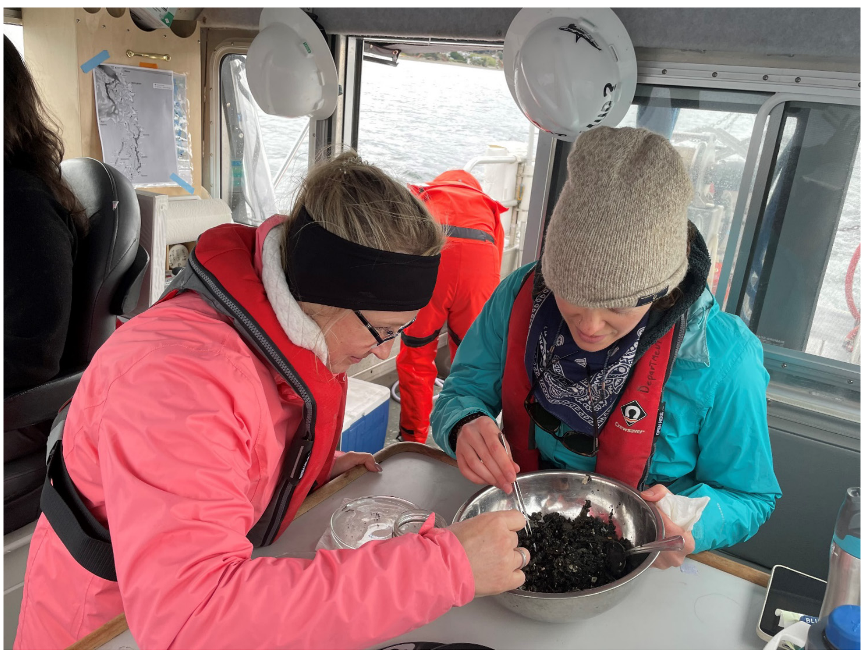
DEPARTMENT OF ECOLOGY
State of Washington

Quality Assurance Project Plan

2025 – 2030 Monitoring Contaminants in Marine Benthic Invertebrates



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Data for this project are available in Ecology's EIM Database.[1]
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COVER PHOTO: Scientists removing benthic invertebrates from marine sediment.
PHOTO BY MARINE SEDIMENT MONITORING TEAM.

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

Quality Assurance Project Plan

Monitoring Contaminants in Marine Benthic Invertebrates

By the Marine Sediment Monitoring Team

August 2025

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EAP: Environmental Assessment Program

1.0 Table of Contents

List of Figures

List of Tables

2.0 Abstract

The sediments of Puget Sound are a key component of the Puget Sound ecosystem. These sediments provide vital ecosystem services such as: burial and sinks for carbon, nutrients, and chemical contaminants; serving as sources for nutrient remineralization by the breakdown of organic matter; and providing critical habitats for sediment-dwelling invertebrates and fish.

Sediment-dwelling invertebrates, known as benthos, make ideal sentinels of ecosystem health because of their direct association living in, and sometimes consuming, sediments. Their sedentary lifestyle means they are unable to escape exposure to stressors such as contaminated sediments, changes in nutrient input, ocean acidification, oxygen depletion, and climate change.

The purpose of this project is to generate information on concentrations of contaminants in marine invertebrates from greater Puget Sound and six Urban Bays. The Puget Sound Ecosystem Monitoring Program (PSEMP) sediment component collects marine sediment chemistry and benthic invertebrate data from 50 sites in greater Puget Sound annually and one of six Urban Bays on an annual rotation. Determination of contaminant levels in benthic invertebrate tissues is not currently a part of this program, leaving a gap in our knowledge of benthic-to-pelagic contaminant transfer in the food web. This project is an expansion of the work conducted by the Department of Ecology's Puget Sound Sediment Monitoring Program (Sediment Program). Contaminant analysis of benthic invertebrate tissue will take advantage of existing resources for collection of sediment chemistry and benthic invertebrate data, helping to fill an important data gap concerning the fate, transport, and food web transfer of priority pollutant chemicals in Puget Sound.

This Quality Assurance Monitoring Plan describes the goals, objectives, and study design. It also provides references for all field and laboratory methods for the collection and analysis of chemical contaminants in marine invertebrate tissues.

3.0 Background

3.1 Introduction and problem statement

Sediments in the Puget Sound basin serve as a significant repository for terrestrial anthropogenic contamination via direct discharge or hydrological transport. This poses potential harm to sedentary benthic invertebrates residing within these sediments and often consuming them. For decades, marine sediments and the biota living in or on them have been impacted by chemical contamination and nutrient loading from municipal and industrial point sources, as well as non-point sources throughout the Puget Sound basin (Malins et al. 1984; PSEMP Toxics Work Group 2023 and 2017; West et al 2023). However, data are lacking on contaminant levels in marine invertebrates from Puget Sound, and transfer of contaminants from sediments to biota has not been adequately evaluated.

Benthic invertebrates are a key component of the Puget Sound ecosystem, supporting important functions such as sediment mixing and aeration, nutrient recycling, and habitat formation. They are also primary consumers at the base of the food web and are therefore potential pathways for transfer of contaminants to higher trophic levels. Marine invertebrates possess complex multi-stage life cycles, with many species featuring a free-swimming larval stage. This characteristic may allow them to transfer contaminants not only within the benthic environment but also to the pelagic zone, with the potential to impact economically important and iconic species such as salmon and orca.

3.2 Study area and surroundings

The Puget Sound study area comprises a variety of interconnected habitat types: shallow estuaries and bays, deep glacially-scoured fjords, broad channels, and river mouths. It is bounded by three major mountain ranges: the Olympics to the west, the mountains of Vancouver Island to the north, and the Cascade Range to the east. The northern end of Puget Sound is open to the Strait of Georgia and to the Strait of Juan de Fuca, connecting Puget Sound to the Pacific Ocean. This large, complex estuary extends over 200 miles from the City of Olympia north to the Canadian border and covers an area greater than 2,000 km^2, ranging in width from 10 to 40 km (Kennish 1998).

Freshwater enters the Puget Sound estuary via precipitation, surface runoff, groundwater inflow, and various rivers. Major rivers include the Nooksack, Skagit, Snohomish, Cedar, Duwamish, Puyallup, Stillaguamish, and Nisqually). The Skagit, Stillaguamish, and Snohomish rivers account for most of the freshwater input into the Sound (Kennish 1998). However, the Fraser River, in British Columbia, contributes substantially to the hydrography of Puget Sound.

Puget Sound is bordered by both relatively undeveloped rural regions and highly developed urban and industrial areas. Major urban centers, including Bellingham, Everett, Seattle, Bremerton, Tacoma, and Olympia, are situated at the mouths of large river systems that drain highly urbanized watersheds into Puget Sound's largest estuarine embayments (Figure 1).

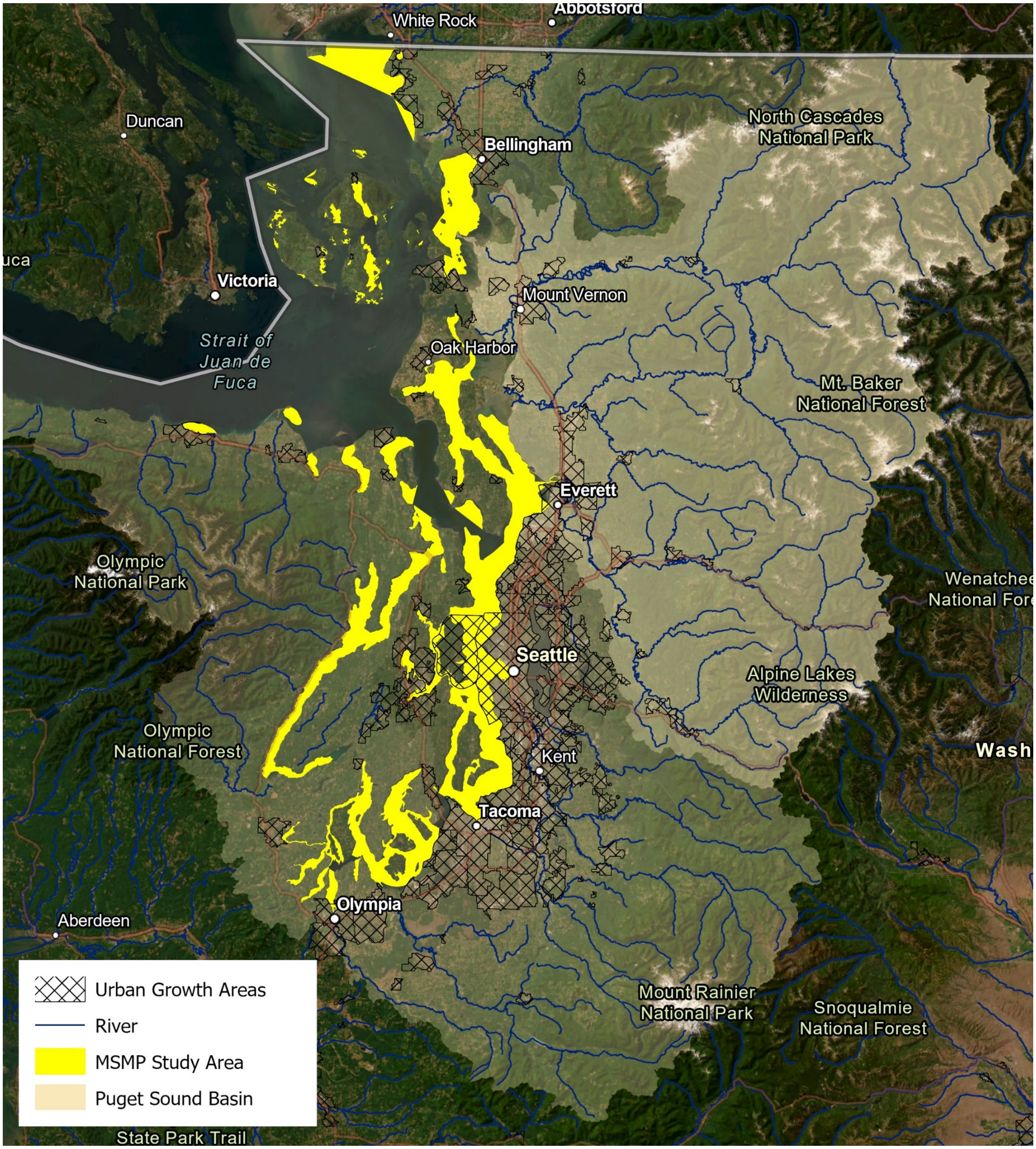

Figure 1. Puget Sound Sediment Monitoring Program (MSMP) study area.

3.2.1 History of study area

A thorough history of the study area is described in the previous Puget Sound Sediment Monitoring Program Quality Assurance Monitoring Plan (Dutch et al. 2018).

3.2.2 Summary of previous studies and existing data

Data are lacking on contaminant levels in marine invertebrates from Puget Sound, and transfer of contaminants from sediments to biota has not been adequately evaluated. Studies generally are localized or species-specific. Only two Puget Sound-wide tissue monitoring studies have been carried out, both focusing on the nearshore environment. Summaries of these studies are provided below. Studies of contaminant levels in subtidal benthic invertebrate communities have not been completed for Puget Sound to date.

- The Washington Department of Fish and Wildlife's (WDFW) Toxics Biological Observation System (TBiOS) monitors the geographic extent and magnitude of toxic contaminants in fish and other organisms inhabiting Puget Sound. Using caged native bay mussels (*Mytilus trossulus*), WDFW has identified widespread exposure of polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs) in nearly all nearshore habitats monitored in Puget Sound (Biomonitoring of Contaminants in the Puget Sound Nearshore)[2].
- The National Oceanic and Atmospheric Administration's (NOAA) National Mussel Watch Program monitors the status and spatial and temporal trends of chemical contaminants and biological stressors in the nation's coastal waters. The program utilizes a sentinel-based approach to monitoring by collecting and analyzing sediment and native bivalves (oysters and mussels) as surrogates for water pollution and bioaccumulation from a network of sites across the United States (U.S.) and territories (Mussel Watch - NCCOS - National Centers for Coastal Ocean Science)[3].

One small pilot study was conducted by the Marine Sediment Monitoring team in 2022. Market basket benthic macroinvertebrate tissues were sampled for a suite of chemical pollutants including metals, PAHs, PCBs, Polybrominated diphenyl ethers (PBDEs), and other organic compounds at eight locations: six in Commencement Bay, and one each in Sinclair Inlet and Nisqually Reach. Results were compared to chemical pollutant concentrations in sediments from those locations. Key findings included:

- Metals and PAHs were most often detected in both sediments and invertebrate tissues.
- Concentrations of metals and PAHs measured in sediments were highly correlated with concentrations found in tissue samples.

[2] Biomonitoring of Contaminants in the Puget Sound Nearshore - https://storymaps.arcgis.com/stories/992bcde65ce8407b887318754a91929e

[3] Mussel Watch - NCCOS - National Centers for Coastal Ocean Science - https://coastalscience.noaa.gov/science-areas/pollution/mussel-watch/#:~:text=NOAA's%20National%20Mussel%20Watch%20Program,in%20the%20nation's%20coastal%20waters.

- Pollutant concentrations found in tissues were generally lower than those in sediments.

3.2.3 Parameters of interest and potential sources

To assess the extent and spatial distribution of anthropogenic chemical contamination in tissues, and to ensure consistency with the list of chemical contaminants measured in surface sediments, we will measure the same contaminants in tissues. These include metals, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), and phthalates.

3.2.4 Regulatory criteria or standards

The Sediment Program's activities and results are non-regulatory. We will collect and analyze invertebrate tissues for chemicals of interest, following goals, objectives, and methodologies designed to determine the status and trends of chemical contaminants at specific Long-term stations and across designated large-scale sampling frames.

4.0 Project Description

Ecology's Marine Sediment Monitoring Team (MSMT) has studied Puget Sound sediments since 1989 as part of the Puget Sound Ecosystem Monitoring Program (PSEMP), with the goal of addressing the following key questions:

- What is the condition of the benthic habitat and associated invertebrate organisms?
- How do the habitats and communities change over time?
- What are the relationships between benthic invertebrates and measured environmental parameters, such as nutrients and chemical pollutants?

The Sediment Program uses consistent techniques to monitor Puget Sound sediments for a suite of physical, chemical, and biological variables and environmental indicators. The program uses a monitoring strategy composed of two elements to assess sediment quality for the greater Puget Sound and six urban bays:

- **Long-term monitoring**: Annual Puget Sound-wide characterization and change over time of sediment quality and benthic infaunal assemblage condition, as estimated from samples collected from 50 stations selected from both random and non-random sample designs., detailed in section 7.
- **Urban Bays monitoring**: Periodic bay-wide characterization and change over time of sediment quality and benthic infaunal assemblage condition, as estimated from samples collected from 30 – 36 randomly-selected stations sampled from one of six urban bays on a rotational basis.

This project aims to measure contaminant levels in benthic invertebrate tissues to enhance our understanding of the relationship between contaminants in sediments and their absorption and impact on benthic biota. The data generated will establish a baseline for contaminants in benthic invertebrate tissues throughout Puget Sound.

4.1 Project goals

- Determine the status of, and document spatial patterns and variation in, chemical contamination in tissues of Puget Sound benthic invertebrates.
- Compare contaminant concentrations found in sediments with those present in the tissues of benthic invertebrates.
- Provide scientifically valid data and summary reports for environmental managers, scientists, tribes, and the general public, and also provide technical support when appropriate.

4.2 Project objectives

- Quantification of Contaminants: Quantify the levels of metals, PAHs, PCBs, PBDEs, and phthalates in benthic invertebrate tissues. This will provide a detailed dataset reflecting the extent of contamination within Puget Sound's benthic invertebrate community.

- Spatial Analysis: The project will map out the spatial distribution of contaminants in benthic invertebrate tissues across long-term monitoring stations and large-scale sampling frames.
- Correlation Studies: By comparing contaminant concentrations in sediments with those in benthic invertebrate tissues, we will be able to identify patterns and correlations. This is crucial for understanding how contaminants transfer from sediments to biota, and how they accumulate in biota.
- Scientifically Sound Data: The findings from this project will provide scientific evidence to inform researchers and environmental managers.

4.3 Information needed and sources

Existing sediment and new tissue chemistry data will be assembled for metals, PAHs, PCBs, PBDEs and phthalates to address the goals, objectives, and questions set forth in this Quality Assurance Monitoring Plan/Quality Assurance Project Plan (QAPP). Existing data include the physical, chemical, and biogeochemical sediment quality parameters, as well as data for the benthic infaunal assemblage collected for the program since 1989. These and additional historical data collected for other Puget Sound monitoring programs, and for regulatory cleanup purposes, are available through Ecology's Environmental Information Management System (EIM) database and from various stakeholders.

Geographic Information System (GIS) layers will be obtained from various governmental web sites to aid in spatial data analysis of newly collected tissue chemistry results.

4.4 Tasks required

For each Sediment Program element, sediment grab samples are collected from target locations within designated sampling frames. Samples for the Long-term element are collected annually in April at 50 locations, while the six urban bays are sampled once every six years with 30 to 36 stations in each bay. In addition to the samples collected under the 2023 – 2028 Puget Sound Sediment Monitoring Program QAMP (Marine Sediment Monitoring Team 2023), a benthic invertebrate tissue sample will be collected at each location. Once the additional sample is collected, it will be washed with in situ water to separate out the animal tissues from the sediments. Tissues will then be placed into appropriate glass jars and sent to the Manchester Environmental Laboratory for chemical analyses. Once laboratory results are produced, they will be reviewed and assessed for data quality. Data analyses and summaries will be included in a publication and all data will be uploaded to EIM.

4.5 Systematic planning process

Any updates to the monitoring plan described in this QAPP will be captured in addenda to this QAPP, or, if significantly different, will be captured in a new Quality Assurance Project Plan.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

Table 1 shows the responsibilities of those who will be involved in this project.

Table 1. Staff roles and responsibilities within the Marine Sediment Monitoring Program.

All are employees of the Washington State Department of Ecology.

Environmental Assessment Program Staff	Title	Responsibilities
Sandra Weakland Marine Monitoring Unit Western Operations Section 360-668-6420 & 360-407-3970	Benthic Ecologist	Team lead, data review and analysis, report preparation, field sampling preparation and conduct, Geographic Information System (GIS) lead, lab contract oversight, web steward, QAMP/QAPP preparation, benthic invertebrate sample processing
Dany Burgess Marine Monitoring Unit Western Operations Section 564-669-1737 & 360-407-3970	Lead Taxonomist	Primary and secondary invertebrate taxonomy, voucher sheet generation, voucher collection maintenance, benthic lab lead, lab contract oversight, field sampling, report preparation
Chad Eshelman Marine Monitoring Unit Western Operations Section Phone: 564-669-4470	Statistician	Statistician and data analyst lead, report preparation, field sampling
Paul Larson Marine Monitoring Unit Western Operations Section 360-280-8369 & 360-407-3970	Taxonomist	Primary and secondary invertebrate taxonomy, voucher sheet generation, voucher collection maintenance, field lead, field sampling, report preparation
Emma LeValley Marine Monitoring Unit Western Operations Section 564-250-2961	Boat operator/ Laboratory technician	Boat operations, benthic invertebrate sample processing
Julianne Ruffner Marine Monitoring Unit Western Operations Section 360-280-4518	Unit Supervisor for the Project Manager	Reviews the project scope and budget, tracks progress, provides internal review of the draft QAPP, and approves the final QAPP

Environmental Assessment Program Staff	Title	Responsibilities
Stacy Polkowske Western Operations Section 360-464-0674	Section Manager for the Project Manager	Reviews the project scope and budget, tracks progress, reviews the draft QAPP, and approves the final QAPP
Rob Waldrop Manchester Environmental Laboratory 360-871-8801	Laboratory Director	Reviews and approves the final QAPP.
Christina Frans 360-480-1960	Acting Ecology Quality Assurance Officer	Reviews and approves the draft QAPP and the final QAMP.

QAMP/QAPP: Quality Assurance Monitoring Plan/Quality Assurance Project Plan

5.2 Special training and certifications

All personnel who conduct field activities receive training on the use of sediment and benthic infaunal sample collection equipment, sample handling, program quality assurance/quality control (QA/QC), and safety. Each person is required to be familiar with this QAPP and field procedures described in our Standard Operating Procedures (SOPs) listed in section 6.2.2. New or volunteer staff are given demonstrations of field procedures before they perform field activities. A senior staff member will also be present on each day of field sampling to verify that proper sampling procedures are followed. Periodic field checks are conducted by senior staff to ensure consistent sampling performance among staff. Results from these checks are discussed with the team and appropriate updates or changes are implemented if necessary.

All personnel conducting screening, sorting, and/or identification of the benthic samples have a college education in marine and/or environmental sciences and direct experience with sample handling, analysis, QA/QC, and chemical safety. Each person is required to be familiar with this QAPP and procedures described in our SOPs. Those conducting identification of the benthic samples have extensive training and experience in marine invertebrate taxonomy and participate in rigorous taxonomic QC checks as described in our SOPs.

5.3 Organization chart

Not Applicable.

5.4 Proposed project schedule

Tables 2 – 4 list key activities, due dates, and lead staff for this project.

Table 2. Schedule for completing field and laboratory work.

Task	Due Date	Lead Staff
Field work	*Long-term element:* April through early May annually. *Urban Bays element:* early June annually.	All Marine Sediment Monitoring Team staff
Manchester Environmental Laboratory analyses	February of the following year	Sandra Weakland
Stable Isotope contract lab analyses	December annually	Sandra Weakland

Table 3. Schedule for data entry.

Task	Due Date	Lead Staff
EIM data loaded[a]	10 months post -collection	Sandra Weakland
EIM QA	11 months post-collection	Chad Eshelman
EIM complete	1 year post-collection	Sandra Weakland

[a] EIM Study ID: PSEMP_LT (Long-term program 2025), UWI (Urban Bays program)
EIM: Environmental Information Management database.

Table 4. Schedule for final report.

Task	Due Date	Lead Staff
Draft to supervisor	13 months post-collection	all senior MSMT staff
Draft to client/ peer reviewer	14 months post-collection	all senior MSMT staff
Draft to external reviewers	14 months post-collection	all senior MSMT staff
Final draft to publications team	15 months post-collection	all senior MSMT staff
Final report due on web	17 months post-collection	all senior MSMT staff

MSMT: Marine Sediment Monitoring Team

5.5 Budget and funding

This project is an expansion of work already conducted by Ecology's Puget Sound Sediment Monitoring Program, (Marine Sediment Monitoring Team 2023). The Sediment Program is funded by the Model Toxics Control Account. Redirected monitoring and unspent biennial funds from the Environmental Assessment Program will be utilized for the contaminant analysis of benthic invertebrate tissue. The projected budget for 2025 is provided in Table 5. The Manchester Environmental Laboratory (MEL) budget is detailed in Table 6.

