Addendum 2 to Quality Assurance Project Plan

Survey of PFAS in the Greater Lake Washington Watershed

October 2022

Publication 22-03-114

Publication Information

This Quality Assurance Project Plan Addendum is on the Department of Ecology's website at https://apps.ecology.wa.gov/publications/SummaryPages/2203114.html. This is an addition to an original Quality Assurance Project Plan (QAPP). It is not a correction (errata) to the original plan.

This QAPP addendum was approved to begin work in July 2022. It was finalized and approved for publication in October 2022.

Suggested citation for this addendum:
Wong, S. and D. Escobedo. 2022. Addendum 2 to Quality Assurance Project Plan: Survey of PFAS in the Greater Lake Washington Watershed. Publication 22-03-114. Washington State Department of Ecology, Olympia.
https://apps.ecology.wa.gov/publications/SummaryPages/2203114.html.

Data for this project will be available on Ecology's Environmental Information Management (EIM) website at EIM Database. Search Study ID SWON0003.

Activity Tracker code:
Ecology's Activity Tracker code for this addendum is 21-020.

Original Quality Assurance Project Plan:
Wong, S. and C. Mathieu. 2020. Quality Assurance Project Plan: Survey of PFAS in the Greater Lake Washington Watershed. Publication 20-03-112. Washington State Department of Ecology, Olympia. https://apps.ecology.wa.gov/publications/SummaryPages/2003112.html.

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Addendum 2 to
Quality Assurance Project Plan

Survey of PFAS in the Greater Lake Washington Watershed

by Siana Wong and Diane Escobedo

October 2022

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1.0 Table of Contents

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

3.0 Background

3.1 Introduction and problem statement

During summer 2020, the Washington State Department of Ecology's (Ecology's) Environmental Assessment Program initiated Phase 1 of a field study to address potential sources of per- and polyfluoroalkyl substances (PFAS) contamination in resident fish from Lake Washington, King County (Furl and Meredith 2010, Mathieu and McCall 2017, Mathieu 2022).

During Phase 1, we assessed concentrations of PFAS in Lake Washington and in potential contaminant pathways to the lake. The Phase 1 study design included characterization of PFAS concentrations in the lake and its direct tributaries, groundwater discharges, stormwater discharges, bridge runoff, and bulk atmospheric deposition (Wong and Mathieu 2021, Escobedo 2021).

This Quality Assurance Project Plan (QAPP) addendum describes the Phase 2 study design. In Phase 2, we will sample in areas of the Lake Washington watershed where we detected some of the highest PFAS concentrations and potential PFAS loading sources among the samples collected in Phase 1. The findings from this study will help us determine the sources and pathways of PFAS entering Lake Washington that may also be applicable to other urban watersheds.

3.2 Study area and surroundings

3.2.2 Summary of previous studies and existing data

Summary of Phase 1 Study Design and Results

Phase 1 Study Design

A detailed description of our Phase 1 study design, field collection procedures, and laboratory methods is provided in the original QAPP (Wong and Mathieu 2021) and groundwater QAPP addendum (Escobedo 2021).

Phase 1 was implemented during September 2020 through May 2021. It included sampling of the following:

- Lake Washington at off-shore and near-shore locations.
- Tributaries that drain to the lake.
- Stormwater outfalls and bridge runoff that discharge to the lake.
- Bulk atmospheric deposition.
- Groundwater in shoreline areas of the lake.

Table 1 shows a summary of the samples collected.

Table 1. Samples collected during Phase 1 of this study.

General Sample Location	Samples Collected
Lake Washington	Surface Water: 23 sites, 2 events. Sediment: 22 sites, 1 event.
Tributary	Surface Water: 32 sites (16 subbasins), 2 events (summer, spring). Surface Water: 5 sites, 5 storm events. Sediment: 16 sites, 1 event. Biofilm: 6 sites, 1 event.
Stormwater	Stormwater Outfall: 7 sites for 1 event, and subset of 2 sites for 4 events. Bridge Runoff: 1 site, 4 events.
Bulk Atmospheric Deposition	1 site, 4 events.
Groundwater	19 sites, 1 event.

Figures 1 and 2 show maps of Phase 1 sampling sites.

