Quality Assurance Project Plan

Lacamas Creek Temperature Source Assessment

Water Quality Program

Washington State Department of Ecology

Southwest Region Office

Olympia, Washington

June 2026, Publication 26-10-053

DEPARTMENT OF ECOLOGY State of Washington

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Contact Information

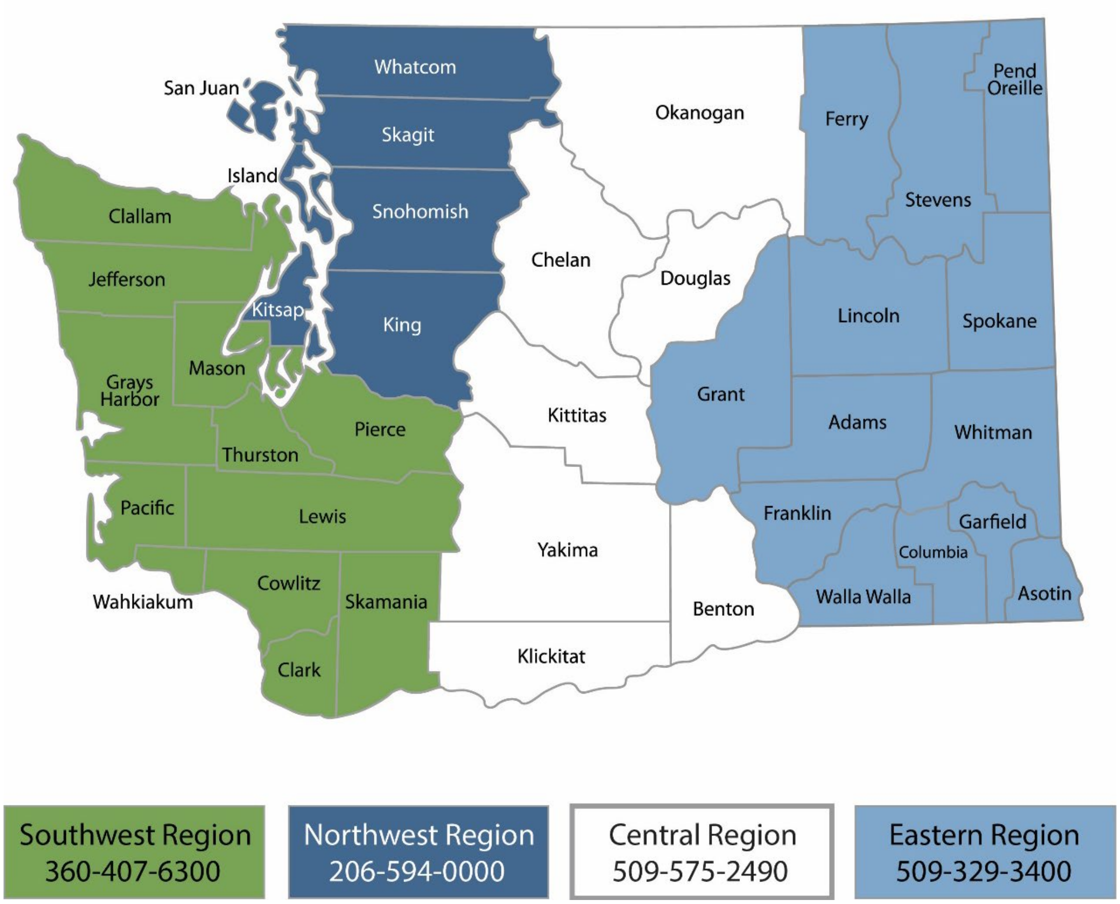
Water Quality Program
Washington State Department of Ecology
P.O. Box 47775
Olympia, WA 98504-7775
Phone:

Washington State Department of Ecology – https://ecology.wa.gov

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

Department of Ecology's Regional Offices

Map of Counties Served



Region	Counties Served	Mailing Address	Phone
Southwest	Clallam, Clark, Cowlitz, Grays Harbor, Jefferson, Mason, Lewis, Pacific, Pierce, Skamania, Thurston, Wahkiakum	PO Box 47775 Olympia, WA 98504	360-407-6300
Northwest	Island, King, Kitsap, San Juan, Skagit, Snohomish, Whatcom	PO Box 330316 Shoreline, WA 98133	206-594-0000
Central	Benton, Chelan, Douglas, Kittitas, Klickitat, Okanogan, Yakima	1250 W Alder St Union Gap, WA 98903	509-575-2490
Eastern	Adams, Asotin, Columbia, Ferry, Franklin, Garfield, Grant, Lincoln, Pend Oreille, Spokane, Stevens, Walla Walla, Whitman	4601 N Monroe Spokane, WA 99205	509-329-3400
Headquarters	Across Washington	PO Box 47600 Olympia, WA 98504	360-407-6000

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Lacamas Creek Temperature Source Assessment

by

Julian Sammons

Water Quality Program

Washington State Department of Ecology

Southwest Regional Office

Olympia, WA

June 2026 | Publication 26-10-053

QAPP Approval Signatures

Signature: *Julian Sammons (electronic)* Date: 4/2/2026

Julian Sammons, Author and Project Manager, WQP

Signature: *Lawrence Sullivan (electronic)* Date: 4/2/2026

Lawrence Sullivan, Author's Unit Supervisor, WQP

Signature: *Andrew Kolosseus (electronic)* Date: 4/8/2026

Andrew Kolosseus, Author's Section Manager, WQP

Signature: *Chris Dudenhoeffer (electronic)* Date: 4/8/2026

Chris Dudenhoeffer, Quality Assurance Coordinator, WQP

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2.0 Abstract

Lacamas Creek and its major tributaries do not meet Washington State water quality criteria for temperature. The Washington State Department of Ecology (Ecology) collected temperature data in this watershed in 2023-2024 as part of a study looking at multiple tributaries to the lower Cowlitz River (Sammons, 2025). This study will use existing temperature data collected in 2023-2024, as well as new temperature data and field measurements collected in 2026, to model existing and potential in-stream temperature scenarios with in PointWQ, a simplified mechanistic surface water model that is used for small streams and rivers. The existing conditions scenario will use outputs from the shade model as well as field measurements collected in 2026 as inputs. It will be calibrated using 2026 stream temperature data. This calibrated model will then be used to estimate stream temperatures in restored (potential shade) model scenarios. The site potential shade information will be used to estimate stream temperatures with full site potential shade using the PointWQ model for temperature. The Source Assessment report generated by this project will be used to develop an Advanced Restoration Plan (ARP) that will identify priority areas for implementation of projects that will improve shade and reduce peak stream temperatures in this watershed.

3.0 Background

3.1 Introduction and problem statement

Lacamas Creek is on Ecology's 303(d) list of impaired waters for temperature. In 2023 and 2024, Ecology collected temperature data in major tributaries to the lower Cowlitz River, including Lacamas Creek. Results from this study show temperature impairments exist in this watershed at each location monitored. These streams provide habitat for numerous species of salmonid, including fall Chinook, winter steelhead, coho, fall chum and coastal cutthroat (WDFW, n.d.). It is an area of focus for habitat restoration efforts in the lower Cowlitz River (RCO, n.d.). In the *Washington Lower Columbia Salmon Recovery and Fish and Wildlife Subbasin Plan for Lower Cowlitz* (LCFRB, 2010) temperature is listed as one of the primary limiting factors impacting coho and winter steelhead in this geography. Ecology is identified as the lead agency responsible for addressing this limiting factor. This subbasin plan also identifies reaches in the Lacamas Creek watershed as Tier 1 and Tier 2 for restoration priority. Large portions of Lacamas Creek contain agriculture and development where little or no riparian buffer exists.