Table 5. Project budget and funding.

Item	Cost ($)
Salary, benefits, and indirect/overhead	$0.0 covered by Sediment Program
Equipment	$0.0 covered by Sediment Program
Travel and other	$0.0 covered by Sediment Program
Stable Isotope analysis	$2000.00
Chemical laboratory analyses (See Table 6 for details.)	Up to* $140,931.70

*The number of samples depends on the availability of sufficient tissue biomass to conduct analyses.

Table 6. Laboratory budget details.

The number of samples depends on the availability of sufficient tissue biomass to conduct analyses. Prices are subject to change at the end of the fiscal year.

Parameter	Number of Samples	Number of QA Samples	Total Number of Samples	Cost Per Sample ($)	Lab Subtotal ($)
Metals	Up to 83	Up to 8	Up to 91	$271.70	$24,724.70
Mercury	Up to 83	Up to 8	Up to 91	$55.00	$5,005.00
Polycyclic aromatic hydrocarbons (PAH) and phthalates	Up to 83	Up to 8	Up to 91	$616.00	$56,056.00
Polychlorinated biphenyls (PCB) Congeners and Aroclors	Up to 83	Up to 8	Up to 91	$259.00	$23,569.00
Polybrominated diphenyl ethers (PBDEs)	Up to 83	Up to 8	Up to 91	$347.00	$31,577.00

6.0 Quality Objectives

6.1 Data quality objectives

The main data quality objective (DQO) for this project is to collect a minimum of 50 benthic invertebrate tissue samples in April that are representative of Puget Sound and 30 to 36 samples in June from six urban bays. These samples will be analyzed, using standard methods, to obtain baseline data on suites of chemical contaminants in benthic invertebrate tissues that meet measurement quality objectives (MQOs) described below and are comparable to sediment chemistry results previously collected.

6.2 Measurement quality objectives

MQOs for the Sediment Program include data quality indicators of precision, bias, sensitivity, representativeness, comparability, and completeness. Definitions of these terms are provided in the Quality Assurance Glossary (see Appendix). The MQOs for the data to be collected in the program are provided in this section.

6.2.1 Targets for precision, bias, and sensitivity

The MQOs for project results, expressed in terms of acceptable precision, bias, and sensitivity, are described in this section and summarized in Table 7.

Table 7. Measurement quality objectives and chemical pollutant analyses of benthic invertebrate tissues.

All terms are defined in the Quality Assurance Glossary (see Appendix).

Parameter	Blind Field Duplicate	Laboratory Duplicate	Lab Control Standard % Recovery	Standard or Certified Reference Material % Recovery	Matrix Spike (MS) % Recovery	Matrix Spike Duplicate	Surrogate Spike % Recovery	Method Blank	Method Reporting Limit
δ13C and δ15N stable isotopes	<0.4 ‰	<0.3 ‰	<0.2 ‰	<0.3 ‰	Not applicable	Not applicable	Not applicable	< 0.5 MDL	1.4 µmol N
Metals (except mercury)	RPD < 20%	Not applicable if below PQL, MS/MSD serve as lab duplicate	85 – 115%	Based on manufacturers set limits	75 – 125%	RPD < 20%	Not applicable	<½ LLOQ; if > ½ LLOQ, lowest analyte concentration. must be >10x method blank or qualified as an estimate	0.1 mg/kg ww (0.2 for Tin, 0.5 for Chromium and Selenium, 1.0 for Copper, 5.0 for Zinc)
Total mercury	RPD < 20%	Not applicable if below PQL, MS/MSD serve as lab duplicate	85 – 115%	Based on manufacturers set limits	75 – 125%	RPD < 20%	Not applicable	<½ LLOQ; if > ½ LLOQ, lowest analyte concentration must be >10x method blank or qualified as an estimate	0.017 mg/kg ww
Phthalates	RPD < 40%	RPD < 40%	Variable	NA	Variable	RPD < 40%	45–130	Follows MEL protocol	40–100 µg/kg ww

Parameter	Blind Field Duplicate	Laboratory Duplicate	Lab Control Standard % Recovery	Standard or Certified Reference Material % Recovery	Matrix Spike (MS) % Recovery	Matrix Spike Duplicate	Surrogate Spike % Recovery	Method Blank	Method Reporting Limit
Polycyclic aromatic hydrocarbons (PAHs)	RPD < 40%	RPD < 40%	Variable	see table 8*	Variable	RPD < 40%	20 – 200%	<MDL; if > MDL, lowest analyte concentration must be >5x method blank or qualified as an estimate	4–20 µg/kg ww
Polychlorinated biphenyls (PCBs) - Aroclors	RPD ≤ 40%	RPD ≤ 40%	Variable	Not applicable	Variable	RPD ≤ 40%	57-130	<MDL; if > MDL, lowest analyte concentration must be >5x method blank or qualified as an estimate	2.5 µg/kg ww
Polychlorinated biphenyls (PCBs) — Congeners	RPD ≤ 40%	RPD ≤ 40%	Variable	see table 8*	Variable	RPD ≤ 40%	47–166	<MDL; if > MDL, lowest analyte concentration Must be >5x method blank or qualified as an estimate	0.5–1 µg/kg ww
Polybrominated diphenyl ethers (PBDEs) — Congeners	RPD ≤ 40%	RPD ≤ 40%	Variable	see table 8*	Variable	RPD ≤ 40%	27–155	<MDL; if > MDL, lowest analyte concentration must be >5x method blank or qualified as an estimate	0.2 – 1 µg/kg ww

* Surrogate recoveries are compound specific.
LLOQ: lowest level of quantification
MDL: method detection limit
MS/MSD: matrix spike/matrix spike duplicate
RPD: relative percent difference
ww: wet weight

Table 8. Standard (Certified) Reference Material (SRM) (NIST 1974) recovery limits Organics in Mussel Tissue (Mytilus edulis).

Analyte	Standard reference material limits (%)
PBDE-047	20–200
PBDE-049	20–200
PBDE-066	not available
PBDE-071	not available
PBDE-099	20–200
PBDE-100	not available
PBDE-138	not available
PBDE-153	not available
PBDE-154	not available
PBDE-183	not available
PBDE-184	not available
PBDE-191	not available
PBDE-209	not available
PCB-008	20–200
PCB-018	20–200
PCB-028	20–200
PCB-044	20–200
PCB-052	20–200
PCB-066	20–200
PCB-077	not available
PCB-101	20–200
PCB-105	20–200
PCB-118	20–200
PCB-126	not available
PCB-128	20–200
PCB-138	20–200

Analyte	Standard reference material limits (%)
PCB-153	20–200
PCB-169	not available
PCB-170	20–200
PCB-180	20–200
PCB-187	20–200
PCB-195	not available
PCB-206	not available
PCB-209	not available
1,1'-Biphenyl	not available
1,6,7-Trimethylnaphthalene	not available
1-Methylnaphthalene	not available
1-Methylphenanthrene	20–200
2,6-Dimethylnaphthalene	not available
2-Chloronaphthalene	not available
2-Methylfluoranthene	not available
2-Methylnaphthalene	not available
2-Methylphenanthrene	20–200
4-Methyldibenzothiophene	not available
5-Methylchrysene	not available
9H-Fluorene, 1-methyl-	not available
Acenaphthene	not available
Acenaphthylene	not available
Anthracene	20–200
Benz[a]anthracene	20–200
Benzo(a)pyrene	20–200
Benzo(b)fluoranthene	not available
Benzo(ghi)perylene	20–200
Benzo(k)fluoranthene	20–200

Analyte	Standard reference material limits (%)
Benzo[e]pyrene	20–200
Bis(2-Ethylhexyl) Phthalate	not available
Butyl benzyl phthalate	not available
Carbazole	not available
Chrysene	not available
Dibenzo(a,h)anthracene	not available
Dibenzofuran	not available
Dibenzothiophene	20–200
Diethyl phthalate	not available
Dimethyl phthalate	not available
Di-N-Butylphthalate	not available
Di-N-Octyl Phthalate	not available
Fluoranthene	20–200
Fluorene	20–200
Indeno(1,2,3-cd)pyrene	not available
Naphthalene	not available
Perylene	20–200
Phenanthrene	20–200
Phenanthrene, 3,6-dimethyl	not available
Pyrene	20–200
Retene	not available

PBDE – Polybrominated diphenyl ether

PCB – Polychlorinated biphenyl

6.2.1.1 Precision

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

For chemical parameters measured in collected tissue, precision will be assessed by analyzing duplicate samples including field replicate (splits), analytical (laboratory) replicate (splits), and matrix spike duplicates. Targets for acceptable precision between duplicate results, in terms of relative percent difference (RPD), are listed in Tables 7 and 8. Acceptable precision among three or more replicate sample results is expressed as relative standard deviation (RSD).

6.2.1.2 Bias

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

Bias for chemical and biogeochemical analyses will be assessed by calibrating field and laboratory instruments, and by analyzing lab control samples, standard reference materials, method blanks, and matrix spikes. Targets for bias are listed in terms of acceptable % recovery of a known quantity, listed in Table 7.

6.2.1.3 Sensitivity

Sensitivity is a measure of the capability of a method to detect a substance when it is present. It is commonly described as a detection limit. Targets for acceptable sensitivity of all chemistry and biogeochemistry lab measurements, including method detection limits (MDL)4, for this project are listed in Table 7.

6.2.2 Targets for comparability, representativeness, and completeness

6.2.2.1 Comparability

One of the goals of the Sediment Program is to provide baseline sediment quality and benthic infaunal data on a large geographic scale which can be used for comparison to data collected for smaller-scale studies conducted by regional stakeholders.

Peer-reviewed published methods and SOPs will be followed for sampling, analysis, and data reduction. When comparing Sediment Program data collected from other projects, the methods and SOPs from those projects will be examined to determine comparability between them. Methods and SOPs for the chemicals in benthic invertebrate tissue project include the following:

Sampling methods

- Puget Sound Estuary Program (PSEP), 1998. Recommended Guidelines for Station Positioning in Puget Sound.
- PSEP 1997a. Recommended Guidelines for Sampling Marine Sediment, Water Column, and Tissue in Puget Sound.
- PSEP 1987. Recommended Protocols for Sampling and Analyzing Subtidal Benthic Macroinvertebrate Assemblages in Puget Sound.

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[4] The lowest quantity of a physical or chemical parameter that is detectable (above background noise) by each field instrument or laboratory method.

- Weakland, S. 2007 [Recertified 2024]. Ecology's Standard Operating Procedures for Obtaining Marine Sediment Samples. EAP039 v1.5.
- Parsons et al. 2021. EAP070 v2.3 SOP — Minimize Spread of Invasive Species.
- Environmental Assessment Program Safety Manual — 2024.

Sample analysis

See peer-reviewed, published methods listed for each analytical test in Section 9.0 Laboratory Procedures, below, and in the following appendices:

Metals and organics chemistry

- Dunn and Carter 2018. Good practice guide for isotope ratio mass spectrometry.
- PSEP 1997b. Recommended Guidelines for Measuring Metals in Puget Sound Marine Water, Sediment and Tissue Samples.
- PSEP 1997c. Recommended Guidelines for Measuring Organic Compounds in Puget Sound Water, Sediment and Tissue Samples.
- MEL 2016. Manchester Environmental Laboratory Lab User's Manual. Version 10.
- MEL 2020. Standard Operating Procedure, MEL720034, Version 1.6, Inductively Coupled Plasma Mass Spectrometer analysis by SW-846 Method 6020B using the Agilent 7900
- USEPA 1996. Method 245.6. Determination Of Mercury in Tissues By Cold Vapor Atomic Absorption Spectrometry[5].
- USEPA 1994. Method 3541. Automated Soxhlet Extraction. https://www.epa.gov/sites/production/files/2015-06/documents/epa-3541.pdf
- USEPA 1996. Method 3051B. Acid digestion of sediments, sludges, and soils.
- USEPA 1996. Method 3665A. Sulfuric Acid/Permanganate Cleanup. https://www.epa.gov/sites/production/files/2015-12/documents/3665a.pdf
- USEPA 2007. Method 8082A. Polychlorinated Biphenyls (PCBs) by Gas Chromatography. https://www.epa.gov/sites/production/files/2015-12/documents/8082a.pdf
- USEPA 2014. Method 3620C. Florisil cleanup. https://www.epa.gov/sites/production/files/2015-12/documents/3620c.pdf
- USEPA 2014. Method 6020B. Inductively Coupled Plasma-Mass Spectroscopy. https://www.epa.gov/sites/default/files/2015-12/documents/6020b.pdf
- USEPA 2014. Method 8270E. Semivolatile Organic Compounds by Gas Chromatography/Mass Spectrometry. https://www.epa.gov/esam/epa-method-8270e-sw-846-semivolatile-organic-compounds-gas-chromatographymass-spectrometry-gc

[5] Method 245.6 - https://www.sciencedirect.com/science/article/abs/pii/B9780815513988500203?via%3Dihub

6.2.2.2 Representativeness

A 0.1 m^2 modified double van Veen grab sampler will be used to collect a sample with minimal disruption to the surface layer. Sampling methods, and criteria for rejecting a non-representative sample, are described in PSEP 1997a.

6.2.2.3 Completeness

Completeness measures the amount of valid data needed from a measurement system to meet study objectives. For the Sediment Program, 95% of observations, measurements, and samples must be acceptably taken and analyzed for the study to be considered successful. Due to the specific safety considerations associated with marine sampling, no attainment objective has been established. The availability of sufficient tissue biomass is a limiting factor, as the laboratory requires up to 30 grams of invertebrate tissue to perform all analyses and achieve suitable MRLs. We make every effort to complete all annual sampling to avoid gaps in the data record.

6.3 Acceptance criteria for quality of existing data

Sediment quality and chemistry data spanning many decades, and associated metadata such as quality monitoring plans and final reports, are available through Ecology's Environmental Information Management database (EIM). Data in EIM were generated by Ecology staff, contractors, and water discharge permit holders for many purposes including ambient monitoring, regulatory site assessments, and cleanup monitoring. A limited number of data exist on chemical pollutants in benthic biota.

Data quality varies depending on the type of quality assurance (QA) required when and where the projects were conducted. If MSMT staff choose to compare data from EIM and other programs to data collected for the Sediment Program, QA documentation for non-program data will be reviewed to ensure comparability of methods and MQOs.

All data collected since 1989 for the Sediment Program were collected according to quality standards specified in QAMPs and annual addenda. All future Sediment Program monitoring work is expected to meet the QC requirements specified in the Sediment Program QAMP and this QAPP. These requirements are summarized in the Quality Control Procedures Section 10.0 of this document and in the SOPs used for each analysis.

This project will measure levels of contaminants in benthic invertebrate tissues, helping to fill an important data gap concerning the fate, transport, and food web transfer of priority pollutant chemicals in Puget Sound. The data generated could be compared to existing contaminant data sets for sediments, macroinvertebrates, and epibenthic and pelagic fish from Puget Sound to better understand the contribution of benthos to contaminant transfer through the food web. In addition, the data can be used to determine biota-sediment accumulation factors (BSAFs) and improve the predictive capabilities of the Puget Sound Models as they relate to food web transfer of contaminants.

6.4 Model quality objectives

Not applicable.

7.0 Study Design

7.1 Study boundaries

The study boundary for the Long-term monitoring element lies within the Puget Sound-wide study area described in Section 3.2 and depicted in Figure 1. The Urban Bays study boundaries include defined sampling frames for Elliott Bay near Seattle; Commencement Bay near Tacoma; the Bainbridge Basin including Sinclair and Dyes Inlets near Bremerton; Bellingham Bay; Budd Inlet near Olympia; and East Possession Sound, including Port Gardner and Everett Harbor. These Urban Bays sampling frames are nested within the Puget Sound-wide Long-term sampling frame. All sampling frames are illustrated in Figure 2.

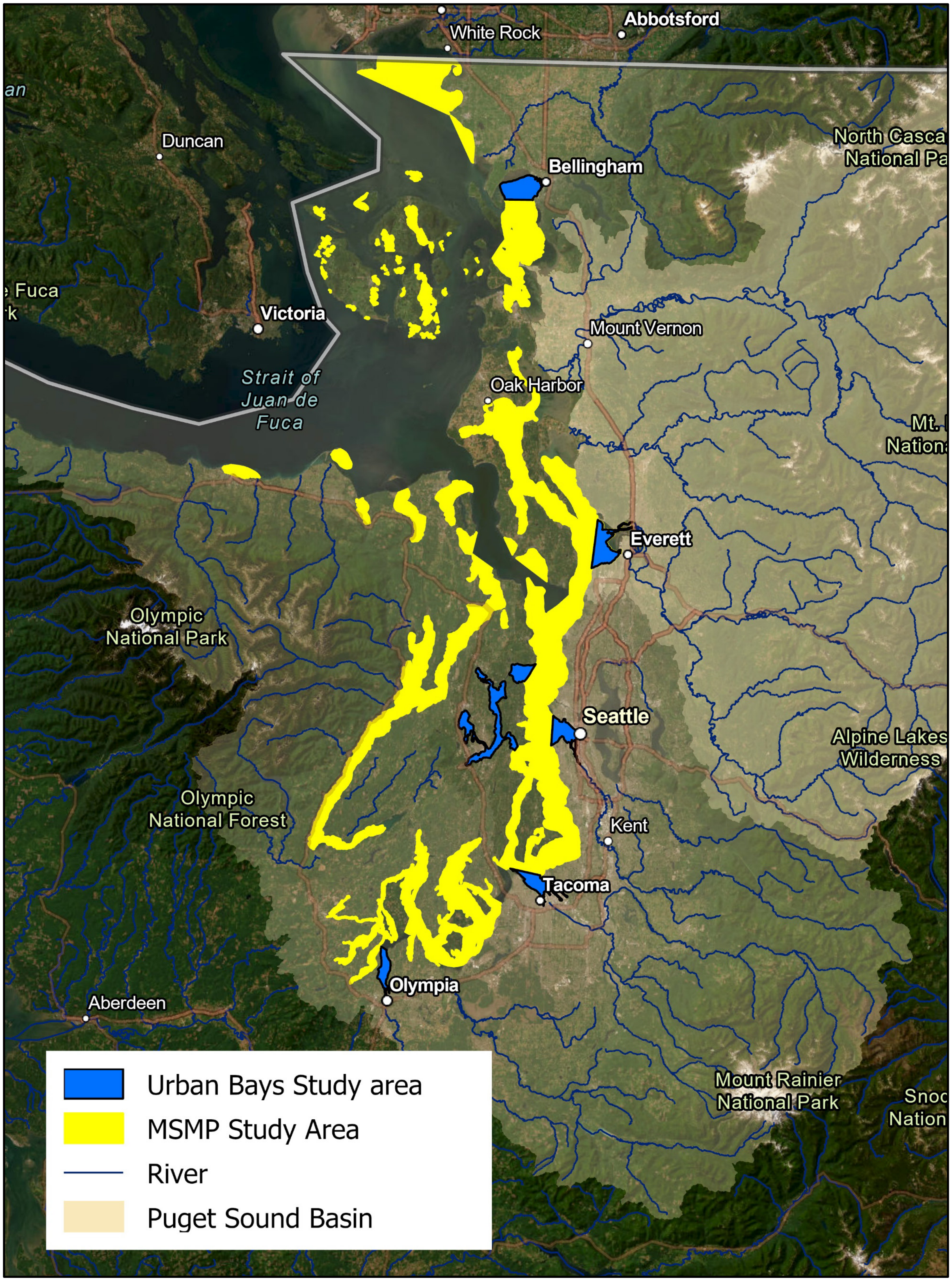

Figure 2. The Puget Sound-wide sampling frame (yellow) and six nested Urban Bays sampling frames (blue only).

7.2 Field data collection

7.2.1 Sampling locations and frequency

Long-term element

The 50 Long-term stations will be sampled once for this project during early April through early May 2025. This allows spatial assessment of chemical pollutant concentration in tissues of the overwintering benthic infaunal community. Table 9 lists the Long-term monitoring stations, sampling location, and sampling design from which the site originated. Locations for the 50 Long-term monitoring stations are depicted in Figure 3. All but one Long-term station, Station 3 in the Strait of Georgia, fall within the generalized random tessellation stratified (GRTS) multi-density design sampling frame, leaving 49 stations that will be equally weighted, each representing 45.054 km^2 of the total 2207.641 km^2 in the sampling frame for estimates of spatial extent of conditions. Alternate coordinates will be chosen if any of the target stations are rejected.

Table 9. Long-term element stations for the Marine Sediment Monitoring Program.

