DEPARTMENT OF ECOLOGY
State of Washington

# Addendum: Puget Sound Nutrient Monitoring Project

# Quality Assurance Monitoring Plan: Statewide River and Stream Ambient Water Quality Monitoring

August 2023
Publication 23-03-102

# Publication Information

This Quality Assurance Monitoring Plan Addendum is on the Department of Ecology's website at https://apps.ecology.wa.gov/publications/SummaryPages/2303102.html.

This addendum was approved to begin work in December 2022. It was finalized and approved for publication in August 2023.

**Suggested citation for this addendum:**
Dugger, D., W. Bretherton, S. Studer. 2023. Addendum: Puget Sound Nutrient Monitoring Project to Quality Assurance Monitoring Plan: Statewide River and Stream Ambient Water Quality Monitoring. Publication 23-03-102. Washington State Department of Ecology, Olympia. https://apps.ecology.wa.gov/publications/SummaryPages/2303102.html.

Data for this project will be available on Ecology's Environmental Information Management (EIM) website at EIM Database. Search Study IDs: AMS001, AMS001-2.

Ecology's Activity Tracker code for this addendum is 01-600

**Original Quality Assurance Project Plan:**
Dugger, D., W. Bretherton, S. Studer, and M. Von Prause. 2023. Quality Assurance Monitoring Plan: Statewide River and Stream Ambient Water Quality Monitoring, 2023 revision. Publication 23-03-106. Washington State Department of Ecology, Olympia. https://apps.ecology.wa.gov/publications/SummaryPages/2303106.html.

# Contact Information

Publications Team
Environmental Assessment Program
Washington State Department of Ecology
P.O. Box 47600
Olympia, WA 98504-7600
Phone: 360-407-6764

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

- Headquarters, Olympia 360-407-6000
- Northwest Regional Office, Shoreline 206-594-0000
- Southwest Regional Office, Olympia 360-407-6300
- Central Regional Office, Union Gap 509-575-2490
- Eastern Regional Office, Spokane 509-329-3400

# Addendum: Puget Sound Nutrient Monitoring Project

# Quality Assurance Monitoring Plan: Statewide River and Stream Ambient Water Quality Monitoring

by

Dan Dugger, Welles Bretherton, and Sean Studer

August 2023

**Approved by:**

| | |
|---|---|
| Signature: | Date: |
| Dan Dugger, Author / Project Manager, WOS, EAP | |
| Signature: | Date: |
| Sean Studer / Principal Investigator, EAP | |
| Signature: | Date: |
| Brad Hopkins, Author's Unit Supervisor, EAP | |
| Signature: | Date: |
| Stacy Polkowske, Author's Section Manager, EAP | |
| Signature: | Date: |
| Dean Momohara, Acting Director, Manchester Environmental Laboratory, EAP | |
| Signature: | Date: |
| Arati Kaza, Ecology Quality Assurance Officer | |

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

# 1.0 Table of Contents



The numbered headings in this document correspond to the headings in the original QAMP. Only relevant sections are included here; some numbered headings may be missing.

# List of Figures and Tables

# 3.0 Background

## 3.1 Introduction and problem statement

This addendum describes the Puget Sound Freshwater Monitoring Network (PSFMN) project. PSFMN expands the Freshwater Monitoring Unit's (FMU's) Statewide River and Stream Ambient Water Quality Monitoring Project (Ambient project) to include continuous monitoring for nutrients and other water quality parameters in Puget Sound. The Ambient project currently collects continuous temperature, pH, dissolved oxygen, conductivity, and turbidity at 15-minute intervals at stations state-wide. Adding continuous monitoring to the largest rivers entering Puget Sound will provide 15-minute increment data to help us better understand temporal changes in water quality.

The Ambient project samples rivers and streams monthly for temperature, pH, dissolved oxygen, conductivity, nutrients, and turbidity data. We detail specifics about these and other Ambient parameters in the Ambient Quality Assurance Monitoring Plan (QAMP; Dugger et al. 2023). The PSFMN project will focus on continuous sampling of these parameters, with additional storm-event sampling. With this project, we intend to obtain high-frequency water quality data, particularly nutrient data, to incorporate into the Salish Sea Model (SSM).

The SSM is a mechanistic model that simulates complex interactions that affect the water quality of the Salish Sea (Ahmed et al. 2019). These processes include:

- Hydrodynamics
- Temperature
- Photosynthesis
- Respiration rates
- Light
- Nutrient availability
- Phytoplankton

These processes, simulated by the SSM, inform the Puget Sound Nutrient Source Reduction Project (PSNSRP), which was initiated to address water quality concerns in the Salish Sea (Ahmed et al. 2019). The goal of the PSNSRP is to reduce point and non-point source nutrients in the Salish Sea (Ahmed et al. 2019). By collecting continuous nutrient data from near the mouths of the major Puget Sound draining rivers, we can provide a more complete picture of the dynamics of riverine inputs into the Salish Sea.

