-check data for field QC check instruments and reject data as appropriate.
- Assign a quality rating to the field check values (excellent, good, fair, poor) based on the post-check criteria in Table 9.
- After data have been finalized and entered, a staff member who was not involved in the data entry will compare the data to the original forms and review for completeness and potential errors.

13.2 Laboratory data verification

MEL staff will perform laboratory verification following standard laboratory practices (MEL, 2016). If using another accredited laboratory, confirm that the laboratory report includes QA/QC verification. Enter data from laboratory report into the Excel spreadsheet or other file system in use. Label data as DRAFT. For each sample, keep a record of field duplicate results.

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. Staff will independently review EIM data 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

Not Applicable

13.4 Model quality assessment

Not Applicable

14.0 Data Quality (Usability) Assessment

14.1 Process for determining project objectives were met

After staff verify and validate all laboratory and field data, 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 criteria have not been met, the project manager will decide if affected data should be qualified or rejected based upon this QAPP's decision criteria. 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. These results will be annotated with a "U" qualifier to signify "under the detection limit" to indicate a higher level of uncertainty in the quantitative value. For bacteria values above the detection limit, the upper detection limit plus one significant digit will be used.

For a more general discussion of treatment of non-detects, see SOP EAP093 (Gries 2017).

14.3 Data analysis and presentation methods

Data analysis consists of comparing results to water quality standards, detecting changes in monitoring parameters over time or summarizing water quality data to identify areas of concern. Procedures comparing results to water quality standards are defined in the following:

- Ecology's Water Quality Program Policy 1-11[16].
- 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).

For parameters that do not have a set numeric water quality criteria, the data analysis may involve a basic summary of results and trends. For example, FC and nutrient data can be used for source identification purposes and prioritization of areas of concern for clean-up efforts. The data may involve a summary to connect the results to land use, land cover patterns or site conditions.

14.3.1 Bacteria data analysis

Bacteria concentration are used to calculate statistics for determining compliance with water quality criteria (e.g. geometric mean, 10 % exceedance criteria). However, if more than 10% of the results for a site represent focused sampling events, such as storms and stormwater runoff,

[16] https://ecology.wa.gov/Water-Shorelines/Water-quality/Water-improvement/Assessment-of-state-waters-303d/Assessment-policy-1-11

then Ecology staff must first exclude these results from calculations. Excluding focused sampling results ensures extreme events are not over-represented. If a random sampling plan dataset includes results captured during storm events, then Ecology will not remove these results. This allows for a low bias.

The process for determining compliance with water quality criteria for bacteria concentrations as follows:

- Both the geometric mean and 10% exceedance criteria are calculated within a 90-day rolling averaging period.
- A minimum of three samples are required to calculate the geometric mean.
- A waterbody may be considered to not meet criteria if the geometric mean of a three-month period exceeds the criterion at least once within a water year.
- A waterbody may be considered to not meet criteria if 10% of samples within a three-month window exceed the criterion and at least two samples exceed the criterion threshold within a water-year.
- A single exceedance of the 10% exceedance criterion can lead to a water body being considered a water of concern.

Though not used for regulatory purposes for freshwater bodies that do not impact shellfish growing areas, FC may still be used to identify pollution sources, help prioritize areas or sites for clean-up efforts and communicate progress of water quality improvement.

In addition to determining compliance to standards, bacteria data may also evaluated to identify areas of increased bacteria loading. This can be done by comparing bacteria concentrations at short-term sampling sites that represent different reaches and calculating bacteria loading. Pollutant loading from sources or tributaries can be estimated if accurate stream flow data are available or can be collected. Loading may also be estimated using established streamflow related staff gages or hydrologic runoffs models, *e.g.* the USGS Precipitation Runoff Modeling System (PRMS)[17] and similar methods when applicable.

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.

[17] https://www.usgs.gov/software/precipitation-runoff-modeling-system-prms

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16.0 Appendices

Appendix A. Regional Nonpoint Pollution Identification Projects

The watersheds and some of the locations in western Washington where Ecology staff will collect samples are described in Appendix A. Staff will update each Appendix A as new projects are developed, or other changes are required. The following Appendix A subsections are associated with each field office:

- Appendix A1. Bellingham Field Office.
- Appendix A2. Northwest Region.
- Appendix A3. Southwest Region.
- Appendix A4. Vancouver Field Office.