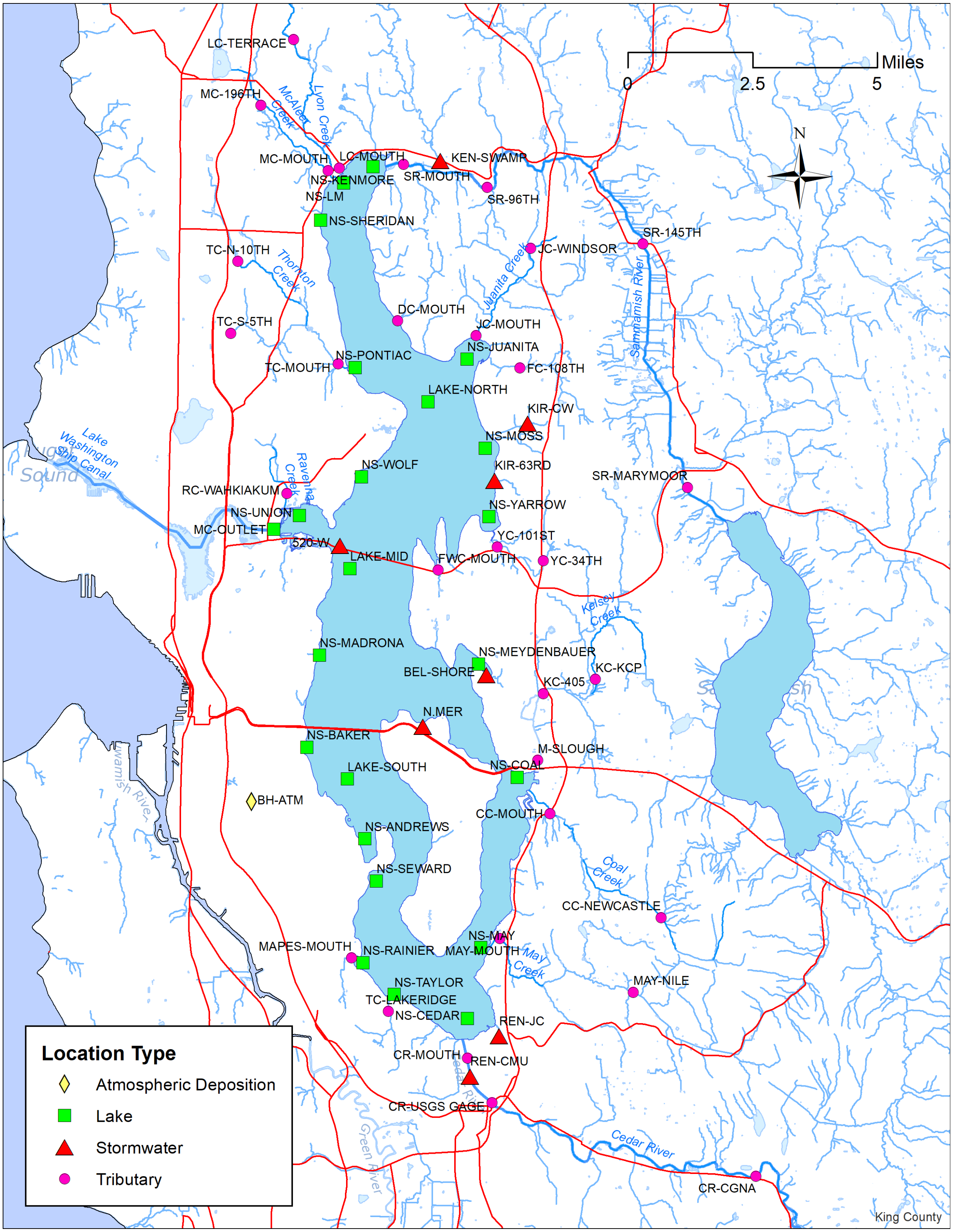

Figure 1. Map of Phase 1 sampling sites in and surrounding Lake Washington (not including groundwater).