## 3.2 Study area and surroundings

We selected sites near the mouths of the seven largest rivers that drain into Puget Sound and one (Nooksack River) that drains into the Strait of Georgia to include in the PSFMN project (Figure 1 and Table 1). In addition to these river mouth sites, we chose an upstream Cedar River site within the City of Seattle's protected Cedar River watershed to represent rivers minimally affected by human activity. The following are site selection criteria for the seven river mouth locations within the watersheds, listed in order of priority:

1. Near the mouth of the river

2. Upstream of the salt wedge (tidal influence is okay but not preferable)
3. Near a U.S. Geological Survey (USGS) or Department of Ecology (Ecology) flow station
4. Near an Ambient monitoring station
5. Safety from vandalism
6. Accessibility

We attempted to co-locate all our PSFMN stations with USGS or Ecology flow stations. Our long-term Skagit River station is already located next to a USGS flow station. For this project, we relocated long-term Ambient stations on the Nooksack, Stillaguamish, Snohomish, Green/Duwamish, and Puyallup Rivers to new PSFMN locations near USGS flow stations, which are all within a few river miles (RM) of an Ambient station (Figure 1, Tables 1 and 2).

To reduce the potential for vandalism, we moved the Nisqually River site from a public fishing area to a less-public location one mile downstream at the Nisqually School District Wa He Lut School.

Moving stations potentially affects streamflow estimates and the data record and might require additional adjustments. For the Snohomish and Nisqually Rivers, we use formulas developed by the USGS before 1993 to calculate estimated flows from multiple stations (Table 2). USGS staff assessed the Snohomish River flow estimate as fair quality and the Nisqually River flow estimate as poor quality. These lower quality assessments were due to the distances between the water quality sites and their respective flow gages and the potential for unknown influences on flow in that intervening space. (B. Hopkins, Ecology Freshwater Monitoring Unit Supervisor, pers. comm., May 30, 2023)

The Nisqually River Wa He Lut School site is about 18 RM downstream of the Nisqually River @ McKenna flow gage (USGS 12089500) and 22 RM downstream of the Centralia Power Canal flow gage (USGS 12089208; Figure 1, Tables 1 and 2). We are assessing alternate flow measurement options for the Nisqually and Stillaguamish sites, installing bubbler stage gages, and planning boat measurements to develop rating curves. We will update publications once we finalize any changes to the PSFMN station and flow station relationships.

For the first water year (Oct 1-Sept 30), we will collect paired monthly grab sample data at the old and new Ambient stations to assess water quality differences due to the move. Paired sample collection will last for the full water year, beginning when we start sampling a replacement station. We used the site selection criteria listed above for all station location changes. We will assess the quantitative differences between the paired samples following the year of paired sampling. If we notice any significant differences between the sites, we will note these in the next revision of the Ambient QAMP.

**Table 1. List of the Puget Sound Freshwater Monitoring Network stations, including Ambient and USGS IDs if co-located.**

| Station ID | USGS ID [a] | Station Name | Latitude [b] | Longitude [b] |
|---|---|---|---|---|
| **01A060** | 12213100 | Nooksack River @ USGS Ferndale | 48.844428 | -122.589130 |
| **03A060** | 12200500 | Skagit River near Mount Vernon | 48.444871 | -122.336285 |
| **05A080** | NA | Stillaguamish River @ Blue Stilly Park | 48.196351 | -122.184214 |
| **07A089** | NA | Snohomish River @ Snohomish PUD | 47.911721 | -122.105973 |
| **08C100** | NA | Cedar River @ RR Grade Rd | 47.384816 | -121.956301 |
| **09A075** | 12113390 | Duwamish River @ Foster GC Rd | 47.478797 | -122.258457 |
| **10A040** | 12101500 | Puyallup River @ USGS Puyallup | 47.208734 | -122.327678 |
| **11A060** | NA | Nisqually River @ Wa He Lut School | 47.066525 | -122.702376 |