Ecology is now focusing on this watershed for a Source Assessment that will be used to develop an Advanced Restoration Plan to address these temperature impairments. This study will identify areas in the stream with the greatest deficits of riparian shade cover and will demonstrate with modeling if a fully restored riparian corridor can lead to stream temperatures meeting water quality standards.

3.2 Study area and surroundings

Lacamas Creek is in WRIA 26 in Lewis County, Washington (Figure 1). The three largest tributaries to Lacamas Creek are Bear Creek, Mill Creek and Baker Creek. All three drain a portion of the Puget Lowland, between the Willapa Hills and the Cascades, ultimately flowing into the Cowlitz River near the town of Toledo. The drainage covers approximately 42 square miles and received an average mean annual precipitation of 46.7 inches from 1981 to 2010 (USGS, n.d.). The confluence of Bear Creek and Lacamas Creek is approximately 0.8 river miles (RM) from the mouth of Lacamas Creek where it flows into the Cowlitz River. Mill Creek flows into Lacamas Creek at approximately RM 5.4 of Lacamas Creek. Baker Creek flows into Lacamas Creek at approximately RM 12.4 of Lacamas Creek.

This study will focus on the mainstem of Lacamas Creek. The three listed tributaries have either relatively intact riparian corridors for much of their lengths or have minimal or no flow during the summer low flow period, or a combination of these factors. Lacamas Creek also has long reaches along the mainstem with intact riparian corridors but suffers from lengthy reaches of agriculture and development where little or no riparian buffer exists. Many of these impacted reaches of Lacamas Creek also see consistent flow through the critical summer low flow period.

Figure 1. Map showing the study area and Water Resource Inventory Area (WRIA) 26 in relation to the larger geographic area.

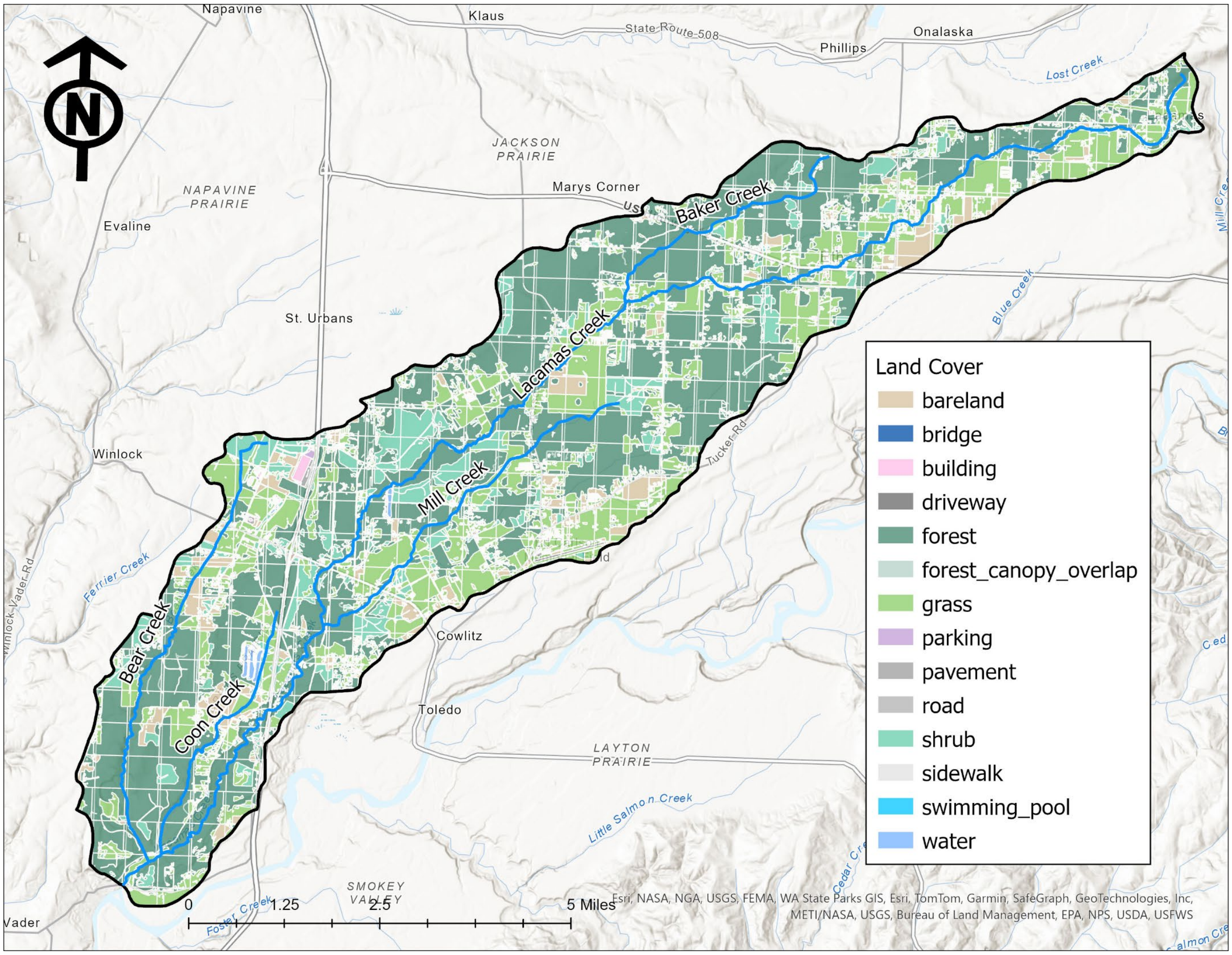

Figure 2. Map showing land cover in the Lacamas Creek watershed (Statewide Ecopia 3ft Land Cover 2021-2022).

3.2.1 History of study area

The watershed is approximately 53% forest land, 33% grass or bare land (much of which is pasture or hayfield for agricultural uses), 9.6% shrub (which is largely composed of forest land containing young plantings) and 3.7% road, driveway, building, pavement and parking (Figure 2). Historically, the area contained Lacamas Prairie, Cowlitz Prairie and Drew's Prairie. These prairies have been almost entirely converted to agriculture. The drainage still contains large wetlands and forested areas.

3.2.2 Summary of previous studies and existing data

See Table 1 for a summary of previous studies and existing data.

Lower Cowlitz River tributaries verification study

In 2023 Ecology's Southwest Regional Office (SWRO) Water Quality Program initiated a verification study in the lower Cowlitz River (Sammons, 2025). The purpose of this study was to fill data gaps along the major tributaries to the lower Cowlitz River. This included bacteria samples and in situ measurements (parameters shown in Table 1) at downstream locations on 11 tributaries, as well as continuous temperature data at 27 locations along those same tributaries. Within the Lacamas Creek subbasin there were four continuous temperature locations, of which one included bacteria and in situ measurements (Table 1).