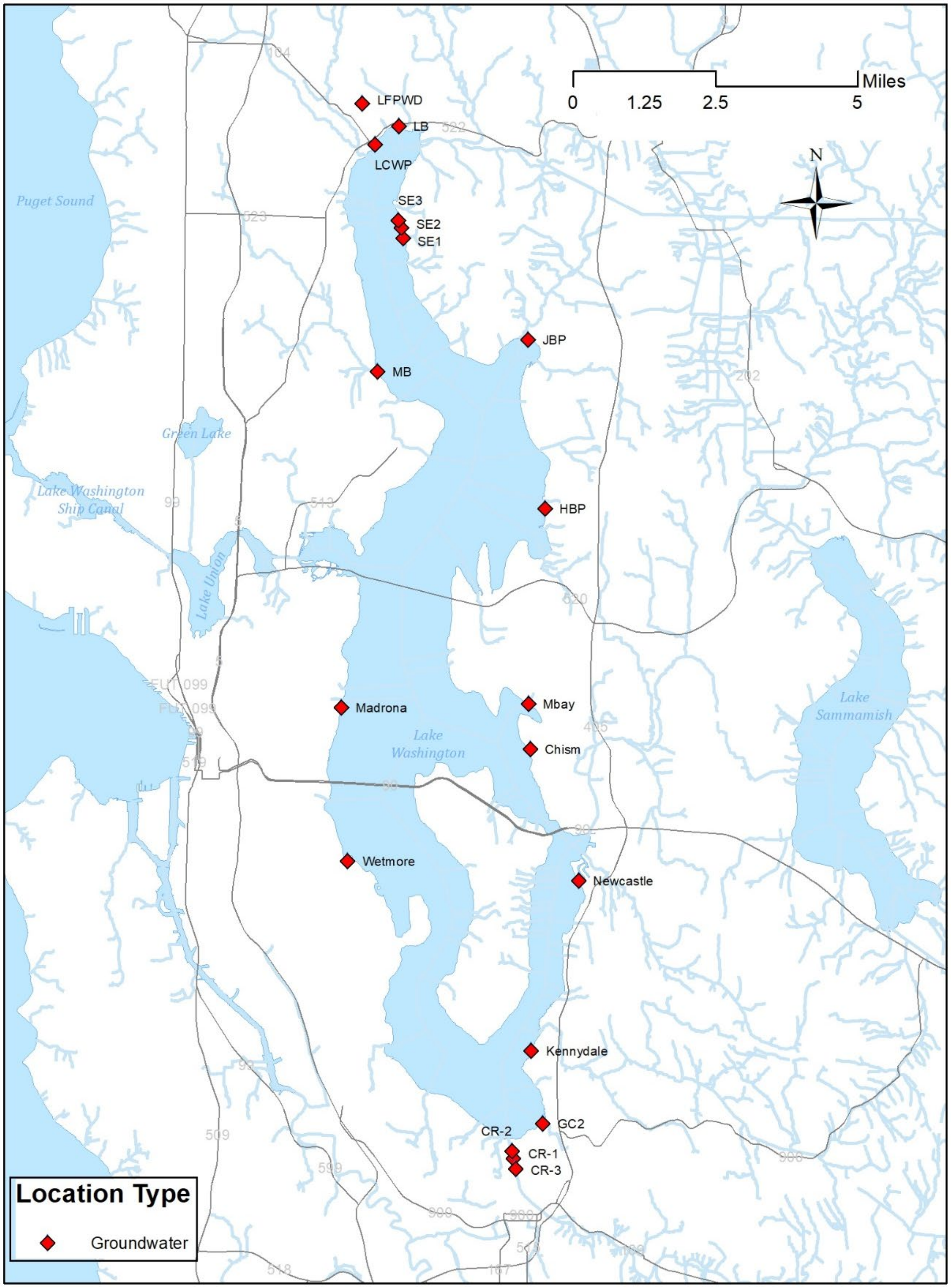

Figure 2. Map of Phase 1 groundwater sampling sites surrounding Lake Washington.

Phase 1 Results

Results from Phase 1 showed PFAS detections to be widespread within the study area (Figure 3). PFAS were detected in 224 of 226 samples, which consisted of lake, tributary, groundwater, stormwater, and bulk atmospheric deposition samples collected during multiple sampling events. The two exceptions were one sample from Cedar River (CR-Landsburg site) during summer and one bulk atmospheric deposition sample in winter.