Station	Station type (Target or Alternate)	Location	Region	County	Watershed	Longitude (NAD83HARN)	Latitude (NAD83HARN)	Approx. Depth (m)	Sampling Scheme
3	Target	Strait of Georgia (North of Patos Island)	Strait of Georgia	Whatcom	Nooksack	-122.97842	48.87025	222	PSEMP Temporal
4	Target	Bellingham Bay	Strait of Georgia	Whatcom	Nooksack	-122.53820	48.68397	25	PSEMP Temporal
13	Target	North Hood Canal (South of Bridge)	Hood Canal	Kitsap	Kitsap	-122.62895	47.83758	20	PSEMP Temporal
19	Target	Saratoga Passage	Whidbey Basin	Island	Island	-122.47134	48.09792	122	PSEMP Historical
21	Target	Port Gardner (Everett)	Whidbey Basin	Snohomish	Snohomish	-122.24283	47.98547	22	PSEMP Temporal
29	Target	Shilshole	Central	Kitsap	Kitsap	-122.45403	47.70075	201	PSEMP Temporal
34	Target	Sinclair Inlet	Central	Kitsap	Kitsap	-122.66208	47.54708	9	PSEMP Temporal
38	Target	Point Pully (3-Tree Point)	Central	King	Duwamish-Green	-122.39363	47.42833	200	PSEMP Temporal
40	Target	Thea Foss Waterway (Commencement Bay)	Central	Pierce	Puyallup-White	-122.43730	47.26130	11	PSEMP Temporal
44	Target	East Anderson Island	South Sound	Pierce	Kitsap	-122.67358	47.16133	20	PSEMP Temporal
49	Target	Inner Budd Inlet	South Sound	Thurston	Deschutes	-122.91347	47.07997	7	PSEMP Temporal
52	Target	West of Devils Head, east end Nisqually Reach	South Sound	Pierce	Kitsap	-122.78051	47.17060	105	GRTS-1
119	Target	Admiralty Inlet, South	Central	Kitsap	Kitsap	-122.47816	47.87616	217	PSAMP/NOAA

Station	Station type (Target or Alternate)	Location	Region	County	Watershed	Longitude (NAD83HARN)	Latitude (NAD83HARN)	Approx. Depth (m)	Sampling Scheme
191	Target	Central Elliott Bay	Central	King	Duwamish-Green	-122.37581	47.59842	99	PSAMP/NOAA
222	Target	Hood Canal, north of Seabeck	Hood Canal	Jefferson	Quilcene-Snow	-122.81466	47.67821	128	PSAMP/NOAA
252	Target	Case Inlet	South Sound	Pierce	Kitsap	-122.85101	47.26957	55	PSAMP/NOAA
265	Target	Carr Inlet	South Sound	Pierce	Kitsap	-122.66572	47.25240	107	PSAMP/NOAA
281	Target	Commencement Bay	Central	Pierce	Puyallup-White	-122.44193	47.29229	143	PSAMP/NOAA
40005	Target	Inner Port Angeles Harbor	Strait of Juan de Fuca	Clallam	Elwha-Dungeness	-123.44985	48.13872	23	GRTS-2
40006	Target	Murden Cove	Central	Kitsap	Kitsap	-122.49390	47.63777	57	GRTS-2
40007	Target	Saratoga Passage, North, Camano Island	Whidbey Basin	Island	Island	-122.54375	48.22609	55	GRTS-2
40008	Target	Carr Inlet, northeast of Gertrude Island	South Sound	Pierce	Kitsap	-122.64787	47.22686	129	GRTS-2
40009	Target	Strait of Georgia, outer Birch Bay	Strait of Georgia	Whatcom	Nooksack	-122.82638	48.90625	28	GRTS-2
40010	Target	Central Hood Canal, south of Triton Cove	Hood Canal	Mason	Skokomish-Dosewallips	-122.97817	47.59726	124	GRTS-2
40011	Target	Central Basin, north of Shilshole	Central	King	Cedar-Sammamish	-122.41759	47.76108	211	GRTS-2
40012	Target	Elliott Bay, Smith Cove	Central	King	Cedar-Sammamish	-122.38563	47.6259	19	GRTS-2
40013	Target	Reads Bay	San Juan Archipelago	San Juan	San Juan	-122.82139	48.49626	7	GRTS-2
40015	Target	Saratoga Passage, South	Whidbey Basin	Island	Island	-122.44853	48.08877	110	GRTS-2

Station	Station type (Target or Alternate)	Location	Region	County	Watershed	Longitude (NAD83HARN)	Latitude (NAD83HARN)	Approx. Depth (m)	Sampling Scheme
40016	Target	Henderson Inlet	South Sound	Thurston	Deschutes	-122.83635	47.12549	4	GRTS-2
40017	Target	Boundary Bay	Strait of Georgia	Whatcom	Nooksack	-122.96789	48.99473	19	GRTS-2
40018	Target	Hood Canal, Hoodsport	Hood Canal	Mason	Skokomish-Dosewallips	-123.11736	47.41787	121	GRTS-2
40019	Target	South Possession Sound	Central	Snohomish	Cedar-Sammamish	-122.33076	47.90607	93	GRTS-2
40020	Target	Shilshole Bay	Central	King	Cedar-Sammamish	-122.42252	47.69588	87	GRTS-2
40021	Target	Crescent Harbor	Whidbey Basin	Island	Island	-122.61517	48.27948	13	GRTS-2
40022	Target	Brownsville	Central	Kitsap	Kitsap	-122.59952	47.67154	19	GRTS-2
40025	Target	West Sound	San Juan Archipelago	San Juan	San Juan	-122.96331	48.62446	20	GRTS-2
40026	Target	Dabob Bay	Hood Canal	Jefferson	Quilcene-Snow	-122.83153	47.76217	188	GRTS-2
40027	Target	Admiralty Inlet, north of Rose Point	Central	Kitsap	Kitsap	-122.5082	47.86624	21	GRTS-2
40028	Target	Totten Inlet	South Sound	Thurston	Kennedy-Goldsborough	-123.01006	47.136	7	GRTS-2
40029	Target	North Samish Bay	Strait of Georgia	Whatcom	Lower Skagit-Samish	-122.55226	48.63718	22	GRTS-2
40030	Target	Sinclair Inlet	Central	Kitsap	Kitsap	-122.65102	47.545	10	GRTS-2
40032	Target	Inner Case Inlet, Rocky Bay	South Sound	Pierce	Kitsap	-122.80549	47.34949	18	GRTS-2

Station	Station type (Target or Alternate)	Location	Region	County	Watershed	Longitude (NAD83HARN)	Latitude (NAD83HARN)	Approx. Depth (m)	Sampling Scheme
40034	Target	Port Townsend, mouth of Kilisut Harbor	Admiralty Inlet	Jefferson	Quilcene-Snow	-122.73316	48.09354	3	GRTS-2
40036	Target	Des Moines	Central	King	Duwamish-Green	-122.35733	47.41975	173	GRTS-2
40037	Target	Central Basin, North	Whidbey Basin	Island	Island	-122.58646	48.19991	54	GRTS-2
40038	Target	North Central Basin	Central	Kitsap	Kitsap	-122.47829	47.69895	186	GRTS-2
209R	Target	Skagit Bay	Whidbey Basin	Island	Island	-122.48846	48.29586	22	PSEMP Historical
305R	Target	Lynch Cove	Hood Canal	Mason	Kitsap	-122.93124	47.39717	20	PSEMP Historical
BLL009	Target	Bellingham Bay, Pt. Frances (Portage Island)	Strait of Georgia	Whatcom	Nooksack	-122.5942	48.68593	18	PSEMP-waters
HCB003	Target	Hood Canal, Central	Hood Canal	Kitsap	Kitsap	-123.0096	47.53787	152	PSEMP-waters
40039	Alternate	Gedney Island	Whidbey Basin	Snohomish	Snohomish	-122.31735	48.02361	No Data	GRTS-2
40040	Alternate	NW Anderson Island, Drayton Passage	South Sound	Pierce	Kitsap	-122.72910	47.17831	No Data	GRTS-2
40041	Alternate	South Boundary Bay	Strait of Georgia	Whatcom	Nooksack	-122.89714	48.93582	No Data	GRTS-2
40042	Alternate	Hood Canal, Right Smart Cove	Hood Canal	Mason	Skokomish-Dosewallips	-122.87476	47.72126	No Data	GRTS-2
40043	Alternate	South Possession Sound	Central	King	Cedar-Sammamish	-122.39947	47.83917	No Data	GRTS-2

Station	Station type (Target or Alternate)	Location	Region	County	Watershed	Longitude (NAD83HARN)	Latitude (NAD83HARN)	Approx. Depth (m)	Sampling Scheme
40044	Alternate	Central Basin, north of Alki	Central	King	Duwamish-Green	-122.42488	47.59770	No Data	GRTS-2
40045	Alternate	Bellingham Bay, Fairhaven	Strait of Georgia	Whatcom	Nooksack	-122.51920	48.72049	No Data	GRTS-2
40046	Alternate	Central Basin, north of Normandy Park	Central	King	Duwamish-Green	-122.38814	47.47329	No Data	GRTS-2
40047	Alternate	Admiralty Inlet, Outer Oak Bay	Admiralty Inlet	Jefferson	Quilcene-Snow	-122.66036	47.97690	No Data	GRTS-2
40048	Alternate	Case Inlet	South Sound	Pierce	Kennedy-Goldsborough	-122.84642	47.23001	No Data	GRTS-2

PSEMP Temporal: original suite of non-random monitoring stations sampled annually since 1989 with few exceptions (Striplin 1988)

PSEMP Historical: original suite of non-random monitoring stations selected for the program in 1989 but not sampled after 1994 (Striplin 1988)

GRTS-1: spatially-balanced, generalized random tessellation stratified (GRTS) multi-density survey design based on 0.06 km² grid (Stevens 1997; Stevens and Olsen 1999, 2003, 2004)

GRTS-2: spatially-balanced, generalized random tessellation stratified (GRTS) multi-density survey design based on 0.00184 km² grid (Stevens 1997; Stevens and Olsen 1999, 2003, 2004)

PSAMP/NOAA: NOAA's National Status and Trends program randomly chosen sites within designated polygons or strata (Paul et al. 1992; Hyland et al. 2000).

PSEMP-waters: non-random, co-located with Ecology's long-term marine water column monitoring (Keyzers et al. 2020)

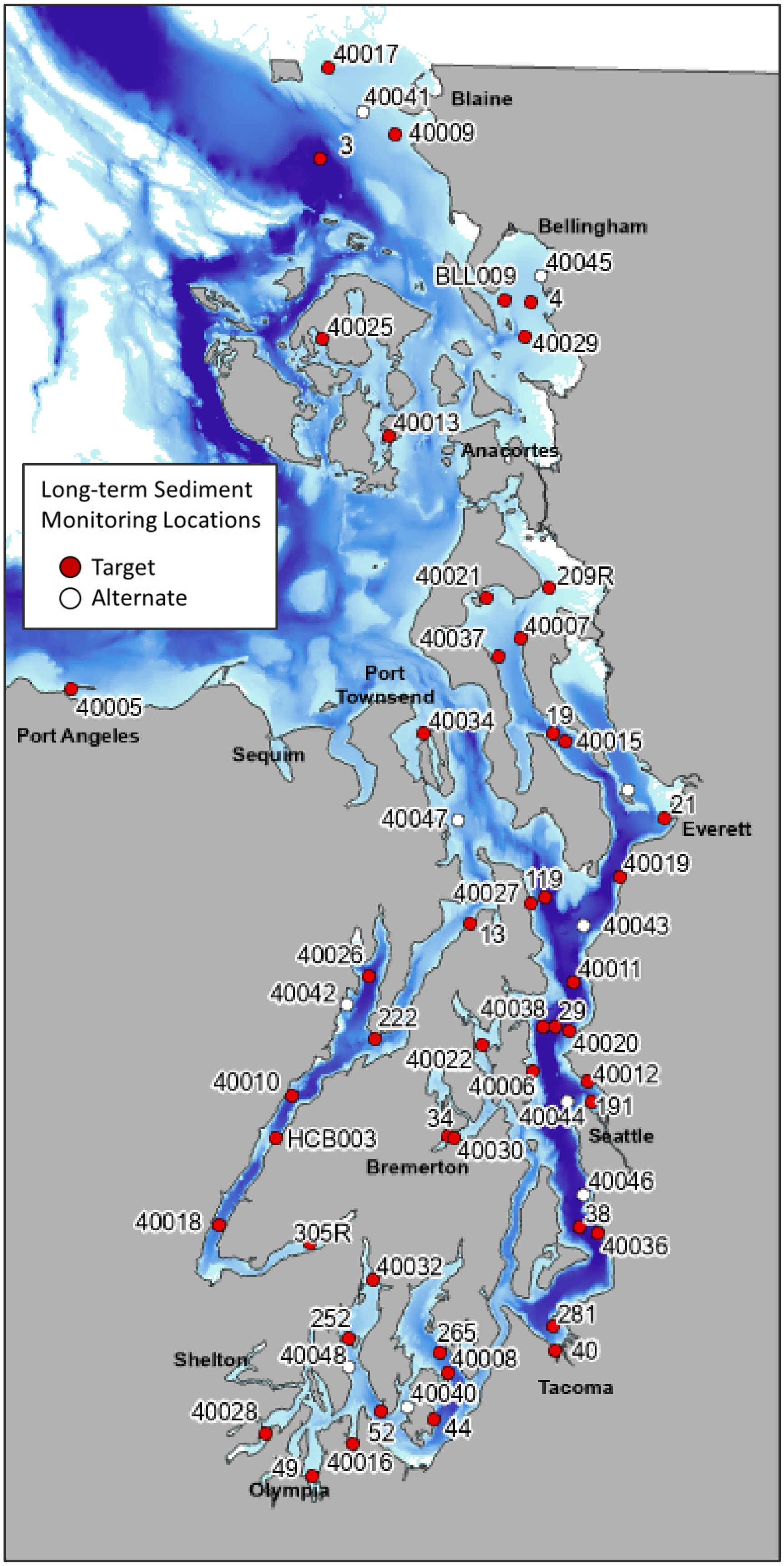

Figure 3. Long-term monitoring station target and alternate locations.

Urban Bays monitoring element

A total of 30 to 36 samples will be collected annually in early June from one of six major urban embayments, based on the schedule below. Funding is currently only available for 2025, Budd Inlet, meaning that additional funding would need to be secured to sample the remaining five urban bays.

- **2025 Budd Inlet:** 12 sites from the GRTS-1 design, 12 sites from the GRTS-2 design, and 6 from the PSAMP/NOAA design
- **2026 East Possession Sound:** 30 sites from the GRTS-2 design
- **2027 Elliott Bay:** 35 sites from the PSAMP/NOAA design and one site from the GRTS-2 design
- **2028 Commencement Bay:** 25 sites from the PSAMP/NOAA design, 1 site from GRTS-1, and 4 from GRTS-2
- **2029 Bainbridge Basin:** 33 sites from the PSAMP/NOAA design
- **2030 Bellingham Bay:** 10 sites from the GRTS-1 design, 5 sites from the GRTS-2 design, and 15 from the PSAMP/NOAA design

Tables 10 – 15 list the monitoring stations, sampling location, and sampling design from which the site originated for each urban bay. Monitoring locations for each urban bay are depicted in Figures 4 – 9.

Bellingham Bay

The sampling design for Bellingham Bay is drawn from a combination of PSAMP/NOAA and the GRTS designs. Most of the previously sampled stations originated in the PSAMP/NOAA design. Therefore, alternate coordinates are chosen from the GRTS-2 design with stratification. All stations are weighted according to which polygon or stratum they are in, summing to a total study area of 41.293 km². Station weights for Bellingham Bay are noted in Table 10.

Table 10. Urban Bay stations for the Bellingham Bay study area.

Polygon ID	Station type (Target or Alternate)	Station	Location	County	Watershed WRIA	Latitude (NAD83HARN)	Longitude (NAD83HARN)	Approx. Depth (m)	Sampling Scheme	Station Weight (km²)
A	Target	40065	Bellingham Bay	Whatcom	Nooksack	48.759030	-122.520720	4	GRTS-2	2.422
A	Target	20	Bellingham Bay	Whatcom	Nooksack	48.737780	-122.607230	9.5	PSAMP/NOAA	2.422
A	Target	21	Bellingham Bay	Whatcom	Nooksack	48.743050	-122.608900	7.6	PSAMP/NOAA	2.422
A	Target	22	Bellingham Bay	Whatcom	Nooksack	48.758330	-122.540280	7	PSAMP/NOAA	2.422
A	Alternate	40033	Bellingham Bay	Whatcom	Nooksack	48.742230	-122.613040	No Data	GRTS-2	
A	Alternate	40449	Bellingham Bay	Whatcom	Nooksack	48.740900	-122.603280	No Data	GRTS-2	
A	Alternate	40577	Bellingham Bay	Whatcom	Nooksack	48.753490	-122.521390	No Data	GRTS-2	
B	Target	23	Bellingham Bay	Whatcom	Nooksack	48.751420	-122.512780	7	PSAMP/NOAA	0.227
B	Target	24	Bellingham Bay	Whatcom	Nooksack	48.752800	-122.510830	5.5	PSAMP/NOAA	0.227
B	Target	25	Bellingham Bay	Whatcom	Nooksack	48.754150	-122.513320	5.5	PSAMP/NOAA	0.227
B	Target	195	Bellingham Bay	Whatcom	Nooksack	48.755210	-122.505140	3	GRTS-1	0.227
B	Target	42113	Bellingham Bay	Whatcom	Nooksack	48.753120	-122.516270	7.5	GRTS-2	0.227
B	Alternate	44161	Bellingham Bay	Whatcom	Nooksack	48.753400	-122.505260	No Data	GRTS-2	
B	Alternate	44289	Bellingham Bay	Whatcom	Nooksack	48.756240	-122.503920	No Data	GRTS-2	
B	Alternate	47233	Bellingham Bay	Whatcom	Nooksack	48.760590	-122.510600	No Data	GRTS-2	
C	Target	32	Bellingham Bay	Whatcom	Nooksack	48.725000	-122.545250	28	PSAMP/NOAA	1.430

Polygon ID	Station type (Target or Alternate)	Station	Location	County	Watershed WRIA	Latitude (NAD83HARN)	Longitude (NAD83HARN)	Approx. Depth (m)	Sampling Scheme	Station Weight (km^2)
C	Target	33	Bellingham Bay	Whatcom	Nooksack	48.716930	-122.545480	29	PSAMP/NOAA	1.430
C	Target	34	Bellingham Bay	Whatcom	Nooksack	48.714730	-122.566450	29	PSAMP/NOAA	1.430
C	Target	35	Bellingham Bay	Whatcom	Nooksack	48.753370	-122.536290	12	GRTS-1	1.430
C	Target	85	Bellingham Bay	Whatcom	Nooksack	48.744140	-122.567410	15	GRTS-1	1.430
C	Target	213	Bellingham Bay	Whatcom	Nooksack	48.724360	-122.566150	26	GRTS-1	1.430
C	Target	227	Bellingham Bay	Whatcom	Nooksack	48.725740	-122.591230	22	GRTS-1	1.430
C	Target	277	Bellingham Bay	Whatcom	Nooksack	48.735900	-122.546210	22	GRTS-1	1.430
C	Target	299	Bellingham Bay	Whatcom	Nooksack	48.738420	-122.591350	12	GRTS-1	1.430
C	Target	40045	Bellingham Bay	Whatcom	Nooksack	48.720490	-122.519200	19	GRTS-2	1.430
C	Target	40205	Bellingham Bay	Whatcom	Nooksack	48.715530	-122.567590	28	GRTS-2	1.430
C	Alternate	40173	Bellingham Bay	Whatcom	Nooksack	48.713960	-122.529460	No Data	GRTS-2	
C	Alternate	40301	Bellingham Bay	Whatcom	Nooksack	48.733780	-122.553760	No Data	GRTS-2	
C	Alternate	40321	Bellingham Bay	Whatcom	Nooksack	48.751110	-122.552090	No Data	GRTS-2	
D	Target	26	Bellingham Bay	Whatcom	Nooksack	48.748050	-122.503880	5	PSAMP/NOAA	0.189
D	Target	27	Bellingham Bay	Whatcom	Nooksack	48.747230	-122.501380	5	PSAMP/NOAA	0.189
D	Target	28	Bellingham Bay	Whatcom	Nooksack	48.749650	-122.490220	3	PSAMP/NOAA	0.189
D	Target	507	Bellingham Bay	Whatcom	Nooksack	48.750320	-122.503740	4.5	GRTS-1	0.189
D	Alternate	41857	Bellingham Bay	Whatcom	Nooksack	48.751560	-122.496870	No Data	GRTS-2	
D	Alternate	45953	Bellingham Bay	Whatcom	Nooksack	48.751750	-122.499790	No Data	GRTS-2	
D	Alternate	48385	Bellingham Bay	Whatcom	Nooksack	48.753190	-122.494290	No Data	GRTS-2	
E	Target	29	Bellingham Bay	Whatcom	Nooksack	48.738620	-122.515280	14	PSAMP/NOAA	1.165
E	Target	59	Bellingham Bay	Whatcom	Nooksack	48.738050	-122.499470	9	PSAMP/NOAA	1.165

Polygon ID	Station type (Target or Alternate)	Station	Location	County	Watershed WRIA	Latitude (NAD83HARN)	Longitude (NAD83HARN)	Approx. Depth (m)	Sampling Scheme	Station Weight (km^2)
E	Target	60	Bellingham Bay	Whatcom	Nooksack	48.734980	-122.499220	8	PSAMP/NOAA	1.165
E	Target	61	Bellingham Bay	Whatcom	Nooksack	48.736350	-122.504700	11	PSAMP/NOAA	1.165
E	Target	163	Bellingham Bay	Whatcom	Nooksack	48.740850	-122.505060	11.5	GRTS-1	1.165
E	Target	40193	Bellingham Bay	Whatcom	Nooksack	48.740720	-122.494625	1.5	GRTS-2	1.165
E	Alternate	40833	Bellingham Bay	Whatcom	Nooksack	48.743460	-122.507220	No Data	GRTS-2	
E	Alternate	42881	Bellingham Bay	Whatcom	Nooksack	48.740900	-122.510610	No Data	GRTS-2	
E	Alternate	43393	Bellingham Bay	Whatcom	Nooksack	48.742910	-122.506280	No Data	GRTS-2	
F	Target	30	Bellingham Bay	Whatcom	Nooksack	48.733280	-122.511130	14	PSAMP/NOAA	2.331
F	Target	31	Bellingham Bay	Whatcom	Nooksack	48.726930	-122.515820	18	PSAMP/NOAA	2.331
F	Target	53	Bellingham Bay	Whatcom	Nooksack	48.722680	-122.514940	12	PSAMP/NOAA	2.331
F	Alternate	42093	Bellingham Bay	Whatcom	Nooksack	48.722090	-122.507950	No Data	GRTS-2	
F	Alternate	43021	Bellingham Bay	Whatcom	Nooksack	48.729890	-122.517970	No Data	GRTS-2	
F	Alternate	44045	Bellingham Bay	Whatcom	Nooksack	48.732440	-122.509090	No Data	GRTS-2	

GRTS-1: spatially-balanced, generalized random tessellation stratified (GRTS) multi-density survey design based on 0.06 km^2 grid (Stevens 1997; Stevens and Olsen 1999, 2003, 2004)

GRTS-2: spatially-balanced, generalized random tessellation stratified (GRTS) multi-density survey design based on 0.00184 km^2 grid (Stevens 1997; Stevens and Olsen 1999, 2003, 2004)

PSAMP/NOAA: NOAA's National Status and Trends program randomly chosen sites within designated polygons or strata (Paul et al. 1992; Hyland et al. 2000).