Statewide river and stream ambient monitoring

The purpose of this ongoing study conducted by Ecology is to "collect long-term water quality data from a state-wide network of stations. Thirteen conventional constituents are measured monthly at 82 stations…". This work was responsible for the data from Lacamas Creek that predated the 2023-2024 verification study.

Table 1. Previous projects in the study area.

Waterbody Name	Study Name(s)	Parameter(s)	Years Collected
Lacamas Creek	Lower Cowlitz river tributaries verification study Statewide river and stream ambient monitoring	Temperature, Dissolved Oxygen, pH, Turbidity, Conductivity, Bacteria (*E. coli*)	2002-2005 2023-2024
Mill Creek	Lower Cowlitz river tributaries verification study	Temperature	2023-2024

3.2.3 Parameters of interest and potential sources

3.2.3.1 Temperature (nonpoint)

Temperature is the parameter of interest in this study. The purpose of this study is to guide the implementation of restoration efforts in the watershed that will lower stream temperatures by addressing areas with large shade deficits. These shade deficits are the likely primary driver of temperature increases in this stream. Stream channel improvements (floodplain reconnection, habitat complexity, etc.) are additional implementation efforts that can address temperature impairments.

3.2.3.2 Point sources

The temperature impairments are driven by nonpoint pollution in the form of solar energy reaching the stream's wetted width during critical periods. In the Lacamas Creek drainage there are currently 20 permitted outfalls under the construction stormwater general permit and one industrial stormwater outfall. None of these outfalls are considered significant contributors to the temperature impairments and thus are not in the scope of this project.

3.2.4 Regulatory criteria or standards

Washington State's Water Quality Standards (WQS) listed under the Washington Administration Code (WAC) Chapter 173- 201A are the basis for protecting and assessing the health of waterbodies. The purpose of these standards is to protect public health and recreation in state waters as well as protect fish, shellfish, and wildlife. Based on guidance from the Clean Water Act, the standards specify the designated beneficial uses for different water bodies and assign numeric and narrative criteria to protect those uses. The anti-degradation policy provides additional protections for waters that meet a higher quality than the limits set in the standards and are considered an outstanding resource.

The main beneficial uses protected under the WQS include:

- Aquatic life use — all indigenous fish and nonfish aquatic species
- Primary contact recreation — activities where direct contact with water to the point of complete submergence is possible.
- Water supply uses — domestic consumption, industrial production, agriculture or hobby farm livestock.
- Miscellaneous uses — wildlife habitat, harvesting, commerce/navigation, boating, and aesthetics (WAC 173-201A-600).

All the streams monitored in this study have designated aquatic life use of "core summer salmonid habitat". All the streams are designated "primary contact recreation" for recreation use and are subject to the water supply and miscellaneous uses mentioned above.

Table 2 includes the designated use classifications and water quality criteria for each water quality parameter monitored in this study.

Table 2. Washington State freshwater use designations (WAC 173-201A-600) and criteria for specific parameters (WAC 173-201A-200) for listed parameters in this study.

Water Quality Parameter	Designated Use Classification	Criteria
Temperature	Core summer salmonid habitat	16°C 7-day average of the daily (DAD) maximum temperature[a]

[a]7-DAD Max represents the highest annual running 7-day average of daily maximum temperatures.

3.3 Water quality impairment studies

This study will be completed as a Source Assessment and used to develop an Advanced Restoration Plan (ARP). ARPs are increasingly important tools for water quality improvement. While TMDLs have proven to be complex and resource intensive, an ARP provides a near-term plan that is more immediately beneficial or practicable to water quality improvement. Source Assessments are usually narrower in scope than a TMDL study and may not fully quantify the influence of point sources. The ARP informed by this Source Assessment will be implemented in advance of a TMDL, which may be necessary if water quality standards are still not met.

Additionally, a Source Assessment is used to identify and prioritize sources of pollutants, mainly from nonpoint sources. Source Assessments are an appropriate option under circumstances which are listed below. The Lacamas Creek Watershed meets these criteria:

- The watershed is dominated by nonpoint sources.
- The watershed is primarily rural (less than 50% of the watershed area is developed).
- Any point sources that are present are dominated by stormwater.
- There are local resources available to support implementation efforts from volunteer groups, organized local government programs and conservation districts.

The Environmental Protection Agency (EPA) sets recommendations for the watershed planning process of an ARP. The EPA evaluates Ecology’s Source Assessment and ARP and determines acceptance based on the completion of the following:

- Identification of specific water segments or waters bodies that do not meet water quality standards and identification of pollution sources.
- Analysis to support the use of the alternative restoration approach to meet water quality standards.
- An Implementation Plan to document the actions to address sources of pollution and a projected timeline for milestones and deliverables.
- Identification of available funding opportunities to implement the ARP.
- Identification of all entities involved in the implementation and additional parties needed.
- An estimated timeline for when water quality standards will be met.
- Plans for effectiveness monitoring to evaluate progress toward meeting water quality standards, including an adaptive management and evaluation process.
- Commitment to periodically evaluate whether the ARP approach is immediately beneficial or practicable in achieving water quality standards compared to the TMDL approach.

Each of these components will be addressed in the Lacamas Creek Source Assessment and ARP.

4.0 Project Description

4.1 Project Goals

The goal for this project is as follows:

- Identify priority areas to enhance riparian shade or implement stream restoration that will improve (reduce) elevated stream temperatures.

4.2 Project objectives

The goal for this project will be reached through the completion of the following objectives:

- Develop shade model to determine effective shade and system potential shade for the Lacamas Creek watershed and identify areas with shade deficits.
- Determine if impaired waters can meet temperature criteria in a fully restored system potential shade scenario by using the outputs of the Shade model with the PointWQ temperature model calibrated with 2026 measurements.

4.3 Information needed and sources

This study will utilize temperature data collected in 2026 by Ecology. This will include continuous temperature data, bankfull width measurements, stream depth measurements, and hemispherical photos or Solar Pathfinder measurements.

Geospatial data used for TTools will be obtained from the Washington State Department of Natural Resources (DNR) LiDAR portal and other sources as needed (i.e. orthoimagery).

4.4 Tasks required

The tasks required to complete this study are outlined in Table 3 below.

Table 3. Tasks required for this project.

Category	Task	Lead
2026 QAPP	Write and publish QAPP	WQP
Temperature	Field work	WQP
Temperature	EIM	WQP
Temperature	Data analysis	WQP
Temperature	Shade modeling	WQP
Temperature	PointWQ modeling	WQP
Data Quality Review	EIM QA	WQP
Report	Source Assessment report	WQP

4.5 Systematic planning process

This QAPP for the Lacamas Creek source assessment serves as the basis for the planning process for this project.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

Table 4 shows the responsibilities of those who will be involved in this project.

Table 4. Organization of project staff and responsibilities.

Staff	Title	Responsibilities
Julian Sammons Watershed Cleanup & Technical Assistance Unit WQP SWRO Phone: (360)584-2753	Project Manager	Writes the QAPP. Conducts fieldwork. Conducts QA review of data, analyzes and interprets data, and enters data into EIM. Writes the draft report and final report.
Lawrence Sullivan Watershed Cleanup & Technical Assistance Unit WQP SWRO Phone: (564) 999-3585	Unit Supervisor for Project Manager	Provides internal review of the QAPP, approves the budget, and approves the final QAPP.
Andrew Kolosseus WQP SWRO Phone: (360) 529-7641	Section Manager for Project Manager	Reviews the project scope and budget, tracks progress, reviews the draft QAPP, and approves the final QAPP.
Chris Dudenhoeffer Quality Assurance Coordinator WQP (360) 870-8409	Quality Assurance Coordinator	Reviews and approves the draft QAPP and the final QAPP.