Each project description in Appendix A should include the following information. See the link below for SOPs and latest QAPP template for a description of what each section should include.

https://ecology.wa.gov/About-us/How-we-operate/Scientific-services/Quality-assurance

- Title, Author, Organization.
- Date Prepared or Revised.
- Approval signatures.
- Table of Contents.
- Introduction and Problem Statement.
- Study area and Surroundings.
- Summary of Previous studies and existing data.
- Parameters of interest and potential sources.
- Tasks Required.
- Proposed Project Schedule.
- Budget and Funding.
- Sampling locations and frequency.
- Field parameters and laboratory analytes to be measured.
- Invasive species evaluation and applicable procedures, depending on the watershed.
- EIM data upload procedures, including project EIM Study ID when applicable.
- Responsible personnel and contact information.

Appendix B. Glossaries, Acronyms, and Abbreviations

B.1 Glossary of General Terms

Ambient: Background or away from point sources of contamination. Surrounding environmental condition.

Anthropogenic: Human-caused.

Bankfull stage: Formally defined as the stream level that "corresponds to the discharge at which channel maintenance is most effective, that is, the discharge at which moving sediment, forming or removing bars, forming or changing bends and meanders, and generally doing work that results in the average morphologic characteristics of channels (Dunne and Leopold, 1978).

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

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.)

Chronic critical effluent concentration: The maximum concentration of effluent during critical conditions at the boundary of the mixing zone assigned in accordance with WAC 173-201A-100. The boundary may be based on distance or a percentage of flow. Where no mixing zone is allowed, the chronic critical effluent concentration shall be 100% effluent.

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

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

Critical condition: When the physical, chemical, and biological characteristics of the receiving water environment interact with the effluent to produce the greatest potential adverse impact on aquatic biota and existing or designated water uses. For steady-state discharges to riverine systems, the critical condition may be assumed to be equal to the 7Q10 flow event unless determined otherwise by the department.

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.

Diel: Of, or pertaining to, a 24-hour period.

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

Dilution factor: The relative proportion of effluent to stream (receiving water) flows occurring at the edge of a mixing zone during critical discharge conditions as authorized in accordance with the state's mixing zone regulations at WAC 173-201A-100. http://apps.leg.wa.gov/WAC/default.aspx?cite=173-201A-020

Diurnal: Of, or pertaining to, a day or each day; daily. (1) Occurring during the daytime only, as different from nocturnal or crepuscular, or (2) Daily; related to actions which are completed in the course of a calendar day, and which typically recur every calendar day (e.g., diurnal temperature rises during the day, and falls during the night).

Effective shade: The fraction of incoming solar shortwave radiation that is blocked from reaching the surface of a stream or other defined area.

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.

Enterococci: A subgroup of the fecal streptococci that includes *S. faecalis*, *S. faecium*, *S. gallinarum,* and *S. avium*. The enterococci are differentiated from other streptococci by their ability to grow in 6.5% sodium chloride, at pH 9.6, and at 10 degrees C and 45 degrees C.

Eutrophic: Nutrient rich and high in productivity resulting from human activities such as fertilizer runoff and leaky septic systems.

Existing uses: Those uses actually attained in fresh and marine waters on or after November 28, 1975, whether or not they are designated uses. Introduced species that are not native to Washington, and put-and-take fisheries comprised of non-self-replicating introduced native species, do not need to receive full support as an existing use.

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.

Hyporheic: The area beneath and adjacent to a stream where surface water and groundwater intermix.

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 CWA. The NPDES program regulates wastewater and stormwater discharges to surface waters from domestic wastewater treatment plants, industrial facilities, and municipalities .

Near-stream disturbance zone (NSDZ): The active channel area without riparian vegetation that includes features such as gravel bars.

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 CWA.

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.

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 and following rainfall or snow melt. Stormwater runoff includes interflow and can also come from hard or saturated grass surfaces such as lawns, pastures, playfields, and from gravel roads and parking lots.

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

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

Synoptic survey: Data collected simultaneously or over a short period of time.

System potential: The design condition used for TMDL analysis.

System-potential channel morphology: The more stable configuration that would occur with less human disturbance.

S**ystem-potential mature riparian vegetation:** Vegetation which can grow and reproduce on a site, given climate, elevation, soil properties, plant biology, and hydrologic processes.

System-potential riparian microclimate: The best estimate of air temperature reductions that are expected under mature riparian vegetation. System-potential riparian microclimate can also include expected changes to wind speed and relative humidity.