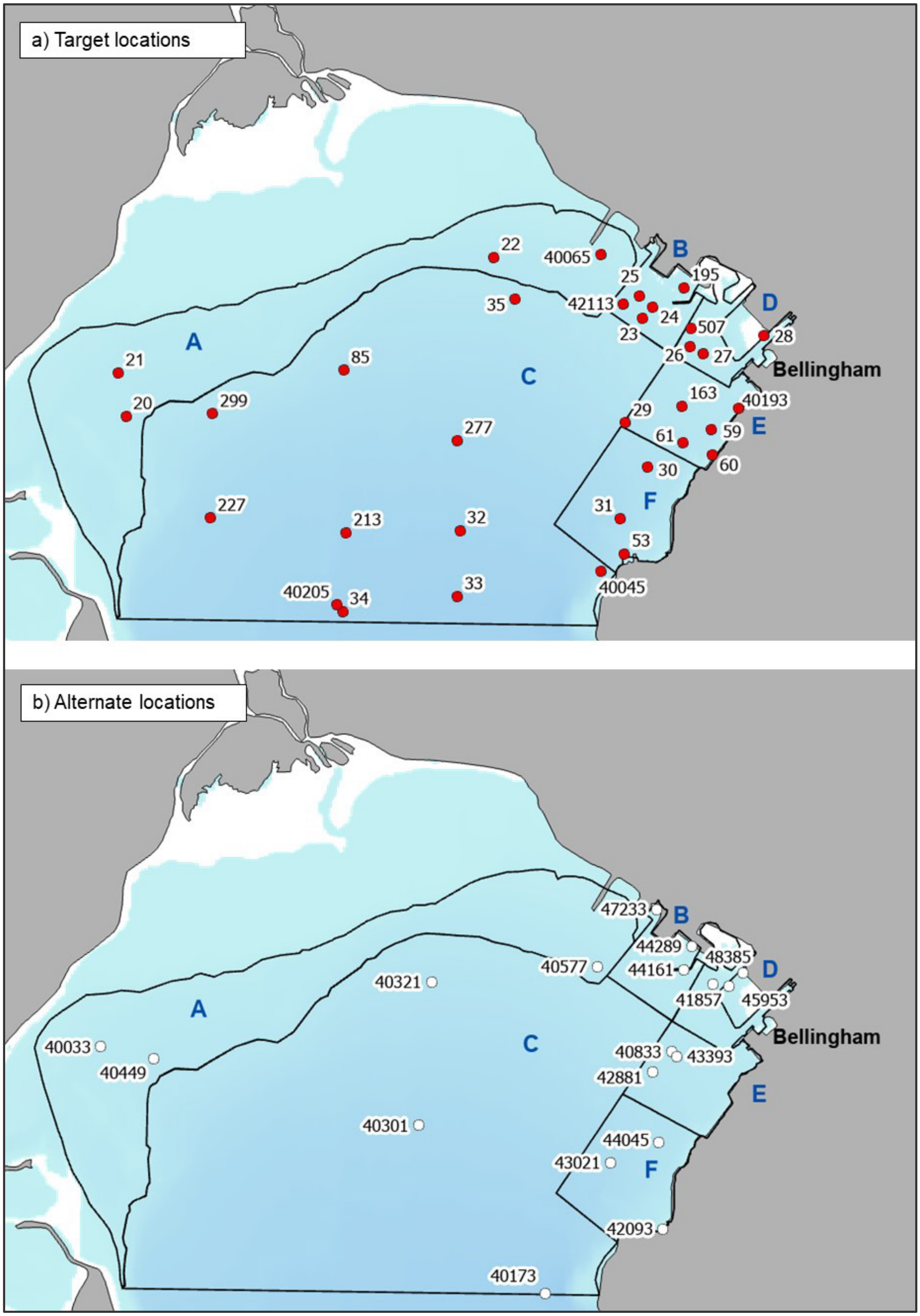

Figure 4. Bellingham Bay sampling frame and monitoring station locations.

East Possession Sound

The sampling design for East Possession Sound is drawn from the GRTS-2 design. Although the intent in 2019 was to resample the same 30 stations from 2012, four stations in the Snohomish Delta could not be resampled. Randomly selected replacements from the GRTS-2 design stations were sampled, resulting in decreased representation of the Snohomish Delta portion of the study area in 2019. Post-sampling, the East Possession Sound study area was stratified into two strata to address the unbalanced representation of the delta. All stations are now weighted according to which stratum they are in, for a total study area of 38.082 km². Station weights for East Possession Sound are noted in Table 11.

Table 11. Urban Bay stations for the East Possession Sound study area.

Polygon ID	Station type (Target or Alternate)	Station	Location	County	Watershed WRIA	Latitude (NAD83HARN)	Longitude (NAD83HARN)	Approx. Depth (m)	Sampling Scheme	Station Weight (km²)
A	Target	40591	Snohomish River Delta	Snohomish	Snohomish	48.008460	-122.261780	2	GRTS-2	1.723
A	Target	41735	Possession Sound	Snohomish	Snohomish	48.022430	-122.272310	3	GRTS-2	1.723
A	Target	42639	Possession Sound	Snohomish	Snohomish	48.015730	-122.268040	3	GRTS-2	1.723
A	Target	42759	Possession Sound	Snohomish	Snohomish	48.023698	-122.278090	15	GRTS-2	1.723
A	Alternate	40023	Snohomish River Delta	Snohomish	Snohomish	48.026590	-122.249860	No Data	GRTS-2	
A	Alternate	40535	Snohomish River Delta	Snohomish	Snohomish	48.037420	-122.223100	No Data	GRTS-2	
A	Alternate	41935	Snohomish River Delta	Snohomish	Snohomish	48.043650	-122.191840	No Data	GRTS-2	
A	Alternate	42071	Snohomish River Delta	Snohomish	Snohomish	48.016850	-122.259230	No Data	GRTS-2	
A	Alternate	42583	Snohomish River Delta	Snohomish	Snohomish	48.027420	-122.234310	No Data	GRTS-2	
B	Target	40079	Port Gardner	Snohomish	Snohomish	47.959910	-122.280590	57.5	GRTS-2	1.200
B	Target	40179	Possession Sound	Snohomish	Snohomish	47.983800	-122.298930	141.5	GRTS-2	1.200
B	Target	40207	Port Gardner	Snohomish	Snohomish	47.975510	-122.237490	94	GRTS-2	1.200
B	Target	40307	Possession Sound	Snohomish	Snohomish	47.978680	-122.297270	142.5	GRTS-2	1.200
B	Target	40335	Possession Sound	Snohomish	Snohomish	48.003290	-122.281790	61	GRTS-2	1.200
B	Target	40455	Possession Sound	Snohomish	Snohomish	48.012560	-122.284950	102	GRTS-2	1.200

Polygon ID	Station type (Target or Alternate)	Station	Location	County	Watershed WRIA	Latitude (NAD83HARN)	Longitude (NAD83HARN)	Approx. Depth (m)	Sampling Scheme	Station Weight (km²)
B	Target	40463	Port Gardner	Snohomish	Snohomish	47.971420	-122.258670	114	GRTS-2	1.200
B	Target	40711	Possession Sound	Snohomish	Snohomish	48.022660	-122.289900	94	GRTS-2	1.200
B	Target	40719	Possession Sound	Snohomish	Snohomish	47.988170	-122.261630	118	GRTS-2	1.200
B	Target	40819	Possession Sound	Snohomish	Snohomish	47.979880	-122.287870	136	GRTS-2	1.200
B	Target	40847	Possession Sound	Snohomish	Snohomish	47.996700	-122.275280	105	GRTS-2	1.200
B	Target	40967	Possession Sound	Snohomish	Snohomish	48.000910	-122.282020	22	GRTS-2	1.200
B	Target	40975	Possession Sound	Snohomish	Snohomish	47.973000	-122.269770	130	GRTS-2	1.200
B	Target	41103	Everett Harbor	Snohomish	Snohomish	47.984500	-122.220210	12	GRTS-2	1.200
B	Target	41223	Possession Sound	Snohomish	Snohomish	48.015780	-122.292390	100	GRTS-2	1.200
B	Target	41231	Everett Harbor	Snohomish	Snohomish	47.981940	-122.225200	11	GRTS-2	1.200
B	Target	41331	Possession Sound	Snohomish	Snohomish	47.977730	-122.280640	129	GRTS-2	1.200
B	Target	41359	Possession Sound	Snohomish	Snohomish	47.993023	-122.292987	137	GRTS-2	1.200
B	Target	41479	Possession Sound	Snohomish	Snohomish	47.994960	-122.294890	40	GRTS-2	1.200
B	Target	41487	Port Gardner	Snohomish	Snohomish	47.964960	-122.264870	108	GRTS-2	1.200
B	Target	41615	Possession Sound	Snohomish	Snohomish	48.012140	-122.277240	97	GRTS-2	1.200
B	Target	41743	Possession Sound	Snohomish	Snohomish	47.984620	-122.248820	61	GRTS-2	1.200
B	Target	41843	Possession Sound	Snohomish	Snohomish	47.971080	-122.293790	148	GRTS-2	1.200
B	Target	41871	Possession Sound	Snohomish	Snohomish	47.987660	-122.289940	140	GRTS-2	1.200
B	Target	42739	Possession Sound	Snohomish	Snohomish	47.990220	-122.297790	140	GRTS-2	1.200
B	Target	42867	Possession Sound	Snohomish	Snohomish	47.964860	-122.297700	160	GRTS-2	1.200
B	Alternate	41999	Possession Sound	Snohomish	Snohomish	47.984920	-122.256620	No Data	GRTS-2	
B	Alternate	42023	Possession Sound	Snohomish	Snohomish	48.037230	-122.281230	No Data	GRTS-2	

Polygon ID	Station type (Target or Alternate)	Station	Location	County	Watershed WRIA	Latitude (NAD83HARN)	Longitude (NAD83HARN)	Approx. Depth (m)	Sampling Scheme	Station Weight (km²)
B	Alternate	42127	Possession Sound	Snohomish	Snohomish	47.961180	-122.273320	No Data	GRTS-2	
B	Alternate	42255	Possession Sound	Snohomish	Snohomish	47.981000	-122.235040	No Data	GRTS-2	
B	Alternate	42355	Possession Sound	Snohomish	Snohomish	47.961410	-122.292400	No Data	GRTS-2	

GRTS-2: spatially-balanced, generalized random tessellation stratified (GRTS) multi-density survey design based on 0.00184 km² grid (Stevens 1997; Stevens and Olsen 1999, 2003, 2004)

PSAMP/NOAA: NOAA's National Status and Trends program randomly chosen sites within designated polygons or strata (Paul et al. 1992; Hyland et al. 2000).

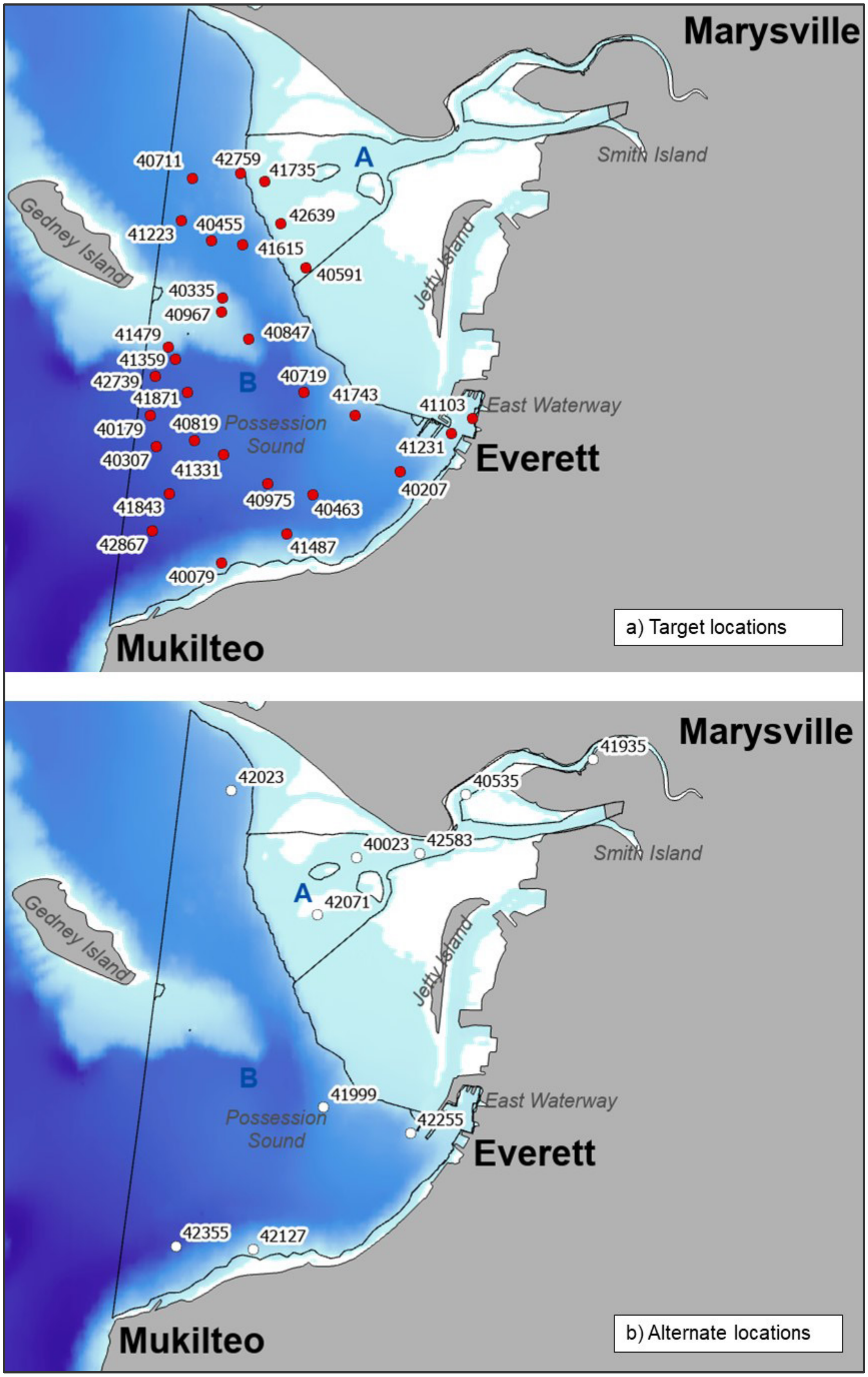

Figure 5. East Possession Sound sampling frame and monitoring station locations.

Elliott Bay

The sampling design for Elliott Bay is drawn from the PSAMP/NOAA design. Therefore, alternate coordinates are chosen from the GRTS-2 design with stratification. All stations are weighted according to which polygon or stratum they are associated with for a total study area of 26.071 km². Station weights for Elliott Bay are noted in Table 12.

Table 12. Urban Bay stations for the Elliott Bay (EB) study area.

Polygon ID	Station type (Target or Alternate)	Station	Location	County	Watershed WRIA	Latitude (NAD83HARN)	Longitude (NAD83HARN)	Approx. Depth (m)	Sampling Scheme	Station Weight (km²)
A	Target	176	Elliott Bay, west of EB Marina	King	Cedar-Sammamish	47.629170	-122.399120	10	PSAMP/NOAA	0.343
A	Target	177	Magnolia Bluff	King	Cedar-Sammamish	47.632355	-122.402750	2.5	PSAMP/NOAA	0.343
A	Target	178	Elliott Bay, south of EB Marina	King	Cedar-Sammamish	47.625798	-122.393560	20.3	PSAMP/NOAA	0.343
A	Alternate	40012	Shoreline Elliott Bay	King	Cedar-Sammamish	47.626540	-122.384690	No Data	GRTS-2	
A	Alternate	45132	Shoreline Elliott Bay	King	Cedar-Sammamish	47.635340	-122.408540	No Data	GRTS-2	
A	Alternate	49100	Shoreline Elliott Bay	King	Cedar-Sammamish	47.634030	-122.406950	No Data	GRTS-2	
B	Target	172	West of Duwamish Head	King	Duwamish-Green	47.594400	-122.412660	152	PSAMP/NOAA	2.777
B	Target	173	Northwest of Duwamish Head	King	Duwamish-Green	47.603738	-122.399365	146	PSAMP/NOAA	2.777
B	Target	174	Southwest of Elliott Bay Marina	King	Cedar-Sammamish	47.624803	-122.399848	40	PSAMP/NOAA	2.777
B	Target	40396	Outer Elliott Bay	King	Cedar-Sammamish	47.621278	-122.397153	60	GRTS-2	2.777

Polygon ID	Station type (Target or Alternate)	Station	Location	County	Watershed WRIA	Latitude (NAD83HARN)	Longitude (NAD83HARN)	Approx. Depth (m)	Sampling Scheme	Station Weight (km^2)
B	Alternate	40556	Outer Elliott Bay	King	Duwamish-Green	47.596240	-122.416350	No Data	GRTS-2	
B	Alternate	40652	Outer Elliott Bay	King	Cedar-Sammamish	47.616980	-122.405280	No Data	GRTS-2	
B	Alternate	40908	Outer Elliott Bay	King	Cedar-Sammamish	47.629210	-122.410530	No Data	GRTS-2	
C	Target	115	Elliott Bay, east side Pier 90	King	Cedar-Sammamish	47.628108	-122.379380	9.5	PSAMP/NOAA	0.337
C	Target	179	Elliott Bay, west of Pier 86	King	Cedar-Sammamish	47.623943	-122.374080	24.5	PSAMP/NOAA	0.337
C	Target	180	Elliott Bay, south of Pier 89-90	King	Cedar-Sammamish	47.624815	-122.378680	20.5	PSAMP/NOAA	0.337
C	Target	181	Elliott Bay, west of Piers 70-71	King	Cedar-Sammamish	47.615033	-122.362300	34.3	PSAMP/NOAA	0.337
C	Alternate	41036	Shoreline Elliott Bay	King	Cedar-Sammamish	47.631420	-122.379640	No Data	GRTS-2	
C	Alternate	43444	Shoreline Elliott Bay	King	Cedar-Sammamish	47.624740	-122.372410	No Data	GRTS-2	
C	Alternate	43828	Shoreline Elliott Bay	King	Cedar-Sammamish	47.610940	-122.350360	No Data	GRTS-2	
D	Target	185	North of Duwamish Head	King	Cedar-Sammamish	47.609983	-122.382020	157	PSAMP/NOAA	1.062
D	Target	186	Elliott Bay, west. of Denny Way	King	Cedar-Sammamish	47.618178	-122.365360	35.5	PSAMP/NOAA	1.062

Polygon ID	Station type (Target or Alternate)	Station	Location	County	Watershed WRIA	Latitude (NAD83HARN)	Longitude (NAD83HARN)	Approx. Depth (m)	Sampling Scheme	Station Weight (km²)
D	Target	187	Elliott Bay, west of Pier 59	King	Cedar-Sammamish	47.607180	-122.359020	103	PSAMP/NOAA	1.062
D	Target	188	Elliott Bay, west of Pier 57	King	Cedar-Sammamish	47.606030	-122.343890	32.5	PSAMP/NOAA	1.062
D	Alternate	40372	Mid Elliott Bay	King	Cedar-Sammamish	47.621610	-122.384040	No Data	GRTS-2	
D	Alternate	40884	Mid Elliott Bay	King	Cedar-Sammamish	47.615540	-122.368170	No Data	GRTS-2	
D	Alternate	41396	Mid Elliott Bay	King	Cedar-Sammamish	47.613160	-122.383570	No Data	GRTS-2	
E	Target	182	Elliott Bay, west of Pier 54	King	Cedar-Sammamish	47.604192	-122.344160	32	PSAMP/NOAA	0.118
E	Target	183	Elliott Bay, Pier 54	King	Cedar-Sammamish	47.603998	-122.340390	14	PSAMP/NOAA	0.118
E	Target	184	Elliott Bay, Pier 55	King	Cedar-Sammamish	47.604670	-122.340980	15.5	PSAMP/NOAA	0.118
E	Alternate	45876	Shoreline Elliott Bay	King	Cedar-Sammamish	47.608140	-122.344700	No Data	GRTS-2	
E	Alternate	54964	Shoreline Elliott Bay	King	Cedar-Sammamish	47.603350	-122.340620	No Data	GRTS-2	
E	Alternate	60212	Shoreline Elliott Bay	King	Cedar-Sammamish	47.609670	-122.347610	No Data	GRTS-2	
F	Target	189	Elliott Bay, east of Duwamish Head	King	Duwamish-Green	47.590513	-122.380505	14.5	PSAMP/NOAA	0.704

Polygon ID	**Station type** (Target or Alternate)	**Station**	**Location**	**County**	**Watershed WRIA**	**Latitude** (NAD83HARN)	**Longitude** (NAD83HARN)	**Approx. Depth (m)**	**Sampling Scheme**	**Station Weight (km²)**
F	Target	190	Elliott Bay, Duwamish Head	King	Duwamish-Green	47.597160	-122.385080	7	PSAMP/NOAA	0.704
F	Target	191	Elliott Bay, east of Duwamish Head	King	Duwamish-Green	47.598420	-122.375810	97	PSAMP/NOAA	0.704
F	Target	192	Elliott Bay, Central	King	Duwamish-Green	47.602270	-122.365950	67	PSAMP/NOAA	0.704
F	Alternate	40244	Mid Elliott Bay	King	Duwamish-Green	47.592450	-122.368940	No Data	GRTS-2	
F	Alternate	40628	Mid Elliott Bay	King	Duwamish-Green	47.602420	-122.366510	No Data	GRTS-2	
F	Alternate	41268	Mid Elliott Bay	King	Duwamish-Green	47.596660	-122.379880	No Data	GRTS-2	
G	Target	193	Elliott Bay, west of Pier 48	King	Duwamish-Green	47.599965	-122.354230	78	PSAMP/NOAA	0.726
G	Target	194	Elliott Bay, west of Pier 48	King	Cedar-Sammamish	47.600253	-122.347308	66.5	PSAMP/NOAA	0.726
G	Target	195	Elliott Bay, Bay Center, west of Pier 48	King	Duwamish-Green	47.599578	-122.361030	75	PSAMP/NOAA	0.726
G	Target	196	Elliott Bay, west of Yesler Way	King	Cedar-Sammamish	47.601218	-122.349650	71.6	PSAMP/NOAA	0.726
G	Alternate	41140	Mid Elliott Bay	King	Duwamish-Green	47.595920	-122.349420	No Data	GRTS-2	
G	Alternate	41652	Mid Elliott Bay	King	Duwamish-Green	47.593430	-122.361720	No Data	GRTS-2	

Polygon ID	**Station type** (Target or Alternate)	**Station**	**Location**	**County**	**Watershed WRIA**	**Latitude** (NAD83HARN)	**Longitude** (NAD83HARN)	**Approx. Depth (m)**	**Sampling Scheme**	**Station Weight (km²)**
G	Alternate	42164	Mid Elliott Bay	King	Duwamish-Green	47.598580	-122.352430	No Data	GRTS-2	
H	Target	198	Elliott Bay, south	King	Duwamish-Green	47.588208	-122.366555	47	PSAMP/NOAA	0.267
H	Target	114	West Waterway, Terminal 5	King	Duwamish-Green	47.575445	-122.360705	20	PSAMP/NOAA	0.267
H	Target	197	Elliott Bay, south Pier 4	King	Duwamish-Green	47.586370	-122.363738	24.4	PSAMP/NOAA	0.267
H	Target	199	Elliott Bay, South just west of Pier 4	King	Duwamish-Green	47.586665	-122.365030	30.3	PSAMP/NOAA	0.267
H	Alternate	42804	West Harbor Island	King	Duwamish-Green	47.586720	-122.364390	No Data	GRTS-2	
H	Alternate	46900	West Harbor Island	King	Duwamish-Green	47.584180	-122.358980	No Data	GRTS-2	
H	Alternate	49972	West Harbor Island	King	Duwamish-Green	47.574430	-122.359020	No Data	GRTS-2	
I	Target	200	East Waterway, Terminal 18	King	Duwamish-Green	47.584643	-122.345790	16.3	PSAMP/NOAA	0.177
I	Target	201	East Waterway, Pier 32	King	Duwamish-Green	47.582618	-122.343445	16.75	PSAMP/NOAA	0.177
I	Target	202	East Waterway, south end	King	Duwamish-Green	47.574320	-122.343328	17.5	PSAMP/NOAA	0.177
I	Alternate	40756	East Harbor Island	King	Duwamish-Green	47.580670	-122.344520	No Data	GRTS-2	

Polygon ID	**Station type** (Target or Alternate)	**Station**	**Location**	**County**	**Watershed WRIA**	**Latitude** (NAD83HARN)	**Longitude** (NAD83HARN)	**Approx. Depth (m)**	**Sampling Scheme**	**Station Weight (km²)**
I	Alternate	44588	East Harbor Island	King	Duwamish-Green	47.569690	-122.344140	No Data	GRTS-2	
I	Alternate	44724	East Harbor Island	King	Duwamish-Green	47.591310	-122.343270	No Data	GRTS-2	
J	Target	203	Duwamish River, north	King	Duwamish-Green	47.561400	-122.347435	12.5	PSAMP/NOAA	0.222
J	Target	204	Duwamish River, north	King	Duwamish-Green	47.560923	-122.345088	7.1	PSAMP/NOAA	0.222
J	Target	205	Duwamish River, Southwest of Slip 2	King	Duwamish-Green	47.545110	-122.336870	9.25	PSAMP/NOAA	0.222
J	Alternate	40492	Duwamish Waterway	King	Duwamish-Green	47.540080	-122.329390	No Data	GRTS-2	
J	Alternate	42540	Duwamish Waterway	King	Duwamish-Green	47.560320	-122.348400	No Data	GRTS-2	
J	Alternate	52780	Duwamish Waterway	King	Duwamish-Green	47.557890	-122.344370	No Data	GRTS-2	

GRTS-2: spatially-balanced, generalized random tessellation stratified (GRTS) multi-density survey design based on 0.00184 km² grid (Stevens 1997; Stevens and Olsen 1999, 2003, 2004)

PSAMP/NOAA: NOAA's National Status and Trends program randomly chosen sites within designated polygons or strata (Paul et al. 1992; Hyland et al. 2000).