EIM: Environmental Information Management database.
SWRO: Southwest Regional Office
WQP: Water Quality Program
QAPP: Quality Assurance Project Plan.

5.2 Special training and certifications

Field staff will be trained in sampling methods by becoming familiar with procedures and quality control practices outlined in the relevant Ecology standard operating procedures (SOPs), which are listed in Section 8.2.

Staff with experience in evaluating environmental data from past Ecology projects like this source assessment will lead the technical assessment of the results.

5.3 Organization chart

Table 4 in Section 5.1 outlines the individuals and organizations involved in this study.

5.4 Proposed project schedule

Tables 3 – 5 list key activities, due dates, and lead staff for this project.

Table 5. Schedule for completing fieldwork, data management and report.

Task	Due Date	Lead Staff
Field work completed	October 2026	Julian Sammons
EIM data loaded[1]	December 2026	Julian Sammons
EIM QA[2]	December 2026	Julian Sammons
EIM complete[3]	March 2027	Julian Sammons
Data Quality Assessment	October 2027	Julian Sammons
Technical Analysis	October 2027	Julian Sammons
Draft to supervisor	December 2027	Julian Sammons
Draft to peer reviewer	December 2027	Julian Sammons
Final draft to publications team	April 2028	Julian Sammons
Final report due on web	July 2028	Julian Sammons

EIM: Environmental Information Management database.
[1] All data entered into EIM by the lead person for this task.
[2] Data verified to be entered correctly; any data entry issues identified. Allow one month.
[3] All data entry issues identified in the previous step are fixed.

5.5 Budget and funding

Staff time for data collection, analysis and reporting will be provided by Ecology's Water Quality Program. This project will not require any laboratory analysis or the purchase of additional equipment or supplies.

6.0 Quality Objectives

Quality objectives are statements of 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. The definitions in this section and information in Tables 6 & 7 are from the Programmatic QAPP for Water Quality Impairment Studies (McCarthy and Mathieu, 2017).

6.1 Data quality objectives

Data quality objectives (DQOs) establish acceptable quantitative criteria on the quality and quantity of the data to be collected, relative to the ultimate use of the data. These criteria are known as performance or acceptance criteria, or DQOs. DQOs represent the overarching quality objectives of the study, including that collected data meet measurement quality objectives (MQOs).

The main DQO for the source assessment data collection is to collect continuous temperature at each site from late spring through the summer using established SOPs to meet the measurement quality objectives (MQOs) outlined in the following sections.

6.2 Measurement quality objectives

Measurement quality objectives (MQOs) are performance or acceptance criteria for individual data quality indicators, including precision, bias, sensitivity, completeness, comparability, and representativeness.

Field sampling procedures inherently have associated uncertainty, which results in data variability. Together precision and bias express data accuracy. The MQOs for field procedures in this study are shown in Table 6 and described in the following sections.

Table 6. MQOs for field measurements and equipment information.

Parameter	Equipment Type/Method	Precision – Field Duplicates	Bias	Equipment Accuracy	Equipment Resolution	Equipment Range	Estimated Range
Continuous Water Temperature	HOBO TidbiT MX Temperature	NA	NA	0.2° C	0.01° C	-20° to 50° C	0° to 30° C

6.2.1 Targets for precision, bias and sensitivity

6.2.1.1 Precision

Precision is a measure of variability among replicate measurements due to random error. Potential sources of random error include natural temporal and spatial variability of stream conditions during sampling or variability introduced by field procedures. Field sampling precision will be addressed by collecting replicate measurements.

6.2.1.2 Bias

Bias is the difference between a sample mean and the true value. Bias in field sampling procedures will be reduced by following the relevant Ecology SOPs as described in Section 8.2.

For field collection, bias for field measurements will be addressed by performing pre-check measurements, mid-deployment QC checks, and post-check measurements to a known standard or NIST-traceable instrument (i.e. NIST certified/traceable thermistor). Table 7 presents the data quality objectives for continuous temperature QC checks. First, the measurement data are reviewed, adjusted (if applicable), and finalized. The median residual of the finalized data and QC checks is then calculated and compared to the MQOs listed in Table 7.

Table 7. MQOs for continuous temperature measurements.

Parameter	Unit	Accept	Qualify	Reject
Water Temperature	°C	≤ ± 0.2	> ± 0.2 and ≤ ± 0.8	> ± 0.8

6.2.1.3 Sensitivity

For field measurements, the sensitivity of the instrument is described by its range, accuracy, and resolution. This is usually reported for each instrument by the manufacturer. Examples of this information are provided in Table 6.

6.2.2 Targets for comparability, representativeness, and completeness

6.2.2.1 Comparability

To improve comparability to previously collected Ecology data, field staff will adhere to data quality criteria and follow EAP protocols outlined in the Standard Operating Procedures (SOPs) outlined in Section 8.2.

6.2.2.2 Representativeness

See Section 6.2.2.2 of the Programmatic QAPP (McCarthy and Mathieu, 2017).

6.2.2.3 Completeness

See Section 6.2.2.2 of the Programmatic QAPP (McCarthy and Mathieu, 2017).

6.3 Acceptance criteria for quality of existing data

Any water quality data from outside this study used in the analysis must meet the agency's credible data policy requirements: Water Quality Policy 1-11 Chapter 2 — Ensuring Credible

Data for Water Quality Management (Ecology, 2018). The final report will include an assessment of data quality for any outside data used for analysis and certification that the data meets a level of quality acceptable for use in development of the ARP. The data quality assessment would include one or all the following elements:

- Reference to a peer-reviewed and published Quality Assurance Project Plan (QAPP) or equivalent plan.
- Demonstration that the data collected yielded results of comparable quality to the study (based on data quality objectives and requirements in this QAPP).
- Documentation that the objectives of the QAPP or equivalent quality assurance procedures were met and that the data are suitable for water quality-based actions. The assessment of the data must consider whether the data, in total, fairly characterize the quality of the water body at that location at the time of sampling.
- Documentation of the planning, implementation, and assessment strategies used to collect the information, including:
    - Documentation of the original intended use of the information gathered (e.g., chemical/physical data for TMDL analyses).
    - Description of the limitations on use of the data (e.g., these measurements only represent storm-event conditions).

Datasets must be complete, that is, not censored to include only part of the data results from the project.

6.4 Model quality objectives

Universally applied quantitative criteria for model performance do not exist. Quantitative criteria can be appropriate if thoughtfully set for individual projects. This project uses quantitative and qualitative model quality objectives to assess model performance.

See Section 6.3 of the Programmatic QAPP (McCarthy and Mathieu, 2017) for a discussion of the broader model quality objectives for water quality impairment studies and a list of specific qualitative model quality objectives related to the key driving processes.

Table 8 presents numerical targets that will be used to help evaluate the PointWQ model's water quality calibration. These targets will guide a thoughtful, comprehensive evaluation of model quality within a larger domain. As such, poor calibration in parts of the model outputs compared to any of these targets does not necessarily indicate that the model's calibration is unacceptable. Conversely, a good or fair rating does not necessarily mean the model will be deemed acceptable for all study objectives.