[a] NA = not applicable

[b] Latitude and Longitude in Decimal Degrees WGS 1984 projection

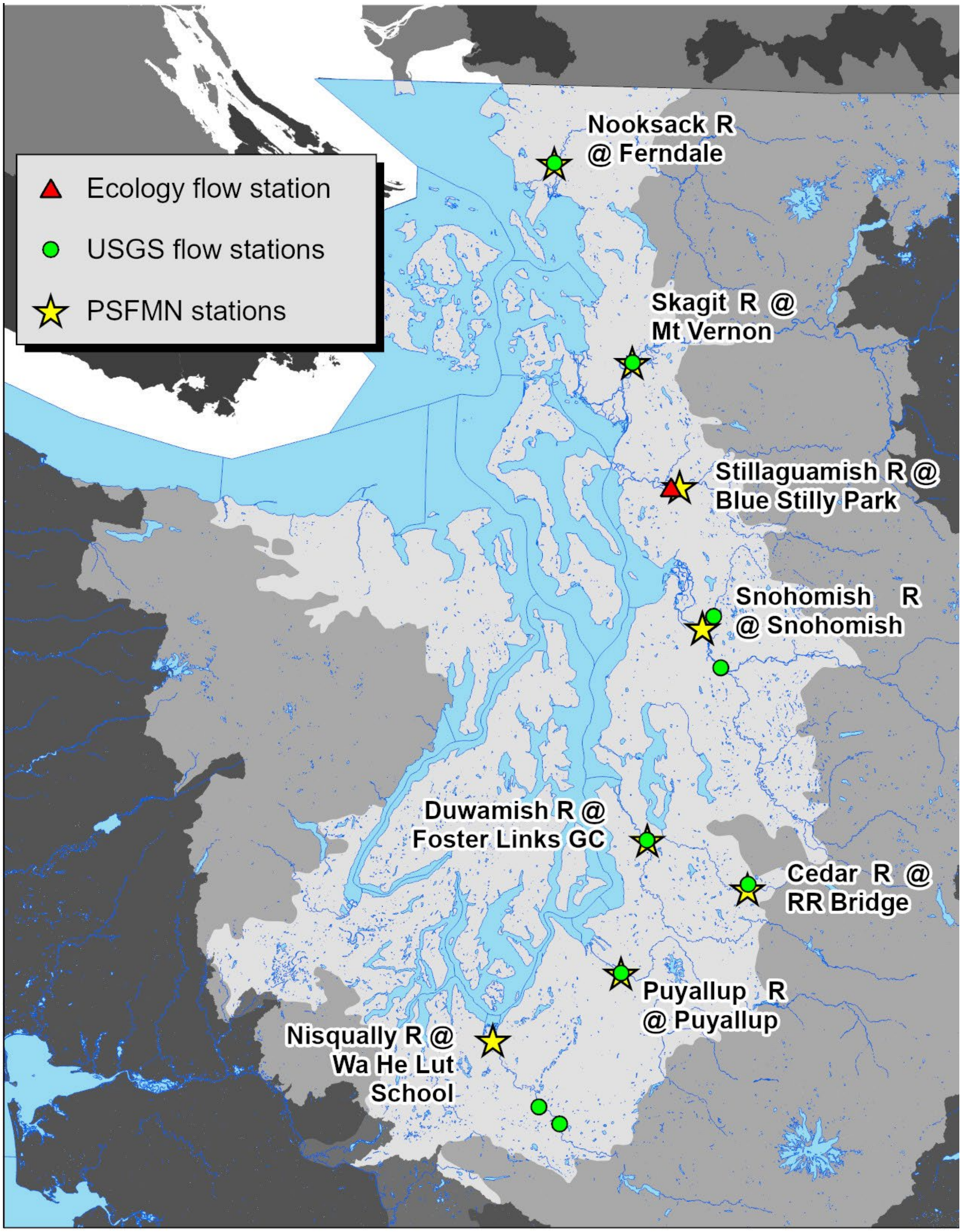


**Figure 1. Map of the eight watersheds and the water quality monitoring stations included in this project (PSFMN Stations), along with the nearest Ecology and USGS flow stations.**