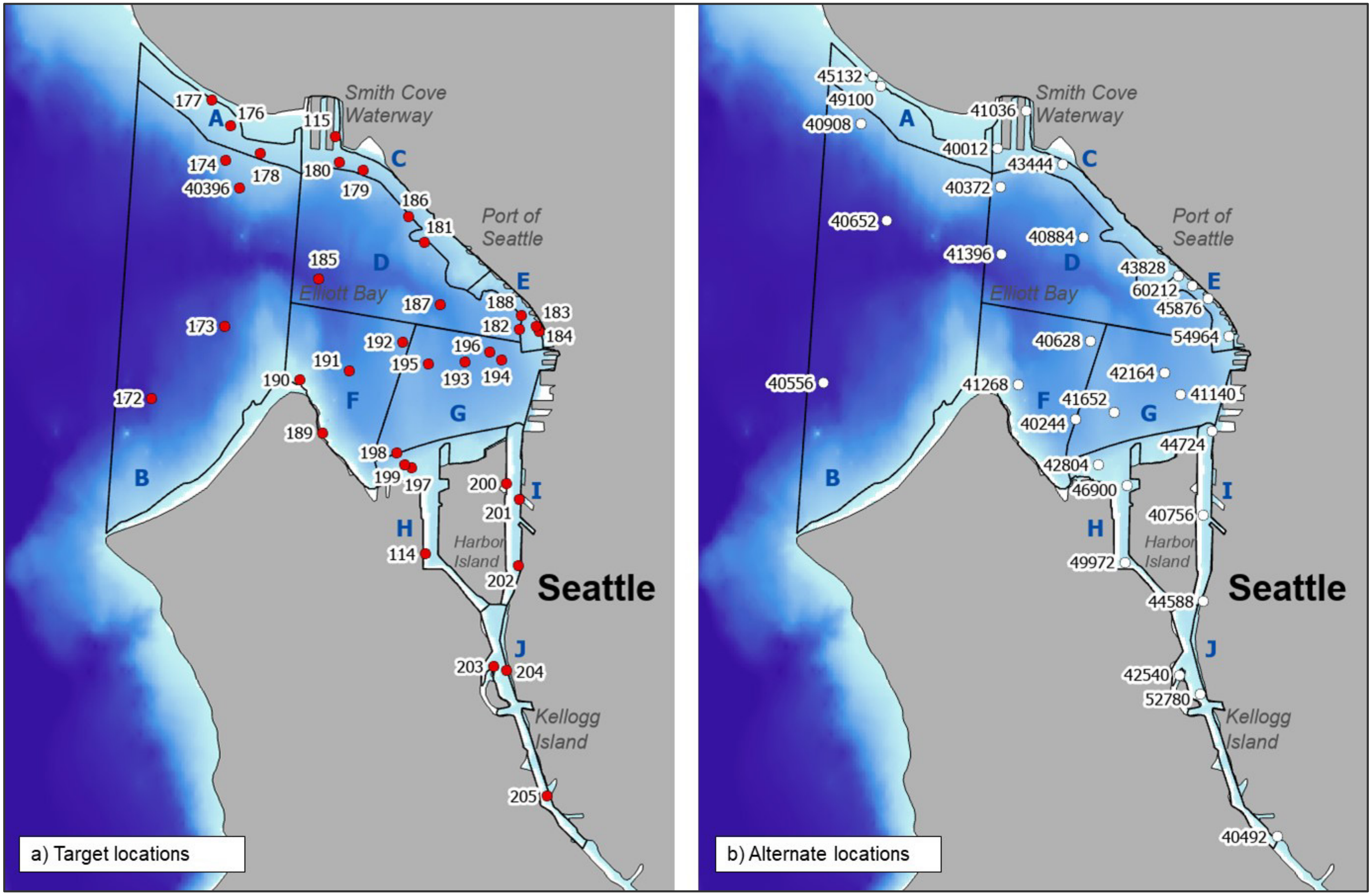

Figure 6. Elliott Bay sampling frame and monitoring station locations.

Bainbridge Basin

The Bainbridge Basin study area encompasses 81.853 km². The sampling design for the basin is drawn from the PSAMP/NOAA design. Alternate coordinates are chosen from the GRTS-2 design with stratification. All stations are weighted according to which polygon or stratum they are associated with. Station weights for the Bainbridge Basin are noted in Table 13.

Table 13. Urban Bay stations for the Bainbridge Basin study area.

Polygon ID	Station type (Target or Alternate)	Station	Location	County	Watershed WRIA	Latitude (NAD83HARN)	Longitude (NAD83HARN)	Approx. Depth (m)	Sampling Scheme	Station Weight (km²)
A	Target	124	Port Madison	Kitsap	Kitsap	47.713818	-122.527320	28	PSAMP/NOAA	5.558
A	Target	125	Port Madison	Kitsap	Kitsap	47.733040	-122.537250	38	PSAMP/NOAA	5.558
A	Target	126	Port Madison	Kitsap	Kitsap	47.726022	-122.530480	42	PSAMP/NOAA	5.558
A	Alternate	40075	Port Madison	Kitsap	Kitsap	47.743390	-122.494420	No Data	GRTS-2	
A	Alternate	40102	Port Madison	Kitsap	Kitsap	47.725600	-122.510910	No Data	GRTS-2	
A	Alternate	40230	Port Madison	Kitsap	Kitsap	47.723270	-122.545740	No Data	GRTS-2	
B	Target	142	Liberty Bay	Kitsap	Kitsap	47.723160	-122.647020	5	PSAMP/NOAA	0.623
B	Target	143	Liberty Bay	Kitsap	Kitsap	47.720342	-122.648990	3	PSAMP/NOAA	0.623
B	Target	144	Liberty Bay	Kitsap	Kitsap	47.721818	-122.642105	10	PSAMP/NOAA	0.623
B	Alternate	40326	Liberty Bay	Kitsap	Kitsap	47.716470	-122.643900	No Data	GRTS-2	
B	Alternate	41206	Liberty Bay	Kitsap	Kitsap	47.732970	-122.654300	No Data	GRTS-2	
B	Alternate	41350	Liberty Bay	Kitsap	Kitsap	47.730680	-122.650470	No Data	GRTS-2	
C	Target	145	Liberty Bay	Kitsap	Kitsap	47.714690	-122.629300	4	PSAMP/NOAA	0.986
C	Target	146	Liberty Bay	Kitsap	Kitsap	47.719400	-122.641285	8	PSAMP/NOAA	0.986

Polygon ID	Station type (Target or Alternate)	Station	Location	County	Watershed WRIA	Latitude (NAD83HARN)	Longitude (NAD83HARN)	Approx. Depth (m)	Sampling Scheme	Station Weight (km²)
C	Target	147	Liberty Bay	Kitsap	Kitsap	47.706498	-122.635540	4	PSAMP/NOAA	0.986
C	Alternate	40198	Liberty Bay	Kitsap	Kitsap	47.719330	-122.627860	No Data	GRTS-2	
C	Alternate	42246	Liberty Bay	Kitsap	Kitsap	47.708670	-122.615830	No Data	GRTS-2	
C	Alternate	42886	Liberty Bay	Kitsap	Kitsap	47.706150	-122.611470	No Data	GRTS-2	
D	Target	148	Southeast of Keyport	Kitsap	Kitsap	47.692928	-122.610110	13	PSAMP/NOAA	4.320
D	Target	149	North Port Orchard Point Bolin	Kitsap	Kitsap	47.688762	-122.588940	6	PSAMP/NOAA	4.320
D	Target	150	North Port Orchard	Kitsap	Kitsap	47.681230	-122.585490	19	PSAMP/NOAA	4.320
D	Alternate	40022	North Port Orchard	Kitsap	Kitsap	47.671370	-122.604850	No Data	GRTS-2	
D	Alternate	40278	North Port Orchard	Kitsap	Kitsap	47.676580	-122.606990	No Data	GRTS-2	
D	Alternate	40454	North Port Orchard	Kitsap	Kitsap	47.688110	-122.572550	No Data	GRTS-2	
E	Target	151	North Port Orchard east of Brownsville	Kitsap	Kitsap	47.649428	-122.603480	19	PSAMP/NOAA	3.400
E	Target	152	Port Orchard Illahee	Kitsap	Kitsap	47.602370	-122.589060	26	PSAMP/NOAA	3.400
E	Target	153	Port Orchard	Kitsap	Kitsap	47.625812	-122.581298	36	PSAMP/NOAA	3.400
E	Alternate	40070	Port Orchard	Kitsap	Kitsap	47.625650	-122.587030	No Data	GRTS-2	
E	Alternate	40110	Port Orchard Illahee	Kitsap	Kitsap	47.602620	-122.586400	No Data	GRTS-2	
E	Alternate	40534	North Port Orchard east of Brownsville	Kitsap	Kitsap	47.648430	-122.603820	No Data	GRTS-2	

Polygon ID	Station type (Target or Alternate)	Station	Location	County	Watershed WRIA	Latitude (NAD83HARN)	Longitude (NAD83HARN)	Approx. Depth (m)	Sampling Scheme	Station Weight (km²)
F	Target	169	Dyes Inlet southeast of Silverdale	Kitsap	Kitsap	47.635728	-122.679080	6	PSAMP/NOAA	3.891
F	Target	170	Dyes Inlet North Chico Bay	Kitsap	Kitsap	47.613075	-122.701320	13	PSAMP/NOAA	3.891
F	Target	171	Dyes Inlet	Kitsap	Kitsap	47.627382	-122.691895	12	PSAMP/NOAA	3.891
F	Alternate	40154	Dyes Inlet	Kitsap	Kitsap	47.616720	-122.699010	No Data	GRTS-2	
F	Alternate	40282	Dyes Inlet	Kitsap	Kitsap	47.639900	-122.697190	No Data	GRTS-2	
F	Alternate	40430	Dyes Inlet	Kitsap	Kitsap	47.610920	-122.677320	No Data	GRTS-2	
G	Target	166	Dyes Inlet Tracyton	Kitsap	Kitsap	47.608898	-122.663430	17	PSAMP/NOAA	1.062
G	Target	167	Phinney Bay	Kitsap	Kitsap	47.584720	-122.663030	9	PSAMP/NOAA	1.062
G	Target	168	Phinney Bay	Kitsap	Kitsap	47.588352	-122.659960	27	PSAMP/NOAA	1.062
G	Alternate	40174	Port Washington Narrows	Kitsap	Kitsap	47.598570	-122.657260	No Data	GRTS-2	
G	Alternate	40750	Port Washington Narrows	Kitsap	Kitsap	47.579880	-122.639010	No Data	GRTS-2	
G	Alternate	41198	Port Washington Narrows	Kitsap	Kitsap	47.584690	-122.648370	No Data	GRTS-2	
H	Target	154	Rich Passage Pleasant Beach	Kitsap	Kitsap	47.593422	-122.537360	8	PSAMP/NOAA	3.335
H	Target	155	Rich Passage Lynwood Center	Kitsap	Kitsap	47.600570	-122.553790	8	PSAMP/NOAA	3.335
H	Target	156	South Port Orchard	Kitsap	Kitsap	47.579190	-122.584095	47	PSAMP/NOAA	3.335

Polygon ID	Station type (Target or Alternate)	Station	Location	County	Watershed WRIA	Latitude (NAD83HARN)	Longitude (NAD83HARN)	Approx. Depth (m)	Sampling Scheme	Station Weight (km²)
H	Alternate	40238	Rich Passage	Kitsap	Kitsap	47.590400	-122.561230	No Data	GRTS-2	
H	Alternate	40366	Rich Passage	Kitsap	Kitsap	47.594280	-122.543790	No Data	GRTS-2	
H	Alternate	40622	Rich Passage	Kitsap	Kitsap	47.576930	-122.532170	No Data	GRTS-2	
I	Target	157	South Port Orchard East Bremerton	Kitsap	Kitsap	47.569060	-122.602330	22	PSAMP/NOAA	1.978
I	Target	158	South Port Orchard	Kitsap	Kitsap	47.569502	-122.587315	10	PSAMP/NOAA	1.978
I	Target	159	South Port Orchard Point Herron	Kitsap	Kitsap	47.566195	-122.610910	14	PSAMP/NOAA	1.978
I	Alternate	41006	South Port Orchard Point Herron	Kitsap	Kitsap	47.560820	-122.613130	No Data	GRTS-2	
I	Alternate	41054	South Port Orchard Point Herron	Kitsap	Kitsap	47.551280	-122.619080	No Data	GRTS-2	
I	Alternate	41518	South Port Orchard Point Herron	Kitsap	Kitsap	47.550290	-122.606300	No Data	GRTS-2	
J	Target	163	Sinclair Inlet	Kitsap	Kitsap	47.545702	-122.654090	12	PSAMP/NOAA	1.126
J	Target	164	Sinclair Inlet	Kitsap	Kitsap	47.549008	-122.665350	8	PSAMP/NOAA	1.126
J	Target	165	Sinclair Inlet	Kitsap	Kitsap	47.547245	-122.666428	10	PSAMP/NOAA	1.126
J	Alternate	40494	Sinclair Inlet	Kitsap	Kitsap	47.552130	-122.638910	No Data	GRTS-2	
J	Alternate	41262	Sinclair Inlet	Kitsap	Kitsap	47.542820	-122.667240	No Data	GRTS-2	
J	Alternate	41774	Sinclair Inlet	Kitsap	Kitsap	47.557990	-122.628570	No Data	GRTS-2	
K	Target	160	Sinclair Inlet	Kitsap	Kitsap	47.534238	-122.676885	8	PSAMP/NOAA	1.005

Polygon ID	Station type (Target or Alternate)	Station	Location	County	Watershed WRIA	Latitude (NAD83HARN)	Longitude (NAD83HARN)	Approx. Depth (m)	Sampling Scheme	Station Weight (km²)
K	Target	161	Sinclair Inlet	Kitsap	Kitsap	47.543710	-122.641488	13	PSAMP/NOAA	1.005
K	Target	162	Sinclair Inlet	Kitsap	Kitsap	47.547243	-122.641488	13	PSAMP/NOAA	1.005
K	Alternate	40030	Sinclair Inlet	Kitsap	Kitsap	47.545000	-122.651020	No Data	GRTS-2	
K	Alternate	40542	Sinclair Inlet	Kitsap	Kitsap	47.535870	-122.673550	No Data	GRTS-2	
K	Alternate	42078	Sinclair Inlet	Kitsap	Kitsap	47.542330	-122.652410	No Data	GRTS-2	

PSAMP/NOAA: NOAA's National Status and Trends program randomly chosen sites within designated polygons or strata (Paul et al. 1992; Hyland et al. 2000).

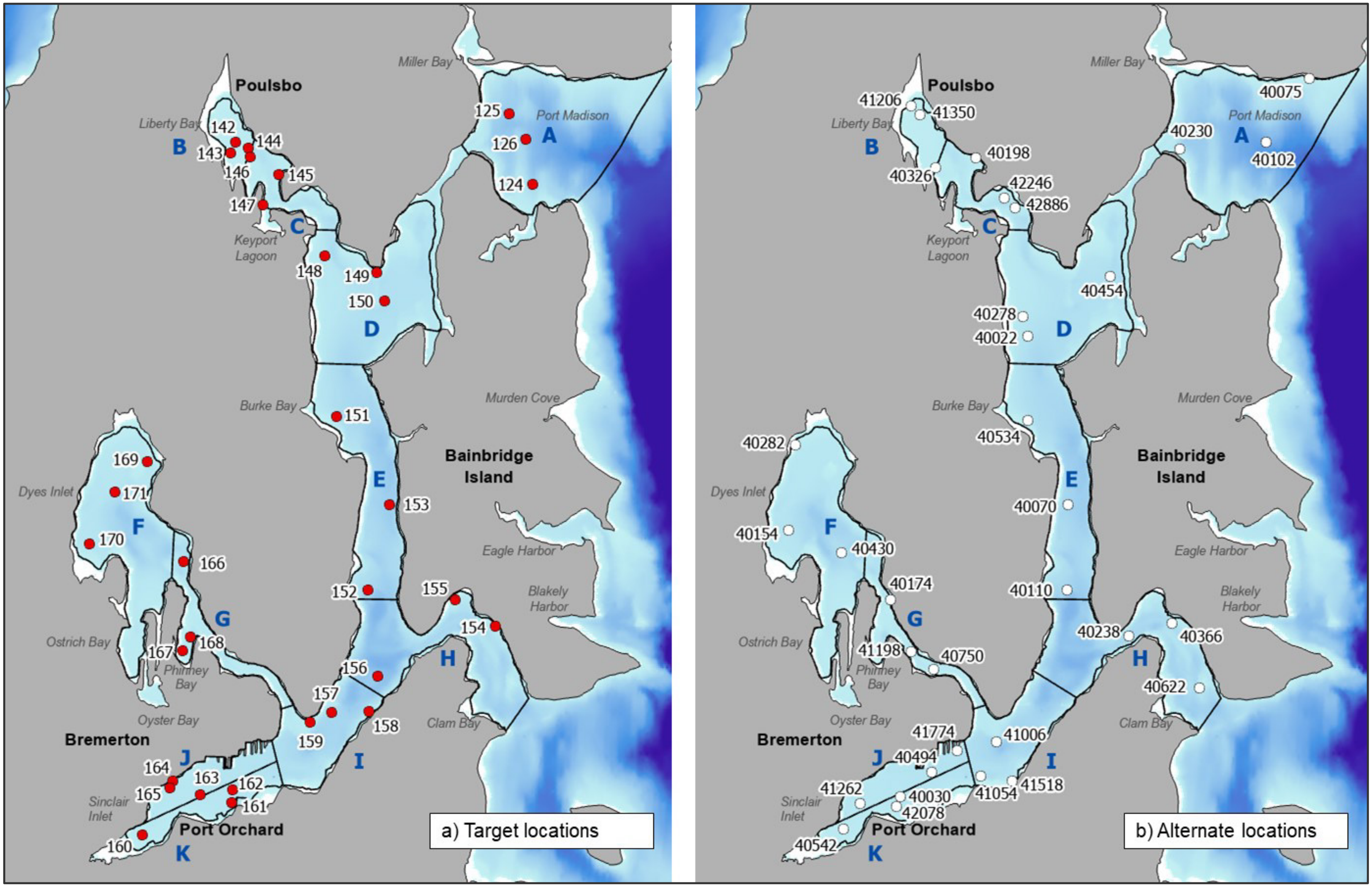

Figure 7. Bainbridge Basin sampling frame and monitoring station locations.

Commencement Bay

The sampling design for Commencement Bay is drawn from the PSAMP/NOAA design. Therefore, alternate coordinates are chosen from the GRTS-2 design with stratification. All stations are weighted according to which polygon or stratum they are associated with for a total study area of 24.059 km². Station weights for Commencement Bay are noted in Table 14.

Table 14. Urban Bay stations for the Commencement Bay study area.