Ecology will not determine the overall quality of the model predictions based on a single statistic alone or comparison to a single established criterion. Instead, Ecology will assess overall quality based on:

- The model's ability to simulate key drivers and processes evident in the observed data.
- Multiple statistical metrics that evaluate model bias, accuracy, and correlation.

Table 8. Numerical targets for evaluation PointWQ calibration.

Parameter (unit)	Metric	Measure	Good	Fair	Poor
Temperature (°C)	Daily Max	RMSE	<0.8	0.8-1.6	>1.6
Temperature (°C)	Daily Max	Bias	<0.4	0.4-0.8	>0.8

7.0 Study Design

7.1 Study boundaries

The Lacamas Creek watershed is in the lower Cowlitz River watershed, near Toledo, WA in WRIA 26. The study boundary, shown in Figure 3 encompasses the Lacamas Creek watershed, which includes Bear Creek, Mill Creek, Coon Creek, Baker Creek, and several unnamed tributaries. Study sites within the study area are also shown in Figure 3.

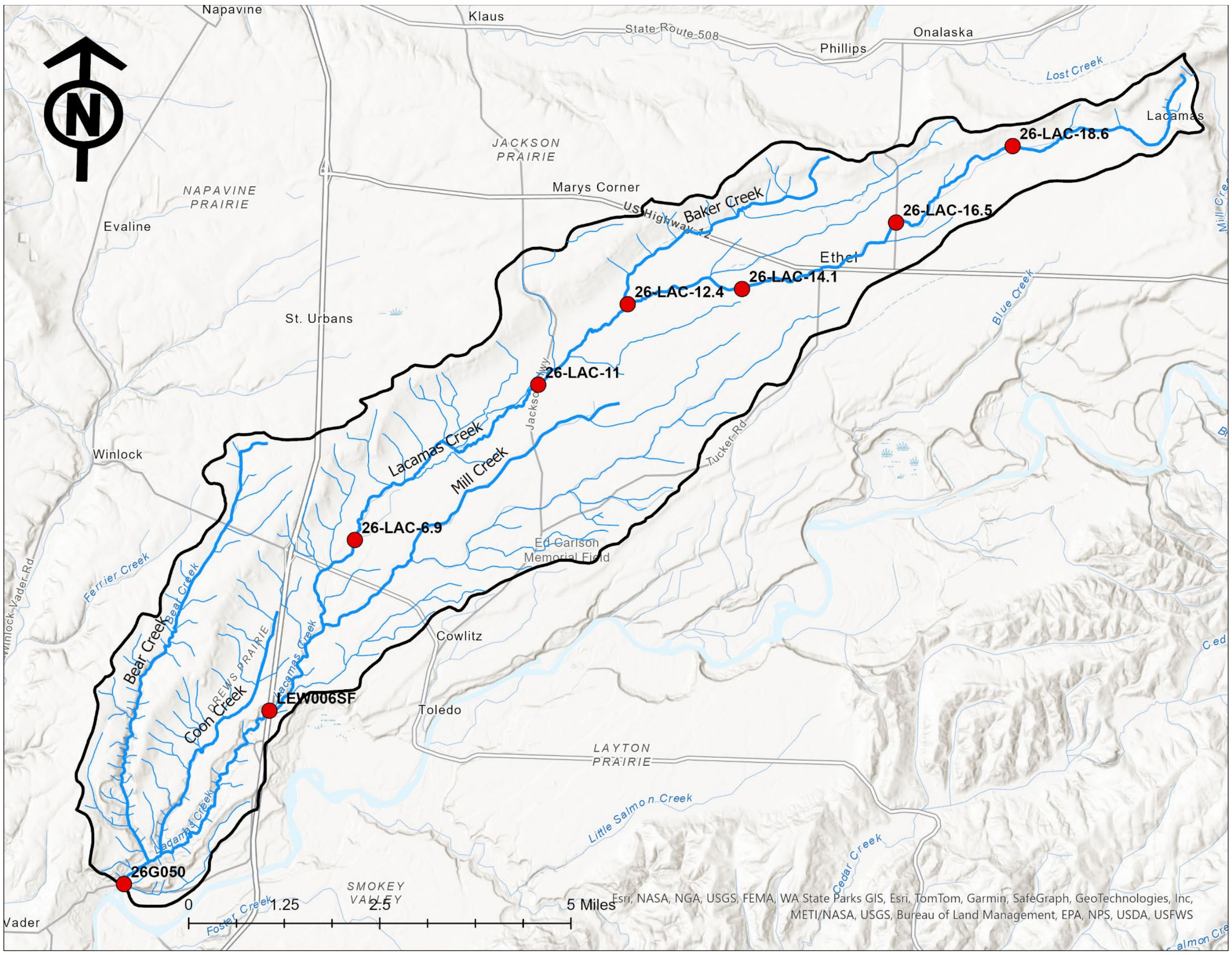

Figure 3. Map showing boundary of project study area and monitoring locations.

7.2 Field data collection

Data collection will occur during the summer of 2026, and will include continuous temperature, discrete flow, stream channel, and canopy measurements, as well as optional continuous multiparameter sonde deployments as outlined below. Ecology may extend the data collection if flow, air temp or weather conditions during this period do not include a period that represents typical conditions where high water temps occur (e.g. a very cool rainy summer with higher flows).

- Continuous temperature monitoring:
    - Ecology will collect continuous temperature data using Onset Tidbit MX data loggers at sites shown in Table 9 from no later than June to September 2026, including air temperature loggers within 1 mile of each water temperature logger.
- Flow measurements:
    - Ecology may collect flow measurements at each continuous temperature site during deployment. Flow will be measured in accordance with EAP 024 (Kardouni and Mathieu, 2019).
- Multiparameter sonde deployments:
    - Ecology may deploy a multiparameter sonde at select locations for limited-duration deployments (1-2 weeks), collecting continuous dissolved oxygen, temperature, conductivity, and pH measurements. This will be done in accordance with EAP129 (Mathieu and Stuart, 2019).
- Vegetation, shade and stream channel measurements:
    - This project will use the transect design used in EAP 084 (Urmos-Berry, 2019). Due to this project's reliance on stream access from public right-of-way, one transect will be established near each continuous temperature logger and additional transects may be established where possible at adjacent upstream or downstream locations.
    - Ecology will collect at least one pool or thalweg depth, and bankfull and wetted width measurement at each transect for comparison with digitized width measurements derived from GIS.

Ecology will collect hemispherical photos (or use Solar Pathfinder as an alternative) at each transect in accordance with EAP 045 (Stohr et al. 2019) for hemispherical photos or section 7.13 of EAP 084 (Urmos-Berry, 2019) for Solar Pathfinder measurements. One photo or measurement will be taken from the thalweg or stream center for effective shade.

7.2.1 Sampling locations and frequency

Continuous temperature loggers will be deployed by the end of June 2026 logging on 15-minute intervals until they are retrieved in September 2026. All field data collection in section 7.2 will occur during these deployments. Locations for data collection are shown in Figure 3 as well as Table 9. The sample locations were selected based on their distribution across the major tributaries as well as the various shade characteristics they capture.

Table 9. Proposed sample locations for continuous water and air temperature monitoring.