Total PFAS concentrations (sum of 40 PFAS analytes) were similar across lake sites, with a median concentration of 15.1 ng/L (Table 2). In the tributaries, concentrations were more variable, ranging from non-detect in one sample from the Cedar River (CR-Landsburg) to 134 ng/L in Fairweather Creek (Table 2, Appendix A). The highest concentration in the sediments was observed in Ravenna Creek (50.6 ng/g), which had PFAS levels over 10 times higher than in other tributary sediment samples.

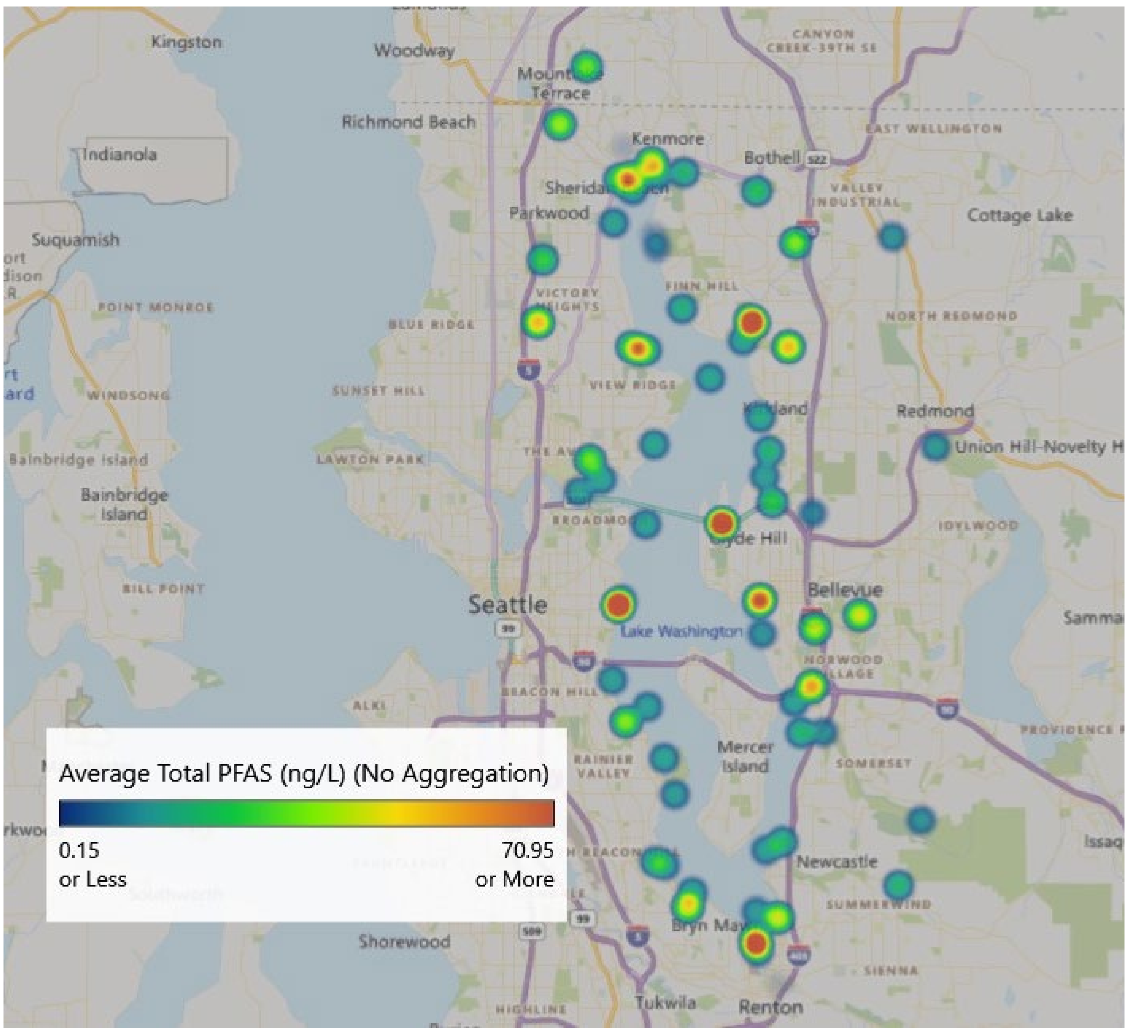

Figure 3. Heat map of total PFAS concentrations in lake, tributary, and groundwater sample locations surrounding Lake Washington.