Polygon ID	**Station type** (Target or Alternate)	**Station**	**Location**	**County**	**Watershed WRIA**	**Latitude** (NAD83HARN)	**Longitude** (NAD83HARN)	**Approx. Depth (m)**	**Sampling Scheme**	**Station Weight (km²)**
A	Target	222	Southeast Commencement Bay	Pierce	Puyallup-White	47.304938	-122.474542	176	GRTS-1	1.851
A	Target	281	Southeast Commencement Bay	Pierce	Puyallup-White	47.292286	-122.441920	144	PSAMP/NOAA	1.851
A	Target	282	Southeast Commencement Bay	Pierce	Chambers-Clover	47.285005	-122.464878	154	PSAMP/NOAA	1.851
A	Target	283	Southeast Commencement Bay	Pierce	Puyallup-White	47.305116	-122.456870	172	PSAMP/NOAA	1.851
A	Target	284	Southeast Commencement Bay	Pierce	Chambers-Clover	47.307718	-122.482145	170	PSAMP/NOAA	1.851
A	Target	318	Southeast Commencement Bay	Pierce	Chambers-Clover	47.288886	-122.464605	158	GRTS-2	1.851
A	Target	380	Southeast Commencement Bay	Pierce	Chambers-Clover	47.297450	-122.487524	146	GRTS-2	1.851

Polygon ID	Station type (Target or Alternate)	Station	Location	County	Watershed WRIA	Latitude (NAD83HARN)	Longitude (NAD83HARN)	Approx. Depth (m)	Sampling Scheme	Station Weight (km²)
A	Alternate	40574	Southeast Commencement Bay	Pierce	Chambers-Clover	47.293690	-122.467560	No Data	GRTS-2	
A	Alternate	40600	Southeast Commencement Bay	Pierce	Chambers-Clover	47.278790	-122.459120	No Data	GRTS-2	
A	Alternate	40862	Southeast Commencement Bay	Pierce	Puyallup-White	47.303810	-122.467060	No Data	GRTS-2	
B	Target	285	Southeast Commencement Bay	Pierce	Chambers-Clover	47.279041	-122.469893	21	PSAMP/NOAA	0.786
B	Target	286	Southeast Commencement Bay	Pierce	Chambers-Clover	47.284871	-122.472073	110	PSAMP/NOAA	0.786
B	Target	287	South Shoreline Commencement Bay	Pierce	Puyallup-White	47.269555	-122.447010	33	PSAMP/NOAA	0.786
B	Alternate	41404	Southeast Commencement Bay	Pierce	Chambers-Clover	47.291680	-122.486230	No Data	GRTS-2	
B	Alternate	43160	Southeast Commencement Bay	Pierce	Chambers-Clover	47.280170	-122.471220	No Data	GRTS-2	
B	Alternate	43708	Southeast Commencement Bay	Pierce	Chambers-Clover	47.285520	-122.472730	No Data	GRTS-2	

Polygon ID	Station type (Target or Alternate)	Station	Location	County	Watershed WRIA	Latitude (NAD83HARN)	Longitude (NAD83HARN)	Approx. Depth (m)	Sampling Scheme	Station Weight (km²)
C	Target	88	East Commencement Bay	Pierce	Puyallup-White	47.278353	-122.424779	61	GRTS-2	0.791
C	Target	288	Southeast Commencement Bay	Pierce	Puyallup-White	47.279333	-122.439961	98	PSAMP/NOAA	0.791
C	Target	289	Southeast Commencement Bay	Pierce	Chambers-Clover	47.277466	-122.450973	122	PSAMP/NOAA	0.791
C	Target	290	Southeast Commencement Bay	Pierce	Puyallup-White	47.280666	-122.447410	120	PSAMP/NOAA	0.791
C	Alternate	41028	Southeast Commencement Bay	Pierce	Puyallup-White	47.275490	-122.425410	No Data	GRTS-2	
C	Alternate	41112	Southeast Commencement Bay	Pierce	Puyallup-White	47.280750	-122.435880	No Data	GRTS-2	
C	Alternate	41944	Southeast Commencement Bay	Pierce	Puyallup-White	47.269130	-122.434570	No Data	GRTS-2	
D	Target	4	Northeast Commencement Bay	Pierce	Puyallup-White	47.283060	-122.411900	12	GRTS-2	0.831
D	Target	291	Northeast Commencement Bay	Pierce	Puyallup-White	47.287868	-122.430570	93	PSAMP/NOAA	0.831

Polygon ID	Station type (Target or Alternate)	Station	Location	County	Watershed WRIA	Latitude (NAD83HARN)	Longitude (NAD83HARN)	Approx. Depth (m)	Sampling Scheme	Station Weight (km²)
D	Target	292	Northeast Commencement Bay	Pierce	Puyallup-White	47.292133	-122.419880	24	PSAMP/NOAA	0.831
D	Target	293	Northeast Commencement Bay	Pierce	Puyallup-White	47.296933	-122.429278	12	PSAMP/NOAA	0.831
D	Alternate	40830	Southeast Commencement Bay	Pierce	Puyallup-White	47.286590	-122.415130	No Data	GRTS-2	
D	Alternate	42052	Southeast Commencement Bay	Pierce	Puyallup-White	47.285320	-122.419190	No Data	GRTS-2	
D	Alternate	42366	Southeast Commencement Bay	Pierce	Puyallup-White	47.283090	-122.425310	No Data	GRTS-2	
E	Target	294	Thea Foss Waterway	Pierce	Puyallup-White	47.249161	-122.431663	3	PSAMP/NOAA	0.126
E	Target	295	Thea Foss Waterway	Pierce	Puyallup-White	47.258048	-122.434440	12	PSAMP/NOAA	0.126
E	Target	296	Thea Foss Waterway	Pierce	Puyallup-White	47.258856	-122.435090	13	PSAMP/NOAA	0.126
E	Alternate	48792	Southeast Commencement Bay	Pierce	Puyallup-White	47.243100	-122.430360	No Data	GRTS-2	
E	Alternate	52888	Southeast Commencement Bay	Pierce	Puyallup-White	47.258420	-122.435310	No Data	GRTS-2	

Polygon ID	Station type (Target or Alternate)	Station	Location	County	Watershed WRIA	Latitude (NAD83HARN)	Longitude (NAD83HARN)	Approx. Depth (m)	Sampling Scheme	Station Weight (km²)
E	Alternate	61080	Southeast Commencement Bay	Pierce	Puyallup-White	47.262300	-122.436280	No Data	GRTS-2	
F	Target	297	Middle Waterway	Pierce	Puyallup-White	47.265278	-122.433330	13	PSAMP/NOAA	0.016
F	Target	298	Middle Waterway	Pierce	Puyallup-White	47.264583	-122.433471	8	PSAMP/NOAA	0.016
F	Target	299	Middle Waterway	Pierce	Puyallup-White	47.264305	-122.432778	12	PSAMP/NOAA	0.016
F	Alternate	99992	Southeast Commencement Bay	Pierce	Puyallup-White	47.263430	-122.430770	No Data	GRTS-2	
F	Alternate	116376	Southeast Commencement Bay	Pierce	Puyallup-White	47.261420	-122.429400	No Data	GRTS-2	
F	Alternate	149144	Southeast Commencement Bay	Pierce	Puyallup-White	47.264920	-122.432890	No Data	GRTS-2	
G	Target	300	Blair Waterway	Pierce	Puyallup-White	47.262173	-122.388040	18	PSAMP/NOAA	0.387
G	Target	301	Blair Waterway	Pierce	Puyallup-White	47.261965	-122.387280	18	PSAMP/NOAA	0.387
G	Target	302	Blair Waterway	Pierce	Puyallup-White	47.258420	-122.381210	18	PSAMP/NOAA	0.387
G	Alternate	42648	Southeast Commencement Bay	Pierce	Puyallup-White	47.270080	-122.418200	No Data	GRTS-2	
G	Alternate	46142	Southeast Commencement Bay	Pierce	Puyallup-White	47.262940	-122.387380	No Data	GRTS-2	

Polygon ID	Station type (Target or Alternate)	Station	Location	County	Watershed WRIA	Latitude (NAD83HARN)	Longitude (NAD83HARN)	Approx. Depth (m)	Sampling Scheme	Station Weight (km²)
G	Alternate	46148	Southeast Commencement Bay	Pierce	Puyallup-White	47.278660	-122.411310	No Data	GRTS-2	
H	Target	303	Hylebos Waterway	Pierce	Puyallup-White	47.275728	-122.386020	11	PSAMP/NOAA	0.223
H	Target	304	Hylebos Waterway	Pierce	Puyallup-White	47.278648	-122.398431	14	PSAMP/NOAA	0.223
H	Target	305	Hylebos Waterway	Pierce	Puyallup-White	47.280316	-122.401471	8	PSAMP/NOAA	0.223
H	Alternate	43076	Southeast Commencement Bay	Pierce	Puyallup-White	47.279200	-122.396080	No Data	GRTS-2	
H	Alternate	44094	Southeast Commencement Bay	Pierce	Puyallup-White	47.275930	-122.384600	No Data	GRTS-2	
H	Alternate	48190	Southeast Commencement Bay	Pierce	Puyallup-White	47.265040	-122.363820	No Data	GRTS-2	

GRTS-1: spatially-balanced, generalized random tessellation stratified (GRTS) multi-density survey design based on 0.06 km² grid (Stevens 1997; Stevens and Olsen 1999, 2003, 2004)

GRTS-2: spatially-balanced, generalized random tessellation stratified (GRTS) multi-density survey design based on 0.00184 km² grid (Stevens 1997; Stevens and Olsen 1999, 2003, 2004)

PSAMP/NOAA: NOAA's National Status and Trends program randomly chosen sites within designated polygons or strata (Paul et al. 1992; Hyland et al. 2000).

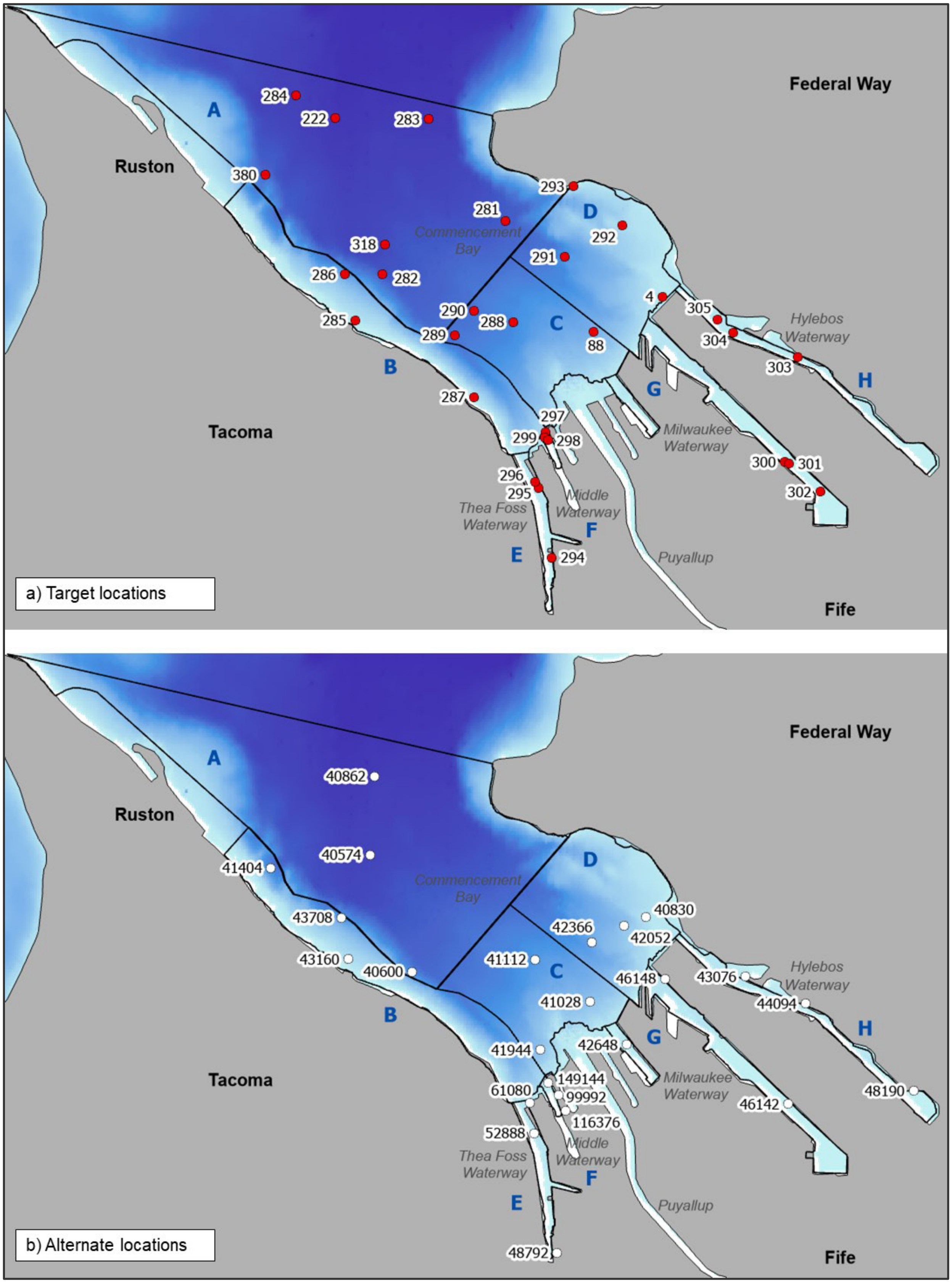

Figure 8. Commencement Bay sampling frame and monitoring station locations.

Budd Inlet

Most of the previously sampled stations in Budd Inlet were drawn from the GRTS designs with only 6 from the PSAMP/NOAA design. Therefore, alternate coordinates are chosen from the GRTS-2 design without stratification. All stations in Budd Inlet are equally weighted, each representing 0.578 km² of the total 17.350 km² area.

Table 15. Urban Bay stations for Budd Inlet.

Station type (Target or Alternate)	**Station**	**Location**	**County**	**Watershed WRIA**	**Latitude** (NAD83HARN)	**Longitude** (NAD83HARN)	**Approx. Depth (m)**	**Sampling Scheme**	**Station Weight (km²)**
Target	PSUW012	Budd Inlet	Thurston	Deschutes	47.124070	-122.907050	14	GRTS-1	0.578
Target	PSUW020	Budd Inlet	Thurston	Deschutes	47.081540	-122.914730	5	GRTS-1	0.578
Target	PSUW084	Budd Inlet	Thurston	Deschutes	47.100080	-122.930650	7.5	GRTS-1	0.578
Target	PSUW100	Budd Inlet	Thurston	Deschutes	47.062410	-122.897780	4.5	GRTS-1	0.578
Target	PSUW116	Budd Inlet	Thurston	Deschutes	47.131270	-122.910920	15	GRTS-1	0.578
Target	PSUW140	Budd Inlet	Thurston	Deschutes	47.122420	-122.909330	14	GRTS-1	0.578
Target	PSUW148	Budd Inlet	Thurston	Deschutes	47.098750	-122.911610	10	GRTS-1	0.578
Target	PSUW228	Budd Inlet	Thurston	Deschutes	47.056800	-122.908990	8.5	GRTS-1	0.578
Target	PSUW244	Budd Inlet	Thurston	Deschutes	47.145880	-122.920640	30	GRTS-1	0.578
Target	PSUW268	Budd Inlet	Thurston	Deschutes	47.110600	-122.903080	10	GRTS-1	0.578
Target	PSUW300	Budd Inlet	Thurston	Deschutes	47.052669	-122.905736	13	GRTS-1	0.578
Target	PSUW556	Budd Inlet	Thurston	Deschutes	47.045097	-122.904651	3.5	GRTS-1	0.578
Target	UW40056	Budd Inlet	Thurston	Deschutes	47.064580	-122.902700	5	GRTS-2	0.578

Station type (Target or Alternate)	**Station**	**Location**	**County**	**Watershed WRIA**	**Latitude** (NAD83HARN)	**Longitude** (NAD83HARN)	**Approx. Depth (m)**	**Sampling Scheme**	**Station Weight (km^2)**
Target	UW40216	Budd Inlet	Thurston	Deschutes	47.099170	-122.916110	11	GRTS-2	0.578
Target	UW40272	Budd Inlet	Thurston	Deschutes	47.126330	-122.905710	19	GRTS-2	0.578
Target	UW40528	Budd Inlet	Thurston	Deschutes	47.119280	-122.915730	15	GRTS-2	0.578
Target	UW40728	Budd Inlet	Thurston	Deschutes	47.089060	-122.908770	5.5	GRTS-2	0.578
Target	UW40984	Budd Inlet	Thurston	Deschutes	47.080670	-122.909880	7	GRTS-2	0.578
Target	UW41040	Budd Inlet	Thurston	Deschutes	47.105510	-122.894200	7	GRTS-2	0.578
Target	UW41240	Budd Inlet	Thurston	Deschutes	47.096400	-122.911970	9	GRTS-2	0.578
Target	UW41296	Budd Inlet	Thurston	Deschutes	47.098530	-122.896040	5.5	GRTS-2	0.578
Target	UW41552	Budd Inlet	Thurston	Deschutes	47.117750	-122.900430	12	GRTS-2	0.578
Target	UW41680	Budd Inlet	Thurston	Deschutes	47.135080	-122.922850	27	GRTS-2	0.578
Target	UW41752	Budd Inlet	Thurston	Deschutes	47.104280	-122.924960	7	GRTS-2	0.578
Target	UWNO236	Budd Inlet	Thurston	Deschutes	47.114230	-122.896950	9	PSAMP/NOAA	0.578
Target	UWNO237	Budd Inlet	Thurston	Deschutes	47.129270	-122.913780	11	PSAMP/NOAA	0.578
Target	UWNO241	Budd Inlet	Thurston	Deschutes	47.135460	-122.914490	11	PSAMP/NOAA	0.578
Target	UWNO242	Budd Inlet	Thurston	Deschutes	47.052860	-122.897360	5	PSAMP/NOAA	0.578
Target	UWNO243	Budd Inlet	Thurston	Deschutes	47.051638	-122.895880	3	PSAMP/NOAA	0.578

Station type (Target or Alternate)	**Station**	**Location**	**County**	**Watershed WRIA**	**Latitude** (NAD83HARN)	**Longitude** (NAD83HARN)	**Approx. Depth (m)**	**Sampling Scheme**	**Station Weight (km^2)**
Target	UWNO244	Budd Inlet, Port of Olympia	Thurston	Deschutes	47.057500	-122.909100	2	PSAMP/NOAA	0.578
Alternate	41880	Budd Inlet	Thurston	Deschutes	47.076530	-122.920050	No Data	GRTS-2	
Alternate	42008	Budd Inlet	Thurston	Deschutes	47.046480	-122.906040	No Data	GRTS-2	
Alternate	42064	Budd Inlet	Thurston	Deschutes	47.102610	-122.907590	No Data	GRTS-2	
Alternate	42264	Budd Inlet	Thurston	Deschutes	47.100070	-122.924640	No Data	GRTS-2	
Alternate	42320	Budd Inlet	Thurston	Deschutes	47.096530	-122.903690	No Data	GRTS-2	
Alternate	42576	Budd Inlet	Thurston	Deschutes	47.123880	-122.905690	No Data	GRTS-2	
Alternate	42704	Budd Inlet	Thurston	Deschutes	47.129820	-122.918890	No Data	GRTS-2	
Alternate	42776	Budd Inlet	Thurston	Deschutes	47.088820	-122.924580	No Data	GRTS-2	
Alternate	42904	Budd Inlet	Thurston	Deschutes	47.069030	-122.916510	No Data	GRTS-2	
Alternate	43032	Budd Inlet	Thurston	Deschutes	47.074660	-122.916100	No Data	GRTS-2	

GRTS-1: spatially-balanced, generalized random tessellation stratified (GRTS) multi-density survey design based on 0.06 km^2 grid (Stevens 1997; Stevens and Olsen 1999, 2003, 2004)

GRTS-2: spatially-balanced, generalized random tessellation stratified (GRTS) multi-density survey design based on 0.00184 km^2 grid (Stevens 1997; Stevens and Olsen 1999, 2003, 2004)

PSAMP/NOAA: NOAA's National Status and Trends program randomly chosen sites within designated polygons or strata (Paul et al. 1992; Hyland et al. 2000).

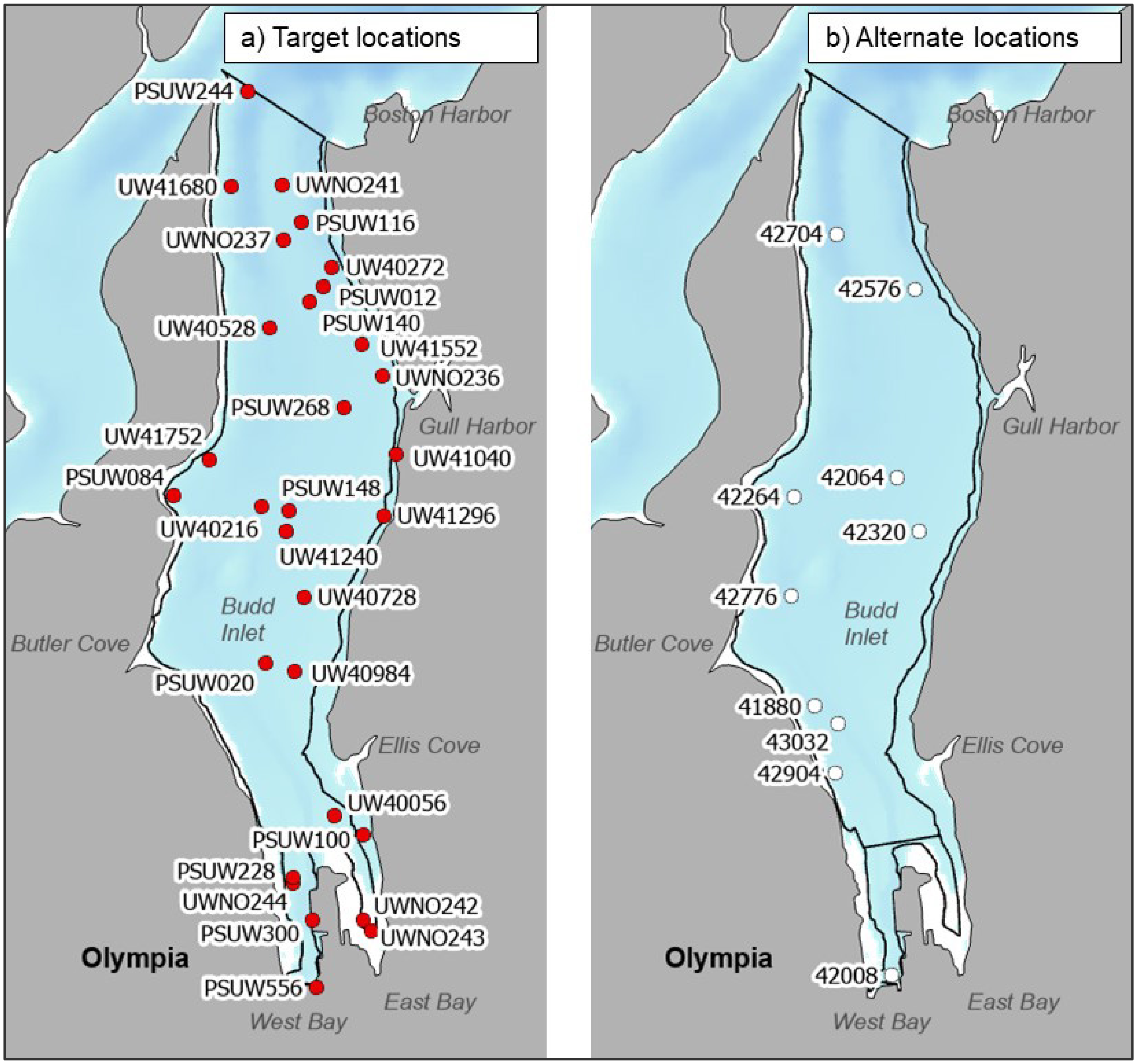

Figure 9. Budd Inlet sampling frame and monitoring station locations.