**Table 2. Flow data sources per Puget Sound Freshwater Monitoring Network site.**

| Station ID | Station Name | Flow Station ID | Flow Station Name | Latitude, Longitude [a] |
|---|---|---|---|---|
| **01A060** | Nooksack River @ USGS Ferndale | USGS 12213100 | Nooksack River at Ferndale, WA | 48.844832, -122.589339 |
| **03A060** | Skagit River near Mount Vernon | USGS 12200500 | Skagit River near Mount Vernon, WA | 48.444828, -122.335437 |
| **05A080** | Stillaguamish River @ Blue Stilly Park | Ecology 05A070 | Stillaguamish River near Silvana | 48.196782, -122.210067 |
| **07A089** | Snohomish River @ Snohomish PUD [b] | USGS 12150800 and 12155300 | Snohomish River near Monroe, WA and Pilchuck River near Snohomish, WA | 47.830932, -122.048459 and 47.934820, -122.073185 |
| **08C100** | Cedar River @ RR Grade Rd | USGS 12117500 | Cedar River near Landsburg, WA | 47.393713, -121.954558 |
| **09A075** | Duwamish River @ Foster GC Rd | USGS 12113390 | Duwamish River at Golf Course at Tukwila, WA | 47.478986, -122.258733 |
| **10A040** | Puyallup River @ USGS Puyallup | USGS 12101500 | Puyallup River at Puyallup, WA | 47.208434, -122.327065 |
| **11A060** | Nisqually River @ Wa He Lut School [c, d] | USGS 12089500 and 12089208 | Nisqually River at McKenna, WA and Centralia Power Canal near McKenna, WA | 46.933432, -122.560956 and 46.900100, -122.498453 |

[a] Latitude and Longitude coordinates in WGS 1984 projection.

[b] The USGS estimated flow formula (USGS personal communication 2011) for Snohomish River @ Snohomish PUD is: Flow = SNO + PIL

Where:

- SNO is the time of travel adjusted flow from USGS Station 12150800, Snohomish River near Monroe, WA.
- PIL is the time of travel adjusted flow from USGS Station 12155300, Pilchuck River near Snohomish, WA.

[c] The USGS estimated flow formula (USGS personal communication 2011) for Ecology's Nisqually River sites near the mouth, Nisqually River @ Wa He Lut School and Nisqually River @ Nisqually, is:
$\text{Flow} = \text{CPC} + 78.128 - 29.684 * \text{Log(MCK)} / \text{Log}(10) + 2.8325 * (\text{Log(MCK)} / \text{Log}(10))^2$

Where:

- CPC is the time of travel adjusted flow from USGS Station 12089208, Centralia Power Canal near McKenna.
- MCK is the time of travel adjusted flow from USGS Station 12089500, Nisqually River at McKenna, WA.

[d] We qualify all flow or load results derived from this formula as estimates due to the distance between the flow monitoring locations and the sample site.

### 3.2.1 History of study area

The PSFMN stations will provide continuous water quality data at the seven largest drainages in the Puget Sound basin as they enter Puget Sound. Ecology's Modeling and TMDL Unit (MTU) requested additional continuous nutrient monitoring at these sites, along with monthly discrete sampling, to enhance the SSM. The additional water quality data collection proposed for this project will provide near real-time verification of the model and enhance the model's effectiveness for guiding Best-Management Practices (BMPs) to improve water quality. Until this project, the SSM used discrete water quality data collected monthly by the Ambient Project and estimated diel flux in nutrient concentrations using a multiple linear regression statistical approach to develop daily nutrient inputs needed for the SSM.

### 3.2.2 Summary of previous studies and existing data

The sites established in this project are located at or within a few miles of established monthly Ambient sites, some with decades of data records, as described in the QAMP (Dugger et al. 2023).

The Skagit, Stillaguamish, and Snohomish Rivers have had discrete data collected since the 1950s. These and the Nooksack, Puyallup, Cedar, and Nisqually Rivers have monthly discrete data collected since 1978, and the Green River since 1991. Stations in the protected upper watershed of the Cedar River also collected continuous pH, dissolved oxygen, conductivity, and temperature data in 15-minute intervals since 2011 to represent upstream least-impacted conditions in an urban watershed. Some stations have also recorded rainfall to provide early warning for landslide-prone areas or to trigger automated stormwater sample collections.

From November 1, 2009, through October 31, 2010, Ecology conducted a continuous nitrogen monitoring pilot study in the Deschutes River, near the mouth, at the E. Street Bridge in Tumwater, Washington (Sackmann 2011). A Submersible Ultraviolet Nitrate Analyzer (SUNA) was deployed to monitor freshwater nitrate plus nitrite concentrations at 15-minute intervals. Ecology collected coincident field grab samples for dissolved nitrate plus nitrite to quantify the accuracy and precision of the SUNA nitrate plus nitrite estimates. The data from the continuous time series helped develop and refine statistical methods for predicting daily loads of nitrate plus nitrite from a limited number of discrete observations. We used the Sackmann (2011) report as a guide for setting up the continuous nitrogen portion of the PSFMN project.

The Ambient Program also briefly deployed a SUNA at a continuous water quality station on the Newaukum River near the city of Chehalis in water year 2019 (Oct 1, 2018 – Sept 30, 2019). In the fall of 2021, Ecology collected nitrate plus nitrite data at the Newaukum River in 15-minute intervals as a pilot study in support of setting up the PSFMN project. A second station in the Cedar River provided additional guidance.