System-potential temperature: An approximation of the temperatures that would occur under natural conditions. System potential is our best understanding of natural conditions that can be supported by available analytical methods. The simulation of the system-potential condition uses best estimates of *mature riparian vegetation, system-potential channel morphology, and system-potential riparian microclimate* that would occur absent any human alteration.

Thalweg: The deepest and fastest moving portion of a stream.

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.

Total suspended solids (TSS): Portion of solids retained by a filter.

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

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

1-DMax or 1-day maximum temperature: The highest water temperature reached on any given day. This measure can be obtained using calibrated maximum/minimum thermometers or continuous monitoring probes having sampling intervals of thirty minutes or less.

303(d) list: Section 303(d) of the federal CWA, 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.

7-DADMax or 7-day average of the daily maximum temperatures: The arithmetic average of seven consecutive measures of daily maximum temperatures. The 7-DADMax for any individual day is calculated by averaging that day's daily maximum temperature with the daily maximum temperatures of the three days before and the three days after that date.

7Q2 flow: A typical low-flow condition. The 7Q2 is a statistical estimate of the lowest 7-day average flow that can be expected to occur once every other year on average. The 7Q2 flow is commonly used to represent the average low-flow condition in a water body and is typically calculated from long-term flow data collected in each basin. For temperature TMDL work, the 7Q2 is usually calculated for the months of July and August as these typically represent the critical months for temperature in our state.

7Q10 flow: A critical low-flow condition. The 7Q10 is a statistical estimate of the lowest 7-day average flow that can be expected to occur once every ten years on average. The 7Q10 flow is commonly used to represent the critical flow condition in a water body and is typically calculated from long-term flow data collected in each basin. For temperature TMDL work, the

7Q10 is usually calculated for the months of July and August as these typically represent the critical months for temperature in our state.

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.

B.2 Acronyms and Abbreviations

BMP	Best management practice
DO	(see Glossary above)
DOC	Dissolved organic carbon
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
GPS	Global Positioning System
i.e.	In other words
MEL	Manchester Environmental Laboratory
MQO	Measurement quality objective
NAF	New Approximation Flow
NPDES	(See Glossary above)
QA	Quality assurance
QC	Quality control
RM	River mile
RPD	Relative percent difference
RSD	Relative standard deviation
SOP	Standard operating procedures
SRM	Standard reference materials
TIR	Thermal infrared radiation
TMDL	(see Glossary above)
TOC	Total organic carbon
TSS	(see Glossary above)
USFS	United States Forest Service
USGS	United States Geological Survey
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WQA	Water Quality Assessment
WRIA	Water Resource Inventory Area
WSTMP	Washington State Toxics Monitoring Program
WWTP	Wastewater treatment plant

B.3 Units of Measurement

°C	degrees centigrade
Cfs	cubic feet per second
Cfu	colony forming units
Cms	cubic meters per second, a unit of flow
Dw	dry weight
Ft	feet
G	gram, a unit of mass
Kcfs	1000 cubic feet per second
Kg	kilograms, a unit of mass equal to 1,000 grams
kg/d	kilograms per day
km	kilometer, a unit of length equal to 1,000 meters
l/s	liters per second (0.03531 cubic foot per second)
m	meter
mm	millimeter
mg	milligram
mgd	million gallons per day
mg/d	milligrams per day
mg/kg	milligrams per kilogram (parts per million)
mg/L	milligrams per liter (parts per million)
mg/L/hr	milligrams per liter per hour
mL	milliliter
mmol	millimole or one-thousandth of a mole
mole	an International System of Units (IS) unit of matter
ng/g	nanograms per gram (parts per billion)
ng/kg	nanograms per kilogram (parts per trillion)
ng/L	nanograms per liter (parts per trillion)
NTU	nephelometric turbidity units
pg/g	picograms per gram (parts per trillion)
pg/L	picograms per liter (parts per quadrillion)
psu	practical salinity units
s.u.	standard units
µg/g	micrograms per gram (parts per million)
µg/kg	micrograms per kilogram (parts per billion)
µg/L	micrograms per liter (parts per billion)
µm	micrometer
µM	micromolar (a chemistry unit)
µmhos/cm	micromhos per centimeter
µS/cm	microsiemens per centimeter, a unit of conductivity
ww	wet weight

B.4 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).

Continuing Calibration Verification Standard (CCV): A quality control (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): 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).

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 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:

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

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: A discrete sample subdivided into portions, usually duplicates (Kammin, 2010).

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

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