7.2.2 Field parameters and laboratory analytes to be measured

In addition to the samples collected under the 2023-2028 Puget Sound Sediment Monitoring Program QAMP (Marine Sediment Monitoring Team 2023), a benthic invertebrate tissue sample will be collected at each location. Chemistry parameters, listed in section 7.2.3, will be measured in invertebrate tissues at all locations with adequate biomass.

7.2.3 Parameters measured in benthic invertebrate tissues for the Marine Sediment Monitoring Program.

+Denotes calculated values (see Section 14).

STABLE ISOTOPES

$\delta^{13}C$ and $\delta^{15}N$ stable isotopes+

CHEMISTRY

Metals

Arsenic
Cadmium
Chromium
Copper
Lead
Mercury
Nickel
Selenium
Silver
Tin
Zinc

Organics

Phthalate Esters

Bis(2-ethylhexyl)phthalate
Butylbenzylphthalate
Diethylphthalate
Dimethylphthalate
Di-n-butylphthalate
Di-n-octyl phthalate

Polynuclear Aromatic Hydrocarbons

Low-molecular-weight polycyclic aromatic hydrocarbon (LPAHs)s

1,6,7-Trimethylnaphthalene
1-Methylnaphthalene
1-Methylphenanthrene
2,6-Dimethylnaphthalene
2-Methylnaphthalene
2-Methylphenanthrene
Acenaphthene
Acenaphthylene
Anthracene
Biphenyl
Dibenzothiophene
Fluorene
Naphthalene
Phenanthrene
Retene
Total LPAHs+

High-molecular-weight polycyclic aromatic hydrocarbon (HPAHs)

Benzo(a)anthracene
Benzo(a)pyrene
Benzo(b)fluoranthene
Benzo(e)pyrene
Benzo(g,h,i)perylene
Benzo(k)fluoranthene
Chrysene
Dibenzo(a,h)anthracene
Fluoranthene
Indeno(1,2,3-c,d)pyrene
Perylene
Pyrene
Total HPAH+
Total benzofluoranthenes+

Polychlorinated Biphenyls

PCB Aroclor 1016
PCB Aroclor 1221
PCB Aroclor 1232
PCB Aroclor 1242
PCB Aroclor 1248
PCB Aroclor 1254
PCB Aroclor 1260
PCB Aroclor 1262
PCB Aroclor 1268
PCB congener 8
PCB congener 18
PCB congener 28
PCB congener 44
PCB congener 52
PCB congener 66
PCB congener 77
PCB congener 101
PCB congener 105
PCB congener 118
PCB congener 126
PCB congener 128
PCB congener 138
PCB congener 153
PCB congener 169
PCB congener 170
PCB congener 180
PCB congener 187
PCB congener 195
PCB congener 206
PCB congener 209

Polybrominated Diphenylethers

PBDE 47
PBDE 49
PBDE 66
PBDE 71
PBDE 99
PBDE 100
PBDE 138
PBDE 153
PBDE 154
PBDE 183
PBDE 184
PBDE 191
PBDE 209

7.3 Modeling and analysis design

Not applicable.

7.3.1 Analytical framework

Not applicable.

7.3.2 Model setup and data needs

Not applicable.

7.4 Assumptions underlying design

An inherent design assumption of annual ambient monitoring is that these snapshots are representative of environmental and biotic conditions year-round. However, annual measurements are a snapshot of conditions at one point in time and may not fully capture the range of conditions nor unique events occurring year-round. Seasonal variability in all parameters may play an important role in shaping conditions within the sediment and benthic infaunal assemblage. Although we take steps to assure representativeness, data users must be careful not to overstate these measurements.

7.5 Possible challenges and contingencies

The Sediment Program study design was developed to achieve the goals and objectives of this program and answer the questions posed. Station locations, monitoring methods, and schedules are updated as information priorities and logistics evolve. Any updates will be captured in future addenda to this monitoring plan or, if significantly different, will be captured in a new Quality Assurance Project Plan.

7.5.1 Logistical problems

Sampling permits

City, county, state, federal, and tribal governments, as well as military bases with boundaries along the Puget Sound shoreline, have regulatory authority regarding sediment sampling within these jurisdictional boundaries. Permits must be obtained from each appropriate agent prior to commencement of sampling. For this Long-term ambient monitoring, permission is typically granted for sediment sampling but has occasionally been denied. When access is denied, stations are rejected and replaced with alternates which are outside the restricted areas.

Sediment type

The target population for this project is the benthic organisms that dwell within the sediments up to 17 cm in depth. Samples are collected with a modified van Veen grab sampler. A representative soft sediment sample cannot be collected successfully from a location with a high proportion of cobble or rocks. If such locations are encountered, they are rejected and replaced with alternate stations.

Biomass availability

At some sampling stations, there might not be sufficient biomass available for a full suite of chemical analyses. In such cases, a second sample can be collected and combined with the first to obtain an adequate sample volume. However, even with two samples, there may still be instances where sufficient tissue biomass is not achieved. When tissue biomass is limited, the chemical analyses should be prioritized in the following order:

- PCB Congeners and Aroclors
- PDBEs
- PAHs and phthalates
- Mercury
- Metals

7.5.2 Practical constraints

Budgetary resources

Funding for the Sediment Program requires staff to conduct sample collection and analysis. EAP's Marine Monitoring Unit (MMU) supervisor and the Marine Sediment Monitoring Team (MSMT) lead must work with EAP's Management Team to ensure adequate funding to conduct the full Puget Sound Sediment Monitoring Program. The tasks outlined in this Quality Assurance Project Plan (QAPP) are secondary to the larger Sediment Monitoring Program and rely on unspent funds at the end of the biennium or funds obtained from grants or budget adds. Inadequate budget can result in data and knowledge gaps.

Staffing capacity

Sample collection on the Ecology vessels typically requires (1) at least three MSMT members to collect and process samples, and (2) two of the Environmental Assessment Program's (EAP's) trained and certified boat operators to serve as captains. Careful scheduling and preparation of a field itinerary must be conducted at least one month in advance of field work to ensure that there is adequate staffing of a field crew during sampling.

Laboratory analysis capacity

After samples are collected, they are delivered to and processed by MEL or a contract laboratory. Careful planning and clear communication with laboratories are needed to ensure timely processing of samples.

7.5.3 Schedule limitations

Even with the best planning, challenges may arise when working on marine waters such as unfavorable weather and tidal conditions, changes in staffing, and equipment issues. Every effort is made to sample all scheduled stations and obtain credible and timely results. Whenever possible, field work is rescheduled until completed. The following activities will help mitigate potential scheduling issues:

- Prepare and implement annual schedule to ensure that adequate time is provided for:
    - QAPP review and approval
    - Obtaining sampling permits
    - Successful contract awards to vendors
    - Confirm laboratory capacity
- Schedule multiple field back-up dates
- Train multiple staff on field procedures
- Have back-up platform options (viable Ecology sampling platforms are the research vessels Salish Seacat and Skookum)
- Maintain interchangeable sets of auxiliary equipment, ensure equipment is well maintained, and thoroughly check functionality before starting fieldwork.

8.0 Field Procedures

8.1 Invasive species evaluation

It is possible that during sampling, invasive species of benthic invertebrates or marine plants could be collected. To avoid the spread of these species to other areas, procedures adapted from Ecology's Standard Operating Procedures to Minimize the Spread of Invasive Species (EAP070 v2.3; Parsons et al. 2021) will be implemented.

During collection of sediments and benthic infauna for the Sediment Program, all sample material not retained for analyses is washed overboard at or near the sampling location. Sieving of sediment samples for benthic infauna will be conducted at or within five nautical miles of the collection site. Additionally, both the van Veen grab and the sieve boxes will be scrubbed clean of any residual sediment and organisms immediately after completion of sampling at each station.

8.2 Measurement and sampling procedures

Field sampling and field analyses Standard Operating Procedures (SOPs) have been established for the Marine Sediment Monitoring Program and are listed in section 6.2.2 and summarized below. These protocols are followed during all sampling efforts. If deviations from the protocols occur, a brief explanation is given in the addenda to this plan.

Prior to deployment of the sampler at each new location, scrub the sampler, stainless steel bowls and lids, sieves, and utensils with site water and Liquinox; rinse with site water; rinse with a small quantity of pesticide-grade acetone; then rinse the with site water.

The benthic macroinvertebrate sample will be taken from one side of the double van Veen grab. Open the grab sampler and gently rinse the infaunal sample into a clean 1.0-mm mesh sieve. Once the interior of the grab and the grab stand are cleaned, transfer the 1.0-mm sieve to the sieve stand and carefully rinse the sample through it. While sieving, collect all large organisms and place them into an 8-ounce glass sample container. After most of the sediment is washed away, transfer all material remaining on the sieve into a stainless-steel bowl. Use a magnifying glass or microscope to continue extracting animals from the sediment, transferring them to the glass container until 30 grams of wet biomass is obtained. If needed, an additional grab may be taken and combined to achieve sufficient tissue material. However, even with two grabs, there may still be situations where the required tissue biomass is not reached. In such cases, chemical analyses should be prioritized as outlined in Section 7.5.1.

8.3 Containers, preservation methods, holding times

Recommended sample sizes, containers, preservation techniques, and holding times for all benthic invertebrate tissue samples are those listed in the MEL's Lab User's Manual (MEL 2016), or from published laboratory methods, and are summarized in Table 16.

Table 16. Sample containers, preservation, and holding times.

Parameter	Minimum Quantity Required	Container	Preservative	Holding Time
Metals, Polycyclic aromatic hydrocarbons (PAHs), Polychlorinated Biphenyls (PCB) Congeners, Aroclors, Polybrominated Diphenyl Ethers (PBDEs)	5–10 grams of sample per analysis for a total of 30 grams ideally, 20 grams minimum	8-oz certified organic-free wide-mouth glass jar with Teflon-lined lid	Freeze at -18°C	1 year
$\delta^{13}C$ and $\delta^{15}N$ stable isotopes	2 grams	50-mL polyethylene centrifuge tubes	Freeze at -18°C or freeze-dry	1 year

8.4 Equipment decontamination

Equipment decontamination procedures will follow Ecology's SOP EAP039 (Weakland 2007). Prior to sampling, and between sampling stations, the grab, sieves, and all other sampling equipment that comes in contact with the sampled sediment will be scrubbed with a soft brush and Alconox soap and rinsed with in situ seawater. This removes any sediment and contaminants from previous stations. The equipment will then be rinsed with acetone, again followed by in situ seawater. Residual acetone used for decontamination evaporates quickly and does not remain in sufficient quantity to collect for disposal.

Clean spoons, spatulas, forceps, and bowls will be placed in the decontaminated stainless steel utensil storage until needed for the next sample. Precautions are taken to avoid contamination of the samples from engine exhaust, atmospheric particulates, and rain.

8.5 Sample ID

All collected samples are labeled with preprinted waterproof labels attached to the outside of the containers with the project, station ID, MEL ID number (when appropriate), date of collection, and analysis to be performed. Barcodes containing this sample information will also be included on the label. The station and replicate numbers will be written on the lid of each sample with a permanent marker.

8.6 Chain of custody

Chain-of-custody procedures will follow those recommended by PSEP (1997a), with modifications to include the use of barcodes for sample tracking. These procedures provide an unbroken trail of accountability that ensures the physical security of samples, data, and records.

All samples collected during a field sampling shift will remain in the possession of the field crew during that shift. At the end of each shift, the field crew will transport the samples to the Ecology Operations Center (OC). There samples are removed from each ice chest, and the barcode on each sample label is scanned with a barcode reader connected to a laptop computer. Information read from each barcode populates an electronic chain-of-custody form for each type of analysis with information about each sample. The form is printed and signed by the relinquishing field crew member. Samples are stored in either the receiving freezer or walk-in cooler at the OC until ready for transport to the appropriate analytical laboratory. The signature block on the chain-of-custody form is signed next by the relinquishing and receiving person during each sample transfer. When the sample reaches its destination lab, the completed chain-of-custody form is scanned and e-mailed to MSMT staff.

8.7 Field log requirements

Information on station positioning and station and sample disposition are recorded in a digital field log. The following information must be included in the field logs for every sample that is collected:

- station identification
- collection success
- crew
- collection gear
- collection coordinates
- sample description
- parameters collected
- grab penetration depth
- sediment temperature
- overlying water salinity
- presence of wood, shell, or plant materials
- sediment odor
- collection date and time
- depth of water at station

A paper log is brought along on every survey to use as a backup if the electronic form or device should fail. Digital copies of the field and sample logs are stored for future reference on a shared, secure network that is frequently backed up.

8.8 Other activities

Lab notification

Prior to sampling, the MSMT project lead will submit a *Pre-Sampling Notification* and a *Sample Container Request Form* to MEL regarding specifications for all analyses conducted there. For analyses conducted by contract laboratories, laboratory notification procedures will be as specified by each laboratory.

The field collection schedule and sample delivery dates will be included in the laboratory notification. Changes in the schedule will be communicated to MEL and the contract labs so they can revise their plans accordingly.

Briefings for field staff and boat operators

A meeting will be held with all field staff prior to the commencement of field work to review all field sampling and safety protocols.

9.0 Laboratory Procedures

9.1 Lab procedures table

See Table 16.

9.2 Sample preparation method(s)

Standard preparation, extraction, and cleanup techniques for laboratory analyses are shown in Table 17.

9.3 Special method requirements

Not applicable.

9.4 Laboratories accredited for methods

All labs performing grain size, biogeochemistry, and chemistry analyses must be accredited by the State of Washington for the parameters and methods used to ensure generation of accurate and defensible analytical data (MEL 2016). Currently, Ecology does not accredit labs for analysis of stable isotopes of C and N. For these parameters, the accreditation requirement has been waived based on laboratory experience and demonstration of method performance.

Table 17. Laboratory methods for parameters measured in invertebrate tissues.

Analyte	Laboratory type	Expected Range of Results	Sample Prep Method	Clean-up Method	Analytical Method	Technique/ Instrument
$\delta^{13}C$ and $\delta^{15}N$ stable isotopes	Contract lab	1 to 10 $\delta^{15}N$; -18 to -25 $\delta^{13}C$	Sample preparation by freeze drying, grinding, acidification (if needed), homogenization, weighing, and encapsulation in tin or silver.	Not applicable	Dumas Combustion (Carter and Barwick, 2011)	Delta Plus XP isotope ratio mass spectrometer couples to CE-1108 CHNS-O Elemental Analyzer via a Conflo III interface

Analyte	Laboratory type	Expected Range of Results	Sample Prep Method	Clean-up Method	Analytical Method	Technique/ Instrument
Metals (except mercury)	MEL	< 0.01 – 500 ppm (up to 1500 for zinc)	EPA 3051	Not applicable	6020B	Inductively Coupled Plasma Mass Spectrometry
Total mercury	MEL	0.01 – 10 ppm	EPA 245.6	Not applicable	EPA 245.6	Cold Vapor Atomic Absorption
Phthalate esters	MEL	0.01 – 500 ppb	EPA 3541	EPA 3620C	EPA 8270E	MEL modification with capillary Gas chromatography/mass spectrometry analysis
Polycyclic aromatic hydrocarbons (PAHs)	MEL	0.01 – 500 ppb	EPA 3541	EPA 3620C	EPA 8270E Selected Ion Monitoring	MEL modification with capillary Gas chromatography/mass spectrometry — Selected Ion Monitoring isotopic dilution analysis
Polychlorinated Biphenyls (PCB) Aroclors	MEL	1 – 400 ppb	EPA 3541	EPA 3620C EPA 3665A	EPA 8082A	Gas Chromatography with Electron Capture Detector
Polychlorinated Biphenyls (PCB) congeners	MEL	< 0.1 – 400 ppb	EPA 3541	EPA 3620C EPA 3665A	EPA 8082A	Gas Chromatography with Electron Capture Detector
Polybrominated Diphenyl Ethers (PBDEs) congeners	MEL	< 0.1 – 400 ppb	EPA 3541	EPA 3620C EPA 3665A	EPA 8270E Selected Ion Monitoring	Capillary Gas chromatography/mass spectrometry — Selected Ion Monitoring

10.0 Quality Control Procedures

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

See Table 18 for field and laboratory MQOs (Section 6.2.1) that will be used to evaluate the quality and usability of the results.

The ongoing effort to provide high-quality data occurs in many steps before, during, and after data collection. QA/QC procedures include the following activities:

- Training personnel
- Preparing, maintaining, and following SOPs
- Maintaining equipment
- Calibrating equipment
- Field data and analytical laboratory and QA/QC procedures (see Section 11.2)
- Performing proper sample chain of custody (see Section 8.6)
- Performing proper data and information management
- Verifying data through regular data review and use of United States Environmental Protection Agency (EPA) guidelines
- Assessing data usability (see Section 14)
- Conducting audits (see Section 12)

10.1 Table of field and laboratory quality control

Quality control samples, types, and frequency for the Marine Sediment Monitoring Program are shown in Table 18.

Table 18. Quality control samples, types, and frequency.

Parameter	Field replicate (% of stations)	Laboratory Replicate	Lab Control Standard (LCS) % Recovery	Standard or Certified Reference Material (SRM/CRM) % Recovery	Matrix Spike (MS) % Recovery	Matrix Spike Duplicate (MSD)	Surrogate Spike % Recovery	Method Blank
$\delta^{13}C$ and $\delta^{15}N$ stable isotopes	%5	Duplicate 1/batch of 20	1/batch of 20	1/batch of 20	Not applicable	Not applicable	Not applicable	1/batch of 20
Metals (except mercury)	%5	MS/MSD serve as lab duplicate	1 LCS + 1 LCS duplicate/ batch of 20	1/batch of 20	1/batch of 20	1/batch of 20	Not applicable	1/batch of 20

Parameter	Field replicate (% of stations)	Laboratory Replicate	Lab Control Standard (LCS) % Recovery	Standard or Certified Reference Material (SRM/CRM) % Recovery	Matrix Spike (MS) % Recovery	Matrix Spike Duplicate (MSD)	Surrogate Spike % Recovery	Method Blank
Total mercury	%5	MS/MSD serve as lab duplicate	1 LCS + 1 LCS duplicate/ batch of 20	1/batch of 20	1/batch of 20	1/batch of 20	Not applicable	1/batch of 20
Phthalates	%5	Duplicate 1/batch of 20	1 LCS + 1 LCS duplicate/ batch of 20	1/batch of 20	1/batch of 20	1/batch of 20	all samples including QC	1/batch of 20
Polycyclic aromatic hydrocarbons (PAHs)	%5	Duplicate 1/batch of 20	1 LCS + 1 LCS duplicate/ batch of 20	1/batch of 20	1/batch of 20	1/batch of 20	all samples including QC	1/batch of 20
Polychlorinated biphenyls (PCBs) — Aroclors	%5	Duplicate 1/batch of 20	1 LCS + 1 LCS duplicate/ batch of 20	1/batch of 20	NA	1/batch of 20	all samples including QC	1/batch of 20
Polychlorinated biphenyls (PCBs) — Congeners	%5	Duplicate 1/batch of 20	1 LCS + 1 LCS duplicate/ batch of 20	1/batch of 20	1/batch of 20	1/batch of 20	all samples including QC	1/batch of 20
Polybrominated diphenyl ethers (PBDEs) — Congeners	%5	Duplicate 1/batch of 20	1 LCS plus 1 LCS duplicate/ batch of 20	1/batch of 20	1/batch of 20	1/batch of 20	all samples including QC	1/batch of 20

10.2 Corrective action processes

If activities and analyses are found to be inconsistent with the QAMP and do not meet MQOs or performance expectations, or if some other unforeseen problem arises, corrective actions may be taken, including:

- Reanalysis of samples that do not meet QC criteria.
- Convening project personnel and technical experts to decide on the next steps that need to be taken to improve performance.

11.0 Data Management Procedures

11.1 Data recording and reporting requirements

Data and information management are critical to maintaining an efficient, organized, long-term monitoring system capable of generating high-quality, up-to-date, informative products for managers and scientists. Data used for analysis and reporting and distributed to the public must pass all QA/QC. The Environmental Information Management System (EIM) database is used to facilitate distribution and long-term secure storage of environmental data. Sediment data for Long-term and Urban Bays programs are stored under the Study IDs PSEMP_LT and UWI, respectively. The invertebrate tissue chemistry data will be stored under the same Study IDs. Figure 10 depicts the organization of the data workflow and products generated.