From April 2018 through December 2021, the USGS monitored continuous nitrates at 3 Nooksack Basin USGS sites: Fishtrap Creek near Lynden, WA (USGS site ID 12212050); Kamm Creek near Lynden, WA (USGS site ID 12211390); and the Nooksack River at Ferndale, WA (USGS site ID 12213100). The data release for this project provided nitrogen loading estimates for the Fish Trap Creek and Nooksack River sites and nitrogen concentration estimates for Kamm Creek. (Senter et al. 2023)

### 3.2.3 Parameters of interest and potential sources of error

Ambient has conducted monthly grab sampling for water quality since the 1950s and monitored for time-series temperature, pH, dissolved oxygen, conductivity, turbidity, and precipitation at select stations throughout Washington for over a decade (Dugger et al. 2023).

The focus of this project is the collection of continuous nitrate data. Like other Ambient continuous stations, the PSFMN project will collect temperature, pH, dissolved oxygen, conductivity, turbidity, and precipitation at 15-minute intervals. We will continue to collect monthly grab samples for conventional Ambient parameters at active Ambient stations, including relocated stations (Table 3).

We will assess impacts due to the relocation of Ambient stations through paired sampling between old and new stations, per the procedures outlined in our statewide QAMP (Dugger et al. 2023).

Strategic storm event sampling, using an automated pump sampler (autosampler), will focus on whole sample (unfiltered) nitrogen parameters and suspended solids, with the possibility of additional parameters added later. For a list of all preliminary parameters and collection methods, see Table 3.

We will document any changes to the Table 3 parameter list in a technical memo or update to this QAMP Addendum.

**Table 3. Parameter methods per collection type.**

| Parameter | Continuous meters | Automated pump samples | Ambient grab samples |
|---|---|---|---|
| Alkalinity | - | - | SM2320B |
| Ammonia (NH3) as N | - | - | SM4500NH3H or SM4500NH3D |
| Chloride | - | - | EPA 300.0 |
| Conductivity | YSI EXO | - | YSI EXO |
| Dissolved Organic Carbon (DOC) | - | - | SM5310B |
| Dissolved Organic Nitrogen (DON) | - | - | Calculated DON = TPN-PN-(NH3+NO2+NO3) |
| Dissolved Oxygen (DO) | YSI EXO | - | YSI EXO |
| E. Coli (EC) | - | - | SM9222G1 |
| Fecal Coliform (FC) | - | - | SM9222D |
| Orthophosphate (OP) | - | - | SM4500PG |
| pH | YSI EXO | - | YSI EXO |
| Particulate Organic Carbon (POC) | - | EPA440.0 | EPA440.0 |
| Particulate Nitrogen (PN) | - | EPA440.0 | EPA440.0 |
| Precipitation | Rainfall gage | | |
| Sulfate | - | - | EPA 300.0 |
| Suspended Sediment Concentration (SSC) | - | ASTMD3977-97 | ASTMD3977-97 |
| Temperature | YSI EXO | - | Thermistor or YSI EXO |
| Total nitrites + nitrates (NO2+NO3) | SUNA V2 | SM4500N03I or EPA 353.2 | SM4500N03I or EPA 353.2 |
| Total Organic Carbon | - | - | SM5310B |
| Total Persulfate Nitrogen | - | SM4500NB or SM4500NC | SM4500NB or SM4500NC |
| Total Phosphorus | - | - | SM4500PH or SM4500PF |
| Total Suspended Solids | - | SM2540D | SM2540D |
| Turbidity | FTS DTS-12 | - | SM2130 |

# 4.0 Project Description

## 4.1 Project goals

In addition to the goals outlined in the QAMP (Dugger et al. 2023), this project will collect high-frequency data to help us understand temporal water quality changes in rivers affecting Puget Sound.

## 4.2 Project objectives

In addition to the objectives in the QAMP (Dugger et al. 2023), the PSFMN aims to:

- Create a network of continuous nutrient and water quality stations in the seven largest watersheds draining into Puget Sound.
- Provide a better picture of temporal nutrient changes within Puget Sound watersheds to compare against potential nutrient reduction targets.
- Better describe the dynamic boundary conditions of nutrient loads to Puget Sound, including diurnal variations and extreme weather events.
- Establish a minimally impacted upstream site in the City of Seattle's protected Cedar River Watershed, intended for comparison to other Puget Sound sites.
- Design, test, and build a new structure for deploying sensors instream to avoid burial and damage by debris that has caused data gaps in other designs.
- Update and refine onsite quality control (QC) checks of continuous sensors.
- Create a threshold sampling protocol using automated samplers to sample storm events for requested parameters.