Average total PFAS refers to the average of results from two sampling events for tributary and lake locations, as well as the results from a single sampling event for groundwater.

Table 2. Total PFAS, PFOS, and PFOA concentration ranges detected in samples collected during Phase 1 of this project by location type.

Concentrations are given as minimum - maximum (median).

Location Type	Sample Matrix	Total PFAS	PFOS	PFOA
Lake	Water (ng/L)	12.3 - 20.8 (15.1)	2.3 - 3.6 (2.9)	1.3 - 2.1 (1.7)
Lake	Sediment (ng/g)	0.91 - 16.9 (4.7)	0.27 - 3.6 (0.69)	ND - 0.22 (0.06)
Tributary	Water (ng/L)	ND - 134 (23.2)	ND - 15.5 (3.6)	ND - 25.6 (2.8)
Tributary	Sediment (ng/g)	0.05 - 50.6 (0.91)	0.03 - 1.0 (0.27)	ND - 0.30 (0.04)
Tributary	Biofilm (ng/g)	0.06 - 0.85 (0.32)	ND	ND
Groundwater	Water (ng/L)	0.23 - 105 (28.4)	ND - 14.1 (3.2)	ND - 19.3 (2.7)
Stormwater	Water (ng/L)	13.3 - 115 (30.8)	ND - 22.2 (3.6)	ND - 19.4 (3.8)
Atmospheric Deposition	Water (ng/L)	ND - 10.8 (2.0)	ND	ND - 0.58 (0.13)

ND = Non-detect

Among the tributaries, the Sammamish River had the highest estimated instantaneous total PFAS loads from our summer and spring sampling, followed by the Cedar River (Figure 4). The Sammamish River instantaneous loads represent sampling site SR-145th. This site is upstream of Swamp, North, and Little Bear Creeks which flow into the Sammamish River further downstream. Therefore, the Sammamish River instantaneous load estimates do not account for any potential loadings from these tributaries to the Sammamish River before the river enters Lake Washington.