Location ID	Location Name	Setting	Latitude	Longitude
26G050	Lacamas Creek at SR506	Stream/River	46.411722	-122.926139
26G050a	Lacamas Creek at SR506 (air)	Air/Climate	46.411722	-122.926139
LEW006SF	Lacamas Creek at Camus Rd.	Stream/River	46.44543	-122.88771
LEW006SFa	Lacamas Creek at Camus Rd. (air)	Air/Climate	46.44543	-122.88771
26-LAC-6.9	Lacamas Creek at Henriot Rd.	Stream/River	46.4782	-122.8658
26-LAC-6.9a	Lacamas Creek at Henriot Rd. (air)	Air/Climate	46.4782	-122.8658
26-LAC-11	Lacamas Creek at Jackson Hwy	Stream/River	46.5086	-122.8168
26-LAC-11a	Lacamas Creek at Jackson Hwy (air)	Air/Climate	46.5086	-122.8168
26-LAC-12.4	Lacamas Creek at Nicholson Rd.	Stream/River	46.524395	-122.792893
26-LAC-12.4a	Lacamas Creek at Nicholson Rd. (air)	Air/Climate	46.524395	-122.792893
26-LAC-14.1	Lacamas Creek at Oyler Rd.	Stream/River	46.5279	-122.7616
26-LAC-14.1a	Lacamas Creek at Oyler Rd. (air)	Air/Climate	46.5279	-122.7616
26-LAC-16.5	Lacamas Creek at Leonard Rd.	Stream/River	46.5413	-122.7199
26-LAC-16.5a	Lacamas Creek at Leonard Rd. (air)	Air/Climate	46.5413	-122.7199
26-LAC-18.6	Lacamas Creek at Gilbert Rd.	Stream/River	46.5564	-122.6885
26-LAC-18.6a	Lacamas Creek at Gilbert Rd. (air)	Air/Climate	46.5564	-122.6885

7.2.2 Field parameters and laboratory analytes to be measured

Table 10 lists the parameters that will be collected in this study.

Table 10. Parameters that will be collected in this study.

Parameter	Data Type
Water temperature	Continuous measurement

Air temperature	Continuous measurement
Dissolved Oxygen	Continuous measurement
pH	Continuous measurement
Conductivity	Continuous measurement
Stream flow	Discrete measurement
Solar radiation	Discrete measurement

7.3 Modeling and analysis design

The modeling framework for this study will require multiple modeling and analysis tools. The following sections describe the framework, data requirements, assumptions, potential challenges, and contingencies.

7.3.1 Analytical framework

For Shade modeling, Ecology will follow the framework outlined in Appendix C of the Lacamas Creek Bacteria, Temperature, and Nutrients Source Assessment Report (Trant-Sinclair et al. 2024). Ecology plans to use three primary tools (described in greater detail in a subsequent section) to accomplish the goal of this study:

- TTools (Ecology, 2015) - An Arc-GIS add-in used to process stream channel and riparian corridor spatial information for input into the shade model.
- Shade.xlsm model (Ecology, 2003) - An Excel spreadsheet interface model written in VBA for calculating effective riparian shade.
- PointWQ (Stuart, 2023) - an Excel workbook tool that combines two historical spreadsheet modeling tools: rTemp and River Metabolism Analyzer (RMA). The Programmatic QAPP and Ecology's Models & Tools for TMDLs - Washington State Department of Ecology webpage provide more detail on these tools. This project's use of PointWQ will be limited to the temperature component.

7.3.1.1 Ttools for ArcGIS

TTools will be used to estimate effective shade inputs for use in shade modeling. TTools is an ArcView extension developed by the Oregon Department of Environmental Quality (ODEQ) and adapted by Ecology. Ecology currently maintains an updated, python-scripted ArcGIS Pro version of the tool.

TTools is used to extract GIS data from acquired polygon and grids coverages. It specifically uses these coverages to extract vegetation and topography data perpendicular to the stream channel and longitudinal stream-channel characteristics, such as the near-stream disturbance zone and elevation. Stream width, aspect, topographic shade angles, elevation, and riparian vegetation are sampled with TTools for incorporation into the Shade model. This project will follow the procedure outlined in Appendix C of the Lacamas Creek Source Assessment (Trant-Sinclair et al. 2024), which uses a canopy height model (CHM) created using LiDAR data to calculate canopy height, density and overhang for use as inputs to the shade model.

More details about TTools and other computer models used by Ecology are located on [Ecology's Models and Tools for TMDLs webpage](#).

7.3.1.2 Shade model

Ecology's Shade model is a tool for estimating shade from riparian vegetation (Ecology 2003). The model will be used to evaluate solar radiation and effective shade in the project area.

The Shade model calculates effective shade using either the (1) Chen method (Chen 1996; Chen et al. 1998) or (2) the original method by ODEQ from the HeatSource model version 6 (Boyd 1996; Boyd and Kasper 2003).

The Shade model quantifies the potential daily solar load and generates the percent effective shade. Effective shade is the fraction of shortwave solar radiation that does not reach the stream surface because vegetative cover and topography intercept it. Effective shade is influenced by latitude/longitude, time of year, stream geometry, topography, and vegetative buffer characteristics, such as height, width, overhang, and density.

The Shade model requires physical and vegetation parameters such as stream width, aspect, topographic shade angles, elevation, and riparian vegetation that will be determined using the TTools GIS extension. Most data inputs for the Shade model are easily available through aerial imagery and digital elevation models. Additional field data are collected to characterize riparian shade (to compare observed shade to model-predicted shade) and vegetation. The TTools output is used as input for the Shade model to generate longitudinal effective shade profiles. Riparian vegetation, stream aspect, topographic shade angles, and latitude/longitude will be used to estimate effective shade. For this project, effective and site potential shade will be used as inputs for the PointWQ model for estimating stream temperatures under the different scenarios.

7.3.1.3 PointWQ

Ecology's PointWQ is an Excel workbook tool that combines two historical spreadsheet modeling tools: rTemp and River Metabolism Analyzer (RMA). For this project PointWQ will be used for temperature modeling, using only the rTemp functionality of PointWQ. Ecology's rTemp is a simple response temperature model that is used to predict a time-series of water temperatures in response to heat fluxes determined by meteorological data, groundwater inflow, hyporheic exchange, and conduction between the water and sediment. It is a one-dimensional heat response model that can be used to calculate long-term temperature time series for small streams.

7.3.2 Model setup and data needs

For a detailed overview of model setup and data needs, see Appendix C of the Lacamas Creek Bacteria, Temperature, and Nutrients Source Assessment Report (Trant-Sinclair et al. 2024).

Ttools requires the following data to run:

- Single-part or single segment polyline representing a stream centerline.
- Digitized stream bank layers, either bank polyline layers representing the right and left bank delineation or stream bank polygons representing both left and right banks of the stream using aerial imagery.
- High resolution digital elevation model file to obtain elevation values.
- Vegetation polygon or Canopy Height Model (CHM) raster used for sampling vegetation.

The Lacamas Creek stream centerline will be created using aerial imagery combined with LiDAR and National Hydography Dataset (NHD) flowlines. The digitized stream bank layers will be created in GIS using aerial imagery and information from field measurements. The digital elevation model file for elevation and creating the CHM raster will be obtained from Ecology's GIS database or the Washington State Department of Natural Resources LiDAR portal.