# 5.0 Organization and Schedule

## 5.1 Key individuals and their responsibilities

Table 4 lists project staff and their responsibilities.

**Table 4. Project staff and responsibilities.**

| Staff[1] | Title | Responsibilities |
|---|---|---|
| Dan Dugger<br>Freshwater Monitoring Unit<br>Phone: (360) 701-9671 | Project Manager | Coordination for monitoring program design, run annual planning, field sampling, and transportation of samples to the laboratory. Writes and updates the QAMP and SOPs. Trains staff on methods and does annual method audits. Oversees station selections, run designs, QA review, and tracks progress. Provides field support as needed. |
| Sean Studer<br>Freshwater Monitoring Unit<br>Phone: (206) 462-0517 | Principal Investigator | Oversees station selections and installations, run designs, QA review, and tracks progress. Writes and updates the QAMP and SOPs. Collects samples, records field information, conducts continuous and automated station maintenance, QA review, and additional database support. |
| Markus Von Prause<br>Freshwater Monitoring Unit<br>Phone: (206) 305-8179 | Project Data Manager | Maintains station telemetry and data transfer. Conducts continuous and automated station maintenance, QA review of data, analyzes and interprets data, and enters data into EIM. Provides field support as needed. |
| Ansel Abbett<br>Freshwater Monitoring Unit<br>Phone: (360) 688-4586 | Station Support | Conducts continuous and automated station installation and maintenance. Provides field support as needed. |
| Kevin Wood<br>Freshwater Monitoring Unit<br>Phone: ((360) 764-6232 | Station Support | Conducts continuous and automated station installation and maintenance. Provides field support as needed. |
| Stephanie Estrella<br>Freshwater Monitoring Unit<br>Phone: (564) 669-0822 | Field and Data Support | Conducts QA review of data, analyzes and interprets data, and enters data into EIM. Provides field support as needed. |
| Brad Hopkins<br>Freshwater Monitoring Unit<br>Phone: (360) 701-6686 | Unit Supervisor for Project Manager | Provides internal direction for monitoring activities, develops the budget, and approves the final QAMP. |
| Stacy Polkowske<br>WOS<br>Phone: (360) 464-0674 | Section Manager for Project Manager | Reviews the project scope and budget, tracks progress, reviews the draft QAMP, and approves the final QAMP |
| Dean Momohara<br>Manchester Environmental Lab;<br>Phone: (360) 710-9116 | Acting Director | Reviews and approves the final QAMP. |
| Arati Kaza<br>Phone: (360) 480-1960 | Ecology QA Officer | Reviews and approves the draft QAMP and the final QAMP. |

## 5.4 Proposed project schedule

Tables 5 and 6 list the planned schedule for field, laboratory, and data management in EIM for the ongoing study.

**Table 5. Schedule for completing field and laboratory work.**

| Task | Due date | Lead staff |
|---|---|---|
| Station installations | September 2023 | See Table 4 for responsible staff |
| Fieldwork | Ongoing | See Table 4 for responsible staff |
| Continuous and automated station maintenance | Ongoing, at least monthly, or as required | See Table 4 for responsible staff |
| Laboratory analyses | Ongoing | Manchester Environmental Lab |
| Contract lab data validation | Ongoing, as required by special projects | Manchester Environmental Lab |

**Table 6. Schedule for data entry.**

| Task | Due date | Lead staff |
|---|---|---|
| Discrete data: IM data loading, QA, and complete [1] | Each water year (10/1-9/30), 2-4 months after data collection | Markus von Prause |
| Continuous data: EIM data loading, QA, and complete [1] | Each water year (10/1-9/30), Usually within 9 months after data retrieval | Markus von Prause |

[1] EIM Project IDs: AMS001 for final reviewed data. AMS001-2 for provisional data.

# 7.0 Study Design

## 7.1 Study boundaries

PSFMN includes stations on the major streams along the east side of Puget Sound in Water Resource Inventory Areas (WRIAs) 1, 3, 5, and 7 through 11 (Figure 1 and Table 1).

## 7.2 Field data collection

Since PSFMN is adding a continuous component to established Ambient stations in the Puget Sound basin, we will use monthly Ambient data collections to supplement and QC check our continuous and automated station results.

We will collect three types of data as part of this study:

- Continuous measurements: every 15 minutes.
- Automated pump sampling: triggered when preset conditions are met (e.g., storm events).
- Discrete grab samples: during site visits.

Table 3 shows the parameters associated with each of these types of data collection. The frequency of the grab samples and the automated pump samples will depend on the location and station conditions.