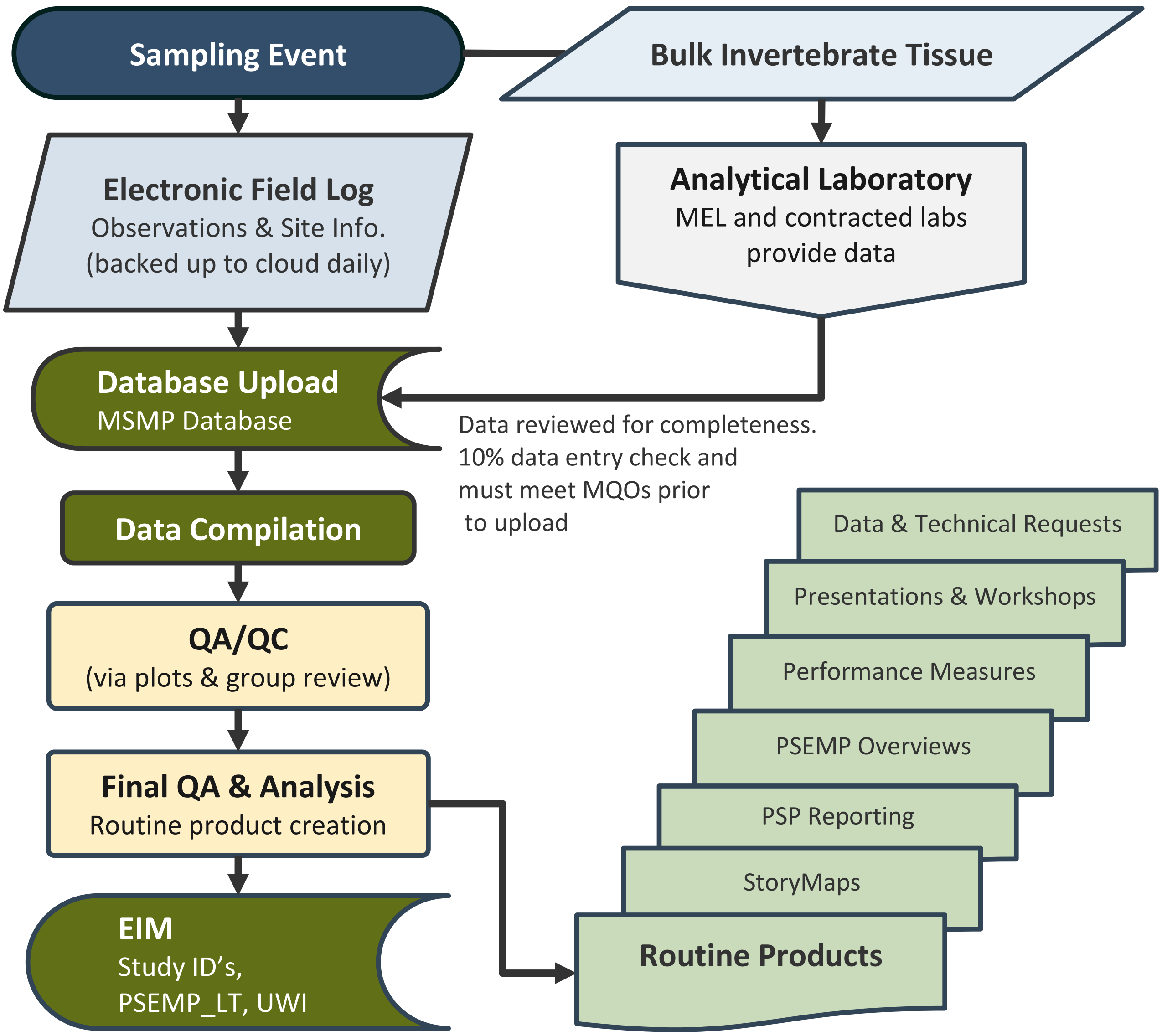

Figure 10. Data workflow for the Marine Sediment Monitoring Program.

11.2 Laboratory data package requirements

Data packages from contract laboratories will include:

- A case narrative or report detailing methods used, any problems with the analyses, corrective actions taken, changes to the referenced method, and an explanation of data qualifiers.
- All associated QC results. This information is needed to evaluate the accuracy of the data and to determine whether the MQOs have been met. This will include results for all required field and laboratory replicates, laboratory control samples, reference materials, method blanks, matrix spike, matrix spike duplicates, and surrogate spikes.
- An electronic version of the data and report in Ecology's EIM or another specified format. Output from MEL's Laboratory Information Management System will be submitted electronically for upload into EIM. Data entered into EIM follow a formal data review procedure in which data are reviewed by the project manager of the study, the person entering the data, and an independent reviewer.

All data received from external providers are verified and reviewed by Marine Sediment Monitoring Team (MSMT) staff. Any discrepancies are discussed with the laboratories or contractors for amendment. Once data have been reviewed and verified, MSMT staff enter final data into EIM database.

11.3 Electronic transfer requirements

All contract labs will be required to submit data electronically in Ecology's EIM templates. These are pre-formatted Excel spreadsheets with specific data-entry requirements. They are used to minimize data entry problems and facilitate data analysis. Current EIM templates and guidance on populating them are provided on the EIM Help Center web page (https://apps.ecology.wa.gov/eim/help/).

11.4 EIM/STORET data upload procedures

All completed project data will be entered into Ecology's Environmental Information Management (EIM) database and receive a formal review process following the internal protocols and business rules detailed in Ecology's Environmental Assessment Program's (EAP) EIM Data Entry Review Procedure (https://apps.ecology.wa.gov/eim/help/). This internal data QC includes a review by the project manager, the person entering the data, and an independent reviewer of the uploaded data.

11.5 Model information management

Not applicable.

12.0 Audits and Reports

12.1 Field, laboratory, and other audits

Field staff may be audited at any time by the appropriate project manager or supervisor to ensure that field work is being completed according to this QAPP, any published QAPP amendment, and any published Ecology SOPs. This would consist of observing and correcting any sampling technique inconsistent with those provided in this QAPP. Experienced MSMT staff will conduct field training sessions and consistency reviews before and/or during each field season. Field consistency reviews are not true audits, but instead serve to improve field work consistency, improve adherence to SOPs, provide a forum for sharing innovations, and strengthen Ecology's data QA program.

All labs conducting analytical work for this project, including MEL, must be accredited in Washington State in accordance with the State Legislature's WAC-173-50, Accreditation of Environmental Laboratories (Washington State Legislature 2010) (http://apps.leg.wa.gov/WAC/default.aspx?cite=173-50). Ecology's Laboratory Accreditation Unit (LAU) implements the accreditation process, which includes routine performance and system audits of analytical procedures. If a lab is not accredited, a waiver must be received from Ecology's QA officer.

12.2 Responsible personnel

Personnel responsible for audits are:

- Field audits: experienced MSMT staff
- Lab audits: LAU audit of MEL

MSMT staff will track the status of samples being analyzed by MEL and the other contract labs, being particularly alert to any significant QC problems as they arise. Team members may visit the contract labs to observe conduct of any of the contracted analyses. MEL and the contract labs will each provide a data report to the MSMT.

12.3 Frequency and distribution of reports

MSMT staff will be responsible for analyzing data and determining how the results will be summarized and documented for the Long-term and Urban Bays monitoring. A variety of traditional formal and informal reporting formats will be used, along with social media publications, depending on the information being reported and the audience it is intended for.

MSMT staff regularly produce the following products:

- Focus sheets
- Interactive story maps
- Interactive data dashboards
- Puget Sound Partnership (PSP) reports
- PSEMP workgroup overviews

- Technical memos
- Performance measures
- Eyes Under Puget Sound blog posts, including Critter of the Month
- Peer-reviewed journal publications
- Presentations, conferences, and workshops
- Data and technical requests

12.4 Responsibility for reports

Report authors will vary for different reports generated for this program and will be identified for each report.

13.0 Data Verification

Data verification will be conducted by MSMT, MEL, and contract lab staff to ensure:

- Specified field and laboratory methods and protocols were followed.
- Data are consistent, correct, and complete, with no errors or omissions.
- All data quality objectives (Section 6.1) were met.
- All measurement quality objectives (Section 6.2) were met.
- All QC procedures (Section 10.0) were followed.
- Established criteria for QC results were met.
- Data qualifiers are properly assigned where necessary.

13.1 Field data verification, requirements, and responsibilities

Throughout the duration of the field sampling, senior staff and all crew members will have responsibilities for implementation of the specified station-positioning and sample-collection procedures. Additionally, there will be systematic review of all field documentation generated (e.g., field logs, chain-of-custody sheets, sample labels) to ensure data entries are consistent, correct, and complete, with no errors or omissions. This review should be completed prior to leaving the site where the measurements were made, particularly with the new implementation of electronic field logs.

13.2 Laboratory data verification

MSMT personnel will check all data received from the laboratories against the following verification criteria:

- Sample chain-of-custody
- Description of analytical methods
- Raw data in electronic format
- QA sample results
- Data evaluation results
- Any problems encountered and corrective actions which were taken
- Any qualification of the results

Any discrepancies will be reported back to the laboratories for amendment in the final data report. Once data have been reviewed and verified, MSMT personnel will enter the data into the MSMT and EIM databases.

13.3 Validation requirements, if necessary

Not applicable.

13.4 Model quality assessment

Not applicable.

14.0 Data Quality (Usability) Assessment

14.1 Process for determining project objectives were met

Upon completion of the data verification process, a Data Quality (Usability) Assessment will be conducted (Lombard and Kirchmer 2004). Data from all field and lab procedures will be examined to determine whether the data were measured with the proper procedures, fall into the expected range of results, and meet reporting limits as described in Sections 8 and 9, above. The data will also be examined to determine whether all MQOs and QC procedures described in Sections 6 and 10, respectively, have been met.

If all specifications are met, the quality of the data should be usable for meeting project objectives. If the MQOs have not all been met, MSMT staff will examine the data to determine whether they are still usable and whether the data quantity and quality are sufficient to meet project objectives. Data that do not meet the criteria detailed in this QAMP will be qualified appropriately for each parameter type. MSMT staff will be responsible for analyzing the data and determining how the results will be summarized and documented in each report.

14.2 Treatment of non-detects

Non-detects in tissue chemistry will be censored at the reporting limits (quantitation limits) specific to those samples. Data will be graphed with censored boxplots or other appropriate graphical methods for visual representation. Summary statistics will be estimated using techniques, such as robust regression on order statistics (ROS) or, if detection rates are > 50% and sample size is large enough, Kaplan-Meier censoring techniques (Helsel 2012).

Data preparation for comparison to WA Sediment Management Standards (Ecology 2013) is prescribed by statute to use only detected results. For sums of contaminant concentrations (e.g., Total HPAH), if all constituent compounds are non-detect, the highest reporting limit is to be used as the total value (Ecology 2013). Contaminant sums consisting of only a single reporting limit will be treated as non-detect for further analyses. Benthos tissue data will be treated the same way as sediment data.

The weighted-analysis techniques developed by EPA specifically for GRTS designs such as used by the Sediment Program (Stevens and Olsen 1999, 2003, 2004) currently are not designed to handle non-detects; however, methods are being developed for handling censored data (Tony Olsen, pers. comm. with Valerie Partridge, 2017). In the interim, because metals and PAHs are almost always detected, weighted-mean and CDF-comparison analyses (Kincaid 2000; Kincaid et al. 2016) will be conducted on detected values only. CDFs will be drawn only when the detection rate is ≥ 90%. Confidence intervals will not be calculated when the non-detect rate is < 90% and ≥ 50%.

The detection rate for other organic compounds has typically been far lower than 90%, and usually lower than 50%; hence these weighted analyses would not be performed.

Zeros in grain size proportions, although sometimes stored in the database as non-detect with a reporting limit of 0.1%, are not true non-detects and will be treated as zeros (detected or estimated) in data analyses.

14.3 Data analysis and presentation methods

The statistical descriptive and inferential techniques used are determined by the questions to be answered (i.e., the research hypotheses). Examples of methods currently used are mentioned in the subsections below.

During any stage of the analysis, especially when reviewing graphical displays, previously undetected data anomalies may be discovered. These anomalies are carefully examined. If errors are found in the data, they are either corrected or removed, and the analyses are re-executed.

Data summaries and displays

For chemical contaminant data with field or lab replicates, or both, the first field or lab replicate result is used as the value for that parameter at that station, for consistency and to preserve the statistical variability of the data. Non-detects in tissue chemistry are censored at the reporting limits (quantitation limits) specific to those samples.

Data are graphed with boxplots (censored boxplots, in the event of non-detects), bar graphs, scatterplots, or other appropriate graphical methods for visual representation. Possible and probable outliers (as indicated by the boxplots or appropriate statistical tests) are researched individually to determine whether the outlier is an error or represents a real, though less probable, member of the population. Data which are in error are corrected or removed before further analysis.

For these probability-based GRTS sample designs, cumulative distribution functions (CDF) of a given variable are computed using EPA's spsurvey analysis routines (Kincaid et al. 2016) and graphed, to describe spatial extent. The calculation of the CDFs includes the weighting of each sample result by the amount of area (within the study area) that that sample represents.

Summary statistics are computed for all variables. When non-detects are present in the data, summary statistics are estimated using techniques such as robust regression on order statistics (ROS) or Kaplan-Meier estimation techniques, as appropriate (Helsel 2012).

Similarities of multiple multivariate samples are graphically displayed with nonmetric multidimensional scaling (nMDS), hierarchical agglomerative clustering, or other graphical descriptive procedures. Appropriate measures of similarity are calculated, depending on the type of data (currently, Euclidean distance is used for environmental variables). Environmental variables are first transformed or normalized as appropriate (Clarke et al. 2014).

Derived variables

Summed concentrations of specific chemicals (Total Aroclors, Total Benzofluoranthenes, Total HPAH, Total LPAH) are calculated from the individual chemicals measured as specified in the Washington State Sediment Management Standards and as shown below in Table 19 (Ecology 2013).

Table 19. Calculated parameters for Long-term and Urban Bays monitoring.

Calculated parameter	Definition	Calculation
δ13C	Isotopic signature of carbon, based on relative abundances of two stable isotopes, ^{13}C and ^{12}C, in a sample compared to a standard	$\delta^{13}\mathrm{C} = \left[\frac{({}^{13}\mathrm{C}/{}^{12}\mathrm{C})_{sample}}{({}^{13}\mathrm{C}/{}^{12}\mathrm{C})_{standard}}\right] \times 1000$
δ15N	isotopic signature of nitrogen, based on relative abundances of two stable isotopes, ^{15}N and ^{14}N, in a sample compared to air	$\delta^{15}\mathrm{N} = \left[\frac{({}^{15}\mathrm{N}/{}^{14}\mathrm{N})_{sample}}{({}^{15}\mathrm{N}/{}^{14}\mathrm{N})_{air}}\right] \times 1000$
Total Low-molecular-weight polycyclic aromatic hydrocarbon (LPAH)	Combined acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, and phenanthrene	Sum of detected concentrations. When all constituents are nondetect, the highest reporting limit will be used as the Total LPAH value.
Total High-molecular-weight polycyclic aromatic hydrocarbon (HPAH)	Combined benzo(a)anthracene, benzo(a)pyrene, benzo(g,h,i)perylene, chrysene, dibenzo(a,h)anthracene, fluoranthene, indeno(1,2,3-c,d)pyrene, pyrene, and total benzofluoranthenes	Sum of detected concentrations. When all constituents are nondetect, the highest reporting limit will be used as the Total HPAH value.
Total benzofluoranthenes	Combined benzo(b)fluoranthene, benzo(j)fluoranthene, and benzo(k)fluoranthene	Sum of detected concentrations. When all constituents are nondetect, the highest reporting limit will be used as the Total Benzofluoranthenes value.
Total Aroclors	Combined PCB Aroclors	Sum of detected concentrations. When all constituents are nondetect, the highest reporting limit will be used as the Total Aroclors value.

Relationships among variables

The Sediment Program surveys do not include determinations of cause/effect relationships among the variables that are measured. However, it is useful to determine whether variables co-vary with each other throughout the study area. Co-varying variables may lead to future experiments to determine and verify cause/effect relationships.

Due to the multivariate nature of the data, multivariate correlation procedures are appropriate. Nonparametric multivariate correlation procedures, such as the BioEnv/BEST procedure in PRIMER v.7 (Clarke et al. 2014), are used.

If bivariate correlations are appropriate, the two variables are plotted against each other. The data are tested for normality. If tests for normality are rejected, i.e., the data are not normally distributed or if the plot of the two variables indicates strong non-linearity, a nonparametric measure of association (usually Spearman's rho) is calculated. Otherwise, we calculate the Pearson correlation coefficient.

Semi-metric distance-based analogs of analyses such as ANOVA, ANCOVA, multivariate multiple regression and discriminant analysis in PERMANOVA+ may be used to model and test relationships between benthic assemblages and habitat variables (Anderson et al. 2008). Techniques such as partial least squares regression may be used to find relationships between habitat and chemical variables.

Comparisons

Because the Sediment Program uses probability-based sampling designs with unequal weighting, temporal or spatial comparisons of population estimates are conducted by comparing CDFs or comparing weighted means using EPA's spsurvey analysis routines (Kincaid 2000; Kincaid et al. 2016). Unweighted (or equally-weighted) comparisons of populations are made with appropriate nonparametric procedures. The CDFs being compared, along with their confidence bands, are graphed.

Since all stations are fixed and have been sampled at least once, except for new parameters, temporal comparisons involving repeat sampling of stations may be made using appropriate paired-comparison tests.

- For unweighted or equally-weighted samples: the Wilcoxon signed ranks test or, when non-detects are present, the paired Prentice-Wilcoxon test (Helsel 2012).
- For unequally weighted samples, repeat-sampled stations are identified in the weighted-mean or weighted categories analyses (Kincaid et al. 2016).

Comparisons of proportions are done with appropriate statistical tests using EPA's spsurvey analysis routines (Kincaid et al. 2016). Area proportions (spatial extent) are calculated using the amounts of area represented by the samples.

Analogous to ANOVA (analysis of variance), the analysis of similarities (ANOSIM) is used to perform multivariate comparisons of results from two or more sets of samples based on their similarities (Clarke et al. 2014). Similarity measures are calculated as described above for data summaries and displays. The ANOSIM procedure uses a permutation test to determine whether samples are more dissimilar between vs. within sets.

The data generated will establish a baseline of chemical contaminants in benthic invertebrate tissues in Puget Sound. This baseline should be followed by an evaluation to determine: (1) the relationships between contaminants, (2) numeric ranges corresponding from poor to high-quality conditions, and (3) target values for environmental management aligned with desired environmental conditions.

14.4 Sampling design evaluation

In application, survey design must balance desired theoretical statistical performance with practical limitations. Given budgetary constraints on the numbers of stations sampled, the type of design employed affects the precision of estimates and the power to make comparisons or detect trends.

In spatially-restricted survey designs (such as GRTS), precision is expected to be better than that for simple random designs (Stoddard et al. 2005). Furthermore, the inherent correlation between resampling of the same sites improves the ability to detect change beyond that of designs without resamples.

14.5 Documentation of assessment

Data usability will be documented in the Marine Sediment Monitoring Program database, EIM database and in annual reports. Data will be unqualified if all specifications are met, and the quality of the data meet the project objectives. If the MQOs have not been met, MSMT staff will examine the data to determine whether they are still usable and whether the data quantity and quality are sufficient to meet project objectives. Data that do not meet the criteria detailed in this QAMP will be qualified appropriately. MSMT staff will be responsible for analyzing the data and determining how the results will be summarized and documented. Data and analytical results are analyzed and summarized regularly and reported in a variety of products listed in section 12.3.

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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.

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

Point source: Source of pollution that discharges 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 waste treatment facilities, and construction sites where more than 5 acres of land have been cleared.

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.

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

Spearman's rho: also known as **Spearman's rank correlation coefficient**, is a nonparametric measure of the strength and direction of association between two ranked variables. Spearman's rho is a way to measure how two sets of numbers are connected based on their order, not their actual values.

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.

Acronyms and Abbreviations

BSAF	Biota-sediment accumulation factors
CDF	Cumulative Distribution Function
CRM	Certified reference material
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
et al.	And others
GIS	Geographic Information System software
GRTS	Generalized Random Tessellation Stratified multi-density survey design
GRTS-1	Generalized Random Tessellation Stratified multi-density survey design based on 0.06 km^2
GRTS-2	Generalized Random Tessellation Stratified multi-density survey design based on 0.00184 km^2 grid
HPAH	High-molecular-weight polycyclic aromatic hydrocarbon
ID	Identification
i.e.	In other words
LAU	Lab AccreditationUnit
LCS	Lab control standards
LLOQ	Lowest level of quantification
LPAH	Low-molecular-weight polycyclic aromatic hydrocarbon
MDL	Method detection limit
MEL	Manchester Environmental Laboratory
MMU	Marine Monitoring Unit
MQO	Measurement quality objective
MS	Matrix spike
MSD	Matrix spike duplicate
MSMT	Marine Sediment Monitoring Team (Dept of Ecology)
NCCOS	National Centers for Coastal Ocean Science
nMDS	Nonmetric multidimensional scaling
NOAA	National Oceanographic Atmospheric Administration
OC	Operations Center
PAH	Polycyclic aromatic hydrocarbon
PBDE	Polybrominated diphenyl ether
PCB	Polychlorinated biphenyl
PQL	Practical quantitation limit
PSAMP	Puget Sound Ambient Monitoring Program (now PSEMP)
PSEMP	Puget Sound Ecosystem Monitoring Program
PSEP	Puget Sound Estuary Program
PSP	Puget Sound Partnership
QA	Quality assurance
QAMP	Quality assurance monitoring plan
QAPP	Quality Assurance Project Plan
QC	Quality control

ROS Robust regression on order statistics
RPD Relative percent difference
RSD Relative standard deviation
Sediment Program Department of Ecology's Puget Sound Sediment Monitoring Program
SOP Standard operating procedure
SRM Standard reference material
TBiOS Toxics Biological Observation System
U.S. United States
USEPA United States Environmental Protection Agency
WDFW Washington Department of Fish and Wildlife's
WAC Washington Administrative Code
WW Wet weight

Units of Measurement

$ United States dollars
cm centimeter, a unit of length equal to 0.01 (one-hundredth) meter
g gram, a unit of mass
kg kilogram, a unit of mass equal to 1,000 grams
km kilometer, a unit of length equal to 1,000 meters
m meter
mm millimeter, a unit of length equal to 0.001 (one-thousandth) meter
mg milligram, a unit of mass equal to 0.001 (one-thousandth) gram
mg/kg milligrams per kilogram (parts per million)
ppb parts per billion
ppm parts per million
µg microgram, a unit of mass equal to 0.000001 (one-millionth) gram
µg/kg micrograms per kilogram (parts per billion)

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 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)

CDF: CDF-comparison analyses involve comparing cumulative distribution functions (CDFs) to understand the differences between two or more datasets. Comparing CDFs involves plotting the CDFs of different datasets on the same graph to visually inspect differences. This can help identify shifts, skews, or other discrepancies between the distributions.

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 occurred. These are:

- Use of raw or instrument data for evaluation.
- Use of third-party assessors.
- Data set is complex.
- Use of EPA Functional Guidelines or equivalent for review.
- Examples of data types commonly validated would be:
- Gas Chromatography (GC).
- Gas Chromatography-Mass Spectrometry (GC-MS).
- Inductively Coupled Plasma (ICP).

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

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

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

Detection limit (limit of detection): The concentration or amount of an analyte 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)

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. (USEPA 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 2025).

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)

Priority pollutants: A set of chemical pollutants that are regulated by the Environmental Protection Agency (EPA) under the Clean Water Act. The EPA has developed analytical test methods for these pollutants to ensure they are properly monitored. The current list of 126 priority pollutants includes various chemicals such as heavy metals, pesticides, and industrial chemicals

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)/Quality Assurance Monitoring Plan (QAMP): A document that describes the objectives of a project or monitoring program, 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)

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