The shade model requires physical and vegetation parameters to estimate effective and potential shade. Ttools output will be used as input for the Shade model to generate longitudinal effective shade profiles. Riparian vegetation, stream aspect, topographic shade angles, and latitude/longitude will be used to estimate effective shade. The shade model uses the following parameters as model inputs based on various data collection methods:

- Stream bankfull and wetted widths determined from a combination of channel survey measurements from GIS digitization from aerial imagery and site visits.
- Riparian canopy height and density.
- Topographic shade, stream elevation, and stream aspect calculated using GIS with Ttools and a digital elevation model file.

Hemispherical photographs or Solar Pathfinder measurements will be used to compare observed shade to model-predicted shade.

System potential shade will also be estimated using the shade model. System potential effective shade is the natural maximum level of shade that a given stream can attain with the growth of system-potential mature riparian vegetation. System-potential mature riparian vegetation refers to the vegetation that can grow and reach a climax succession (in 100 years) at a site without human disturbance, based on climate, elevation, soil properties, plant biology, and hydrologic processes.

PointWQ uses the following inputs for calibration and estimating stream temperature:

- Continuous water temperature data, which will be collected as outlined in section 7.2.
- Meteorological data. This includes air temperature, which will be collected as outlined in section 7.2. Dewpoint, wind speed, cloud cover and shortwave solar radiation will be used, as available, from a nearby weather station with an established QA/QC program.

- Water depth, collected as outlined in section 7.2.
- Groundwater inflow and temperature (optional).
- Effective shade.
- Latitude/longitude and elevation.

7.4 Assumptions underlying design

See Section 7.4 in the Programmatic QAPP (McCarthy and Mathieu, 2017) for an expanded list of applicable data collection and modeling assumptions.

Use of PointWQ for stream temperature modeling assumes certain inputs (depth and effective shade) are representative of stream conditions for an unspecified distance upstream that achieves equilibrium (Stuart et al. 2024). These field measurements will be collected in a manner that, within the constraints present in the field, best represent each reach and consider the effect of travel time (e.g. collecting multiple depth measurements, including pool depth measurements, selecting locations with shade representative of the reach and near a pool, etc.).

7.5 Possible challenges and contingencies

7.5.1 Logistical problems

Logistical problems for this study might include:

- Field collection should occur in a relatively short window of time (June to August) to capture critical conditions. Staff will plan their schedule accordingly.
- It is assumed that the time period previously mentioned will represent low flow conditions, but this is dependent on a typical dry summer period. Staff can adapt their schedules to accommodate changes to this.

7.5.2 Practical constraints

Practical constraints for this study might include:

- Staff time to complete field surveys. The study is designed to accommodate the staff resources available.
- Field equipment; if hemispherical photos are used rather than Solar Pathfinder, SWRO WQP requires equipment loaned from EAP.
- Availability of soils and site potential tree height data for the area.

7.5.3 Schedule limitations

Schedule limitations for this study might include:

- QAPP development, review and approval.
- Weather conditions that delay field collection.
- Available resources (staff and budget).
- Need for additional data during modeling may require additional year of field collection.

8.0 Field Procedures

8.1 Invasive species evaluation

Field staff will be trained and adhere to Standard Operating Procedure EAP070 *Minimize the Spread of Invasive Species* (Parsons et al. 2021).

8.2 Measurements and sampling procedures

For continuous field measurements Ecology will use the following SOPs:

- EAP080 - Continuous Temperature Monitoring of Freshwater Rivers and Streams (Nelson and Dugger, 2022).
- EAP024 – Measuring Streamflow for Water Quality Impairment Studies (Kardouni and Mathieu, 2019).
- EAP129 – Short-term Continuous Data Collection with a Multiparameter Sonde (Mathieu and Stuart, 2019)

For field measurements Ecology will use the following SOPs:

- EAP084 – Conducting Riparian Vegetation and Stream Channel Surveys in Wadeable Stream for Temperature Total Maximum Daily Load Studies (Urmos-Berry, 2019).
- EAP045 (if collecting hemispherical photos) – Hemispherical Digital Photography Field Surveys Conducted as Part of a Temperature Total Maximum Daily Load or Forests and Fish Unit Technical Study (Stohr et al. 2019).
- EAP046 (if collecting hemispherical photos) – Computer Analysis of Hemispherical Digital Images Collected as Part of a TMDL or Forests and Fish Unit Technical Study (Stohr, 2019).

8.3 Containers, preservation methods, holding times

There will be no samples collected for laboratory analysis during this study.

8.4 Equipment decontamination

Staff will follow all recommended protocols for cleaning and decontaminating sampling equipment. Established Ecology procedures will be followed if an unexpected contamination incident occurs.

8.5 Sample ID

There will be no samples collected for laboratory analysis during this study.

8.6 Chain of custody

There will be no samples collected for laboratory analysis during this study.

8.7 Field log requirements

Ecology will use dedicated forms for flow measurements, temperature logger deployments, and all field data collection. Data on these forms includes, but is not limited to:

- Date and time
- Personnel
- Project name
- Location description
- Field observations (weather, site details, equipment notes etc.)
- Field measurement results (flow at each transect, depth, wetted width, canopy cover, vegetation type, etc.)

8.8 Other activities

N/A

9.0 Laboratory Procedures

9.1 Lab procedures tables

There will be no samples collected for laboratory analysis during this study.

9.2 Sample preparation method(s)

There will be no samples collected for laboratory analysis during this study.

9.3 Special method requirements

There will be no samples collected for laboratory analysis during this study.

9.4 Laboratories accredited for methods

There will be no samples collected for laboratory analysis during this study.

10.0 Quality Control Procedures

Table 11 shows this study's quality control (QC) procedures. The Programmatic QAPP for Water Quality Impairment Studies (McCarthy and Mathieu, 2017) explains these procedures in detail.

Table 11. Quality control procedures for this study.

QC Type	QC Procedures
Field Measurement QC	• Meter/logger pre-calibration • Meter/logger post-checks • Meter/logger field QC measurements

10.1 Table of field and laboratory quality control

In Section 10 of the Programmatic QAPP (McCarthy and Mathieu 2017), Table 14 outlines the QC procedures for field measurements.

10.2 Corrective action processes

See Section 10 of the Programmatic QAPP (McCarthy and Mathieu 2017).

11.0 Data Management Procedures

11.1 Data recording and reporting requirements

The Environmental Information System (EIM) Study ID for this project is LAC_26_WQP.

Staff will record all field data in a water-resistant field notebook or field form. Before leaving each site, staff will check field notes for missing or improbable measurements. Staff will enter field-generated data into Microsoft Excel® spreadsheets or a project database as soon as 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.

11.2 Laboratory data package requirements

There will be no samples collected for laboratory analysis during this study.

11.3 Electronic transfer requirements

There will be no samples collected for laboratory analysis during this study.

11.4 EIM/STORET data upload procedures

All field measurement data will be entered into EIM, following all existing Ecology business rules and the EIM User's Manual for loading, data quality checks, and editing.

11.5 Model information management

Modeling can be a complex process involving multiple steps and procedures and various iterations. Model information will be managed by meticulous file organization and naming conventions that will identify, track, and date model input/output files associated with each significant model run and each major iteration in model calibration.