### 7.2.1 Sampling locations and frequency

All stations in the PSFMN (Table 1) will collect continuous data at 15-minute intervals.

When possible, PSFMN stations were co-located with an existing Ambient station so that grab samples could be collected as part of the monthly Ambient runs. Some Ambient stations were moved to the nearby PSFMN station. To assess any differences between sites, we collected samples at the new and old stations for one year, per section 7.2.2 of the QAMP (Dugger et al. 2023), before officially relocating the Ambient station. For any future sites we do not co-locate, we will collect samples once a month as part of the station maintenance schedule.

Storm event sampling will depend on storm frequency, intensity, and duration. We will attempt to collect automated samples from major storm events. Sample collections will also be dependent on staff and equipment availability, schedules, and maintenance needs. We define storm events as precipitation events associated with increased river stage, flow, and runoff.

We set numeric thresholds of the triggering parameter that cause the autosampler to collect samples when exceeded. Sample collection ends when the autosampler is full, or the parameter level triggers the final program threshold (usually by crossing the lowest threshold again). At each location, we will monitor and adjust these thresholds and the timing of sample collection to collect samples that represent the rising and falling periods of the event and the event peak. We will change triggering thresholds seasonally based on expected instream conditions. We may change the thresholds and sampling rates based on available staff time, sampler feedback, equipment maintenance, and our laboratory budget. Potential parameter changes that trigger a storm event sample may include a threshold increase in precipitation, stage, turbidity, or other parameters. We may also manually trigger discrete sample collections to assess other instream events.

During each storm event, we will collect up to 14 automated samples per station (up to 112 samples per event). The number of automated samples per station is dependent on the number of sample collection thresholds that are triggered. We will use these samples to verify the continuous meter results directly (e.g., nitrate-nitrite for the SUNA nitrate-nitrite probe) or to correlate other water quality parameters in Table 3 to the continuous probe results (e.g., SSC for the DTS-12 turbidity probe).

### 7.2.2 Criteria for relocation of long-term stations

The process for relocating long-term Ambient stations associated with the PSFMN is described in the QAMP (Dugger et al. 2023). In water year 2023, we began paired sample collections at long-term stations and new continuous monitoring stations on the Nooksack, Stillaguamish, Snohomish, Duwamish/Green, Puyallup, and Nisqually Rivers. The Skagit Ambient station is currently co-located with the USGS gage and will be the location of the continuous PSFMN station. We moved the Cedar River long-term Ambient station in water year 2022 to a new location with continuous monitoring (Cedar R @ RR Grade Rd) due to bank erosion at the old station (Cedar R @ Landsburg).

# 8.0 Field Procedures

For this project, we will follow the field procedures described in the QAMP (Dugger et al. 2023). We co-located PSFMN stations with Ambient stations and moved some Ambient stations to the new PSFMN station location. This allowed for paired water quality monitoring and QC checks during Ambient water quality runs. We will use data from Ambient station continuous monitoring and storm event sampling within and outside the Puget Sound basin to inform our station design and maintenance.

The section below describes differences in the PSFMN-specific methods and modifications to our QAMP (Dugger et al. 2023) procedures.

## 8.2 Measurement and sampling procedures

Details of specific field procedures are in the relevant standard operating procedures (SOPs) listed in Table 9 of the QAMP (Dugger et al. 2023).

### 8.2.1 Monthly Ambient sampling

During Ambient runs, we will collect grab samples for all PSFMN continuous monitoring stations. We will follow the same process for collecting Ambient and station maintenance grab samples. For co-located stations, we will conduct Ambient sampling and quality control checks, as described in the QAMP (Dugger et al. 2023).

At stations with a deployment shuttle (probe shuttle) and I-beam (Figures 2 and 3), we will collect replicate grab measurements for temperature, pH, dissolved oxygen, and conductivity alongside the probe shuttle.

We will conduct station maintenance monthly or more frequently, depending on staff availability. Our intent with this maintenance schedule is to address any anomalies detected during the Ambient visits when more time is available on-site to assess and fix the issue.

Periodically, staff will re-evaluate stations to see if changes to site locations are in order. Criteria for relocating long-term core stations will conform to those outlined in section 7.2.2 of the QAMP (Dugger et al. 2023).

### 8.2.2 Continuous monitoring

We will follow the continuous monitoring methods outlined in the QAMP (Dugger et al. 2023). We will deploy water quality probes and automated grab sample collection tubes at each continuous station using one or more of the following deployment methods.

Bankside or bridge-mounted deployment methods may include:

- Modified I-beam and probe shuttle (Figures 2 and 3).
- Boom arm (Figure 4).
- Slant pipe (Figure 5).