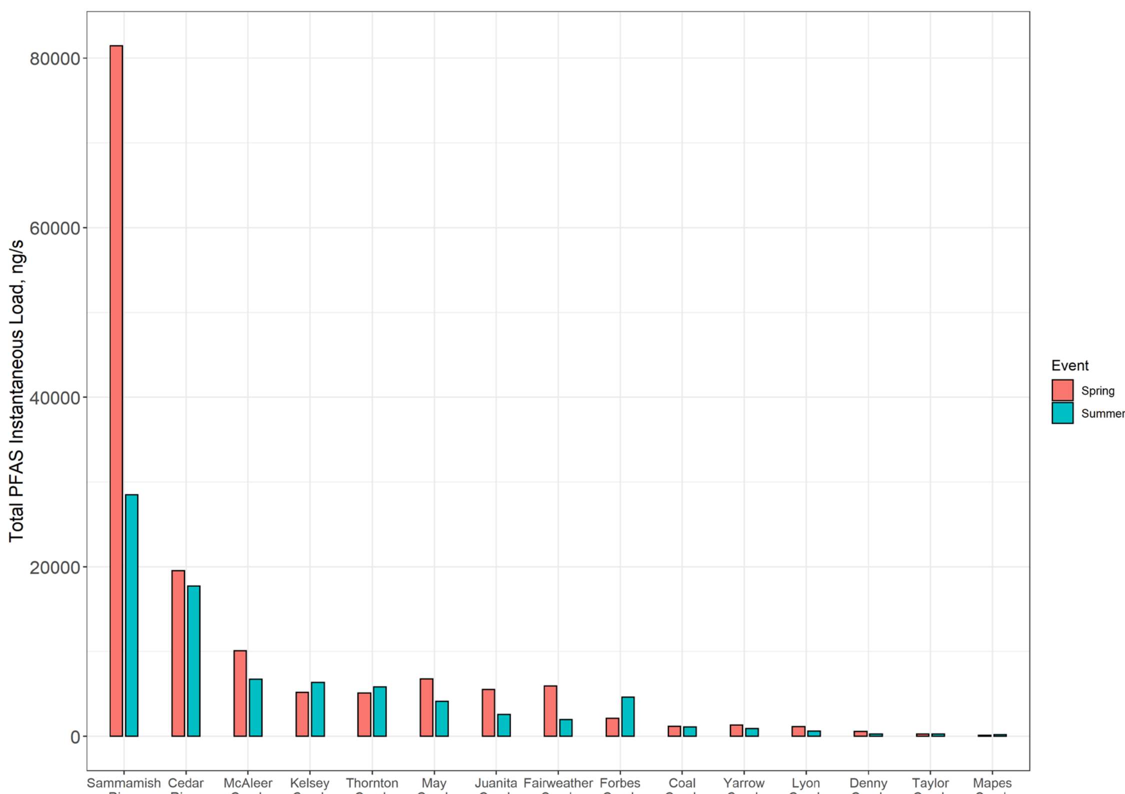

Figure 4. Phase 1 results showing total PFAS instantaneous loads in the sampled tributaries to Lake Washington.

The Sammamish River (at SR-145th) contributed about 35% and 56% of the combined tributary instantaneous total PFAS loads during our summer and spring sampling, respectively. The small tributaries sampled (excluding Sammamish and Cedar Rivers, and excluding Ravenna Creek for which we did not measure flow) collectively contributed about 44% and 31% of the total tributary instantaneous loads from our summer and spring sampling, respectively. Among the smaller tributaries, total PFAS load was correlated to flow (Figure 5).