This will be done by:

- Creating separate sub-folders to contain the inputs and outputs of each significant model/scenario run with the date of each model run.
- Tracking model runs in an Excel spreadsheet that includes the name for each significant model run/scenario run, the name(s) and location(s) of associated input and output files, and major parameters changed for different model scenarios.
- If the model version is changed during the modeling process, all sub-folders/files associated with each version of the model will be placed within a larger folder that identifies the model version used for those model runs.

12.0 Audits and Reports

12.1 Field, laboratory, and other audits

See Programmatic QAPP (McCarthy and Mathieu, 2017). Field audits are not planned for this project; audits may be added if requested by management or field staff.

12.2 Responsible personnel

Personnel responsible for audits are:

- Field audits: project managers or supervisors.
- Field consistency reviews: experienced (at least 3 years) field staff.
- Data analysis and modeling work: project managers or their supervisors.

12.3 Frequency and distribution of reports

See Programmatic QAPP (McCarthy and Mathieu 2017).

12.4 Responsibility for reports

The Source Assessment report will be authored by the project lead from SWRO WQP.

13.0 Data Verification

13.1 Field data verification, requirements, and responsibilities

See Section 13 of the Programmatic QAPP (McCarthy and Mathieu, 2017). Throughout field sampling, the field lead and all crew members are responsible for station positioning, sample collection, and sensor deployment procedures as specified. Additionally, technicians systematically review all field documents (such as field logs, chain-of-custody forms, and sample labels) to ensure data entries are consistent, correct, and complete, with no errors or omissions.

13.2 Laboratory data verification

There will be no samples collected for laboratory analysis during this study.

13.3 Validation requirements, if necessary

See Section 13 of the Programmatic QAPP (McCarthy and Mathieu, 2017).

13.4 Model quality assessment

The Programmatic QAPP for Water Quality Impairment Studies provides detailed information on principles of calibration, validation, and sensitivity/uncertainty analysis. This includes a detailed discussion of precision, bias, representativeness, and qualitative assessment. The following sections provide additional information specific to the Shade model and PointWQ and its application for this project.

13.4.1 Calibration and evaluation

Shade Model

Shade model results will be compared graphically with effective shade estimated from hemispherical photographs or Solar Pathfinder measurements. Similar to previous Ecology reports (McCarthy, 2020; Newell, 2018; Snouwaert and Stuart, 2013) the quality assessment will be qualitatively based on agreement between modeled effective shade and estimated shade from hemispherical photographs or Solar Pathfinder measurements taken at similar locations along the creek.

PointWQ — Temperature

Temperature model calibration in PointWQ is a manual process. This involves repeatedly running the temperature model while adjusting model settings until a good fit between observed and predicted data is achieved using realistic settings. Temperature is a function of well understood physical processes with relatively few important rate parameters. Therefore, manual calibration is typically straightforward. Table 12 summarizes the most important rate settings and their effect.

We will use field data and/or literature to guide the most important parameters: water depth, effective shade, groundwater inflow, and groundwater temperature. This will help to constrain these parameters to avoid “curve-fitting,” i.e., achieving an apparent good model fit to data by invoking the wrong mechanistic explanations.

Table 12. PointWQ settings, their effects and priority.

Setting	Effect	Other Settings that can Mimic the Same Effect	Setting Priority
Water depth	Size of diel variation. Deeper = less diel range; shallower = more diel range	Hyporheic exchange	Primary[a]
Effective shade	Directional bias. Less shade = warmer; more shade = cooler	Bras atmospheric turbidity factor (if using); Ryan-Stolzenbach ATC (if using); wind speed	Primary[a]
Groundwater inflow and temperature	Creates a bias tendency toward the groundwater temperature, reduces diel range	Groundwater could be mistaken for deeper channel and more shade if looking only at the hottest summer conditions; the difference will usually be more obvious if including cool, low-flow autumn conditions	Primary[a]
Effective windspeed coefficient	Directional bias	Shade, solar settings. However, wind varies by time of day and by weather pattern. The effective windspeed coefficient will have disproportionate effects on moments when wind is strong.	Secondary[b]
Bras atmospheric turbidity factor (if using); Ryan-Stolzenbach ATC (if using)	Directional bias	Effective shade	Secondary[b]

Hyporheic exchange	Size of diel variation	Water depth	Secondary[b]
Cloud adjustment parameters (KCL 1-4)	Temperature on cloudy days only	—	Secondary[b]

[a]Primary settings are those that we will adjust first during temperature calibration.
[b]Secondary settings are those that we will adjust next, after adjusting primary settings, or if there is evidence that one of these is important. For examples, if field crews notice visible hyporheic flow through cobble bars, we might increase the hyporheic exchange rate.

13.4.2 Analysis of sensitivity and uncertainty

We will test model sensitivity in the same manner which was used for PointWQ in the Soos Creek TMDL study (Mathieu et al. 2023). This approach tested model sensitivity to a range of input values for key parameters that affect temperature in the model. RMSE and plots will be used to evaluate how fitness and model results change when parameters or key inputs are changed within a reasonable range. We will assess daily heat fluxes for critical dates in the model to help determine sensitivity parameters. Examples of potential sensitivity tests include:

- Groundwater input temperature
- Percent effective shade (± 10% effective shade)
- Longwave radiation model selected.

14.0 Data Quality (Usability) Assessment

14.1 Process for determining project objectives were met

See Section 14 of the Programmatic QAPP (McCarthy and Mathieu, 2017).

14.2 Treatment of non-detects

See Section 14 of the Programmatic QAPP (McCarthy and Mathieu, 2017).

14.3 Data analysis and presentation methods

See Section 14 of the Programmatic QAPP (McCarthy and Mathieu, 2017).

14.4 Sampling design evaluation

See Section 14 of the Programmatic QAPP (McCarthy and Mathieu, 2017).

14.5 Documentation of assessment

See Section 14 of the Programmatic QAPP (McCarthy and Mathieu, 2017).

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16.0 Appendices

Appendix A. Glossaries, Acronyms, and Abbreviations

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.

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.

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.

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

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.

Extraordinary primary contact: Waters providing extraordinary protection against waterborne disease or that serve as tributaries to extraordinary quality shellfish harvesting areas.

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.

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

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

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.

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

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

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

System potential: The design condition used for TMDL analysis.

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.

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

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

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.

Acronyms and Abbreviations

ARP	Advanced restoration plan
BMP	Best management practice
CHM	Canopy height model
DNR	Department of Natural Resources
DQO	Data quality objective
e.g.	For example
EAP	Environmental assessment program
Ecology	Washington State Department of Ecology

EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
ESA	Endangered species act
et al.	And others
GIS	Geographic Information System software
GPS	Global Positioning System
i.e.	In other words
LiDAR	Light detection and ranging
MQO	Measurement quality objective
NHD	National hydrography dataset
NPDES	(See Glossary above)
NSDZ	Near-stream disturbance zones
QA	Quality assurance
QAPP	Quality assurance project plan
QC	Quality control
RM	River mile
RMSE	Root mean square error
RPD	Relative percent difference
RSD	Relative standard deviation
SA	Source assessment
SOP	Standard operating procedures
SWRO	Southwest regional office
TMDL	(see Glossary above)
USGS	United States Geological Survey
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WQA	Water Quality Assessment
WQP	Water quality program
WQS	Water quality standards
WRIA	Water Resource Inventory Area

Units of Measurement

°C	degrees centigrade
Cfs	cubic feet per second

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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