We will obtain appropriate access permission, reviews, and permits for all station installations to comply with federal, state, local, and tribal jurisdictions.

For some slant pipe installations, we will cut anti-stilling windows out of the pipes to allow well mixed water to be measured or sampled from the pipe. We will adjust the size of anti-stilling windows as needed to allow internal water mixing while supporting the pipe's structural integrity.

We will support our shuttle I-beams with guard frames anchored into the bank at several points. When necessary, we will also install upstream deflection structures to protect our station installations from river debris impacts and build our probe installations at an angle to the force of the river to deflect the river power and reduce debris entanglements.

**Figure 2. Probe shuttle and I-beam test deployment at the South Fork Newaukum River at Jorgenson Road.**

**Figure 3. Probe shuttle and an I-beam with an improved anchor frame at the Stillaguamish River at Blue Stilly Park, March 23, 2023.**

**Figure 4. A boom-arm probe deployment on the Newaukum River near Chehalis, adjacent to a slant pipe deployment.**

**Figure 5. A slant pipe with anti-stilling windows at the Skagit River near Mt. Vernon (USGS Station ID 12200500).**

Left: The top end of the slant pipe with a locking cap and upper anti-stilling window.
Right: the half-submerged lower end of the slant pipe with anti-stilling windows, anchor straps, and bolts.

### 8.2.3 Automated sampling

The PSFMN will use autosamplers following the QAMP (Dugger et al. 2023) procedures. We will follow laboratory holding time and preservation guidelines to avoid qualifying samples collected by the autosampler. These laboratory restrictions limit the samples to whole water fractions, as the autosamplers cannot filter dissolved parameters within a 15-minute timeframe. We will use refrigerated autosamplers to preserve whole water samples below 6°C and pre-fill autosampler bottles with the appropriate preservative for the specific parameter. Table 3 shows the list of parameters collected by autosamplers.

To facilitate the storm event sampling, we will develop and refine software that will be loaded on the data loggers designed to trigger the autosamplers to collect a discrete water quality sample. Our field staff will collect these samples from the stations and submit them to Manchester Laboratory for analysis.

# 10.0 Quality Control Procedures

We will conduct quality control (QC) following the procedures outlined in the QAMP (Dugger et al. 2023). Staff will follow all relevant SOPs necessary to perform checks on target parameters. We will perform, at minimum, monthly side-by-side QC checks for all project parameters at the continuous stations. If sensor fouling levels require a more frequent maintenance schedule, we may add more visits to address maintenance needs.

Before deployment, we will check rainfall gages with a known volume of water from a graduated cylinder to compare to the observed rainfall gage level.

We will assess QC results and adjust data for observed bias when appropriate, based on the procedures outlined in the QAMP (Dugger et al. 2023). As described in the QAMP, we will provide secondary quality codes for raw and adjusted data, indicating the relative reliability of data based on the proportional difference of QC checks from the MQOs.

# 15.0 References


Ahmed, A., C. Figueroa-Kaminsky, J. Gala, T. Mohamedali, G. Pelletier, S. McCarthy. 2019. Puget Sound Nutrient Source Reduction Project Volume 1: Model Updates and Bounding Scenarios Washington State Department of Ecology. Publication 19-03-001. Olympia, WA. https://apps.ecology.wa.gov/publications/SummaryPages/1903001.html

Dugger, D., W. Bretherton, S. Studer, and M. Von Prause. 2023. Quality Assurance Monitoring Plan: Statewide River and Stream Ambient Water Quality Monitoring – 2023 Revision. Publication 23-03-102. Washington State Department of Ecology, Olympia. https://apps.ecology.wa.gov/publications/SummaryPages/2303102.html.

Sackmann, B. 2011. Deschutes River Continuous Nitrate Monitoring. Washington State Department of Ecology. Publication 11-03-030. Olympia, WA. https://apps.ecology.wa.gov/publications/SummaryPages/1103030.html

Senter, C., J. Foreman, and R. Sheibley. 2023. Daily Nooksack River Basin Nutrient Loading Estimates from 2018 to 2021. United States Geological Survey (USGS). https://www.usgs.gov/data/daily-nooksack-river-basin-nutrient-loading-estimates-2018-2021


# 16.0 Appendix. Glossary

See Glossary, Acronyms, and Abbreviations in the original QAMP:

Dugger, D., W. Bretherton, S. Studer, and M. Von Prause. 2023. Quality Assurance Monitoring Plan: Statewide River and Stream Ambient Water Quality Monitoring, 2023 revision. Publication 23-03-106. Washington State Department of Ecology, Olympia. https://apps.ecology.wa.gov/publications/SummaryPages/2303106.html.