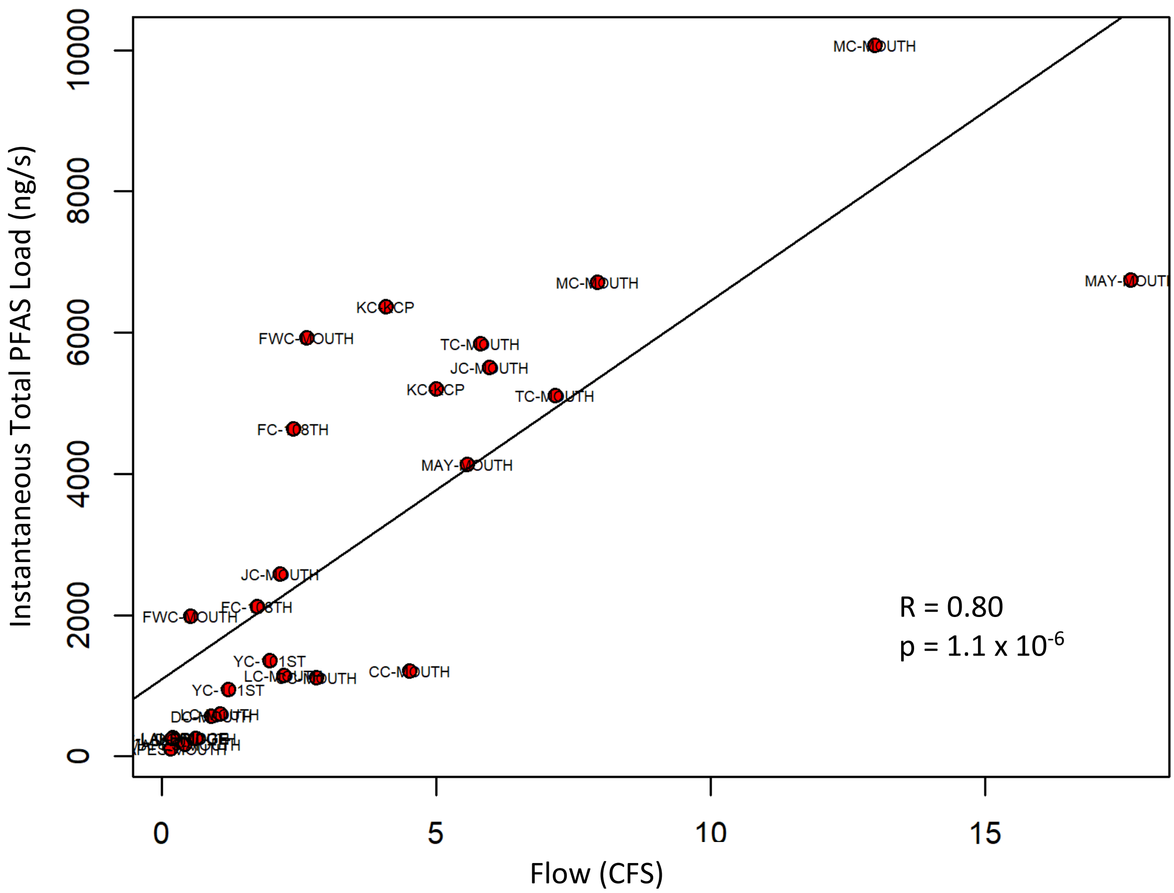

Figure 5. Scatter plot showing correlation (Pearson) between streamflow and total PFAS instantaneous load in the small tributaries.

Among all Phase 1 samples, 32 of 40 PFAS analytes were detected. The 8 analytes not detected in any samples included:

- PFDoS
- 11Cl-PF3OUdS (F53B Major)
- 9Cl-PF3ONS (F53B Minor)
- 4:2 FTS
- 5:3 FTCA
- HFPO-DA (GenX)
- PFEESA
- PFMBA

Lake and tributary surface water samples consistently had high relative concentrations of PFBA, PFPeA, PFHxA, and PFOA (C4, 5, 6, and 8 perfluorocarboxylic acids [PFCAs]), as well as PFBS, PFHxS, and PFOS (C4, 6, and 8 perfluorosulfonic acids [PFSAs]) across the sites (Figure 6). In contrast, lake and tributary sediment samples consistently had relative high concentrations of perfluoroalkane sulfonamido substances (N-MeFOSE, MeFOSAA, EtFOSAA), longer chain PFSAs (C8 and C10), and longer chain PFCAs (C10-13).

Stormwater samples also consistently had high relative concentrations of C4, 5, 6, and 8 PFCAs and C4, 6, and 8 PFSAs. But stormwater samples also had more detections and greater proportion of precursors (perfluoroalkane sulfonamido and fluorotelomer substances—compounds that can transform to PFSAs or PFCAs), as well as long chain PFAS, than in surface water samples. Runoff samples from the 520 bridge were primarily composed of PFCAs.

PFAS, primarily consisting of PFCAs, were detected in bulk atmospheric deposition samples. Biofilm samples also primarily consisted of long chain PFCAs, although 6:2 FTS had the highest relative concentration in two of the six biofilm samples.

In the groundwater samples, total PFAS concentrations were variable, ranging from 0.23–105 ng/L. PFAS composition in groundwater samples also had consistently high relative concentrations of C4, 5, 6 and 8 PFCAs as well as C4, 6, and 8 PFSAs across sites. Relative concentration and frequency of PFCA detections decreased with carbon chain lengths longer than C8, with no C13 or C14 detected. C9 and greater PFSAs were not detected in groundwater samples. Generally, the longer the carbon chain length, the higher the sorption affinity to aquifer solids. Shorter-chain PFAS are more mobile in groundwater and may represent the leading edge of a PFAS plume (greater distance from a source), whereas, the presence of long-chain PFAS may indicate relative proximity to a source. Groundwater samples had minimal contribution of precursors but had frequent detections of the precursor perfluorooctane sulfonamide (PFOSA).

These Phase 1 results show that PFAS are widespread in the study area, with consistencies in PFAS composition across lake, tributary, groundwater, and stormwater samples. This may suggest contributions from sources that are diffuse in nature. In some samples, results also showed PFAS composition that suggested localized inputs not consistent with diffuse sources.

Phase 2

In Phase 2 of this project, we will focus sampling in subbasins of the Lake Washington watershed where we found some of the highest PFAS concentrations and loadings during Phase 1. This will be an effort to identify and characterize potential PFAS sources and pathways within those subbasins.

Section 7 of this addendum describes our sampling design for Phase 2.

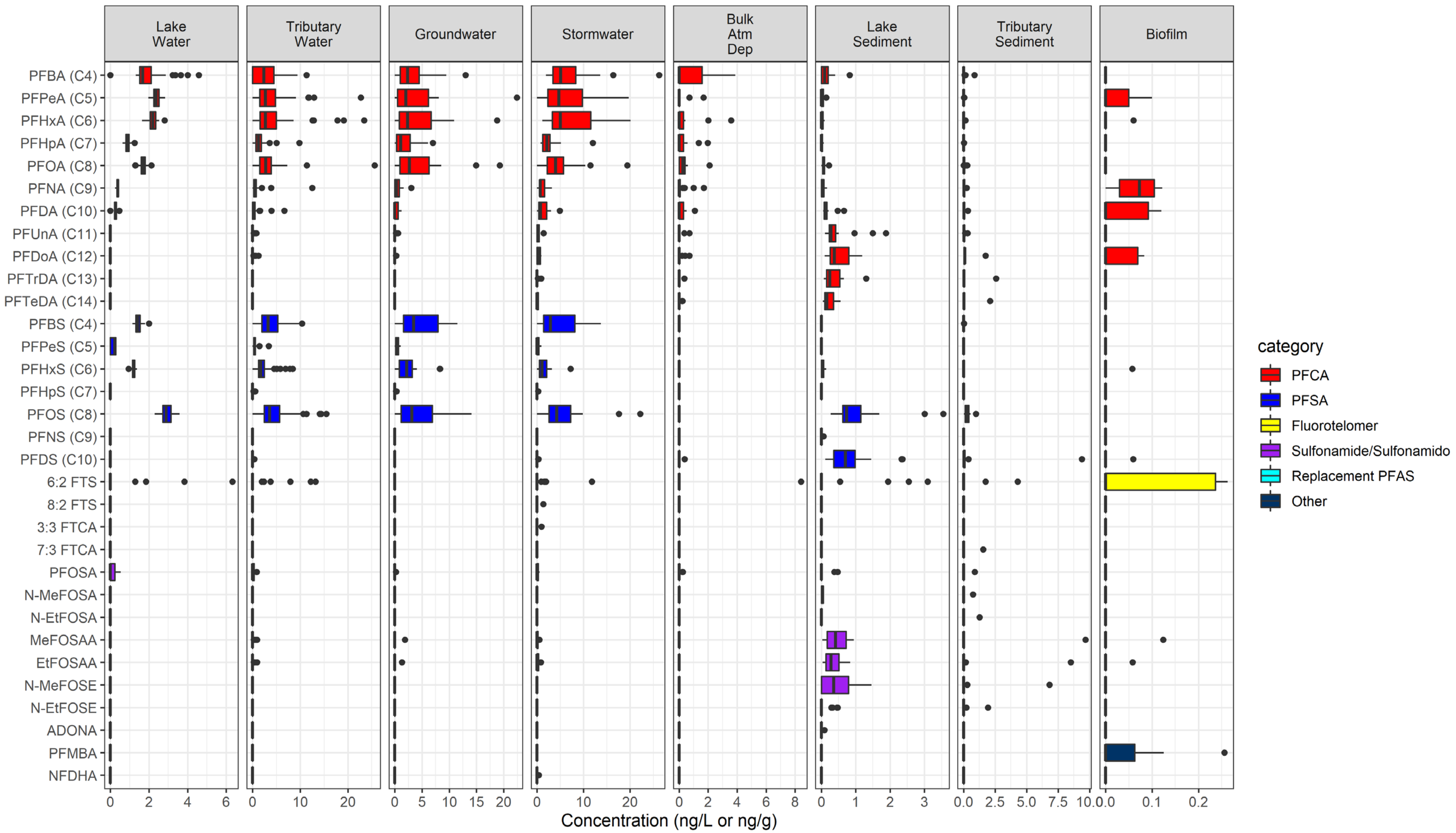

Figure 6. Box plots summarizing PFAS analyte composition by location type and sample matrix.

Each box plot represents the distribution of data among all Phase 1 sampling sites and events for the location type and matrix.
Not shown are the eight analytes that were not detected in the analyzed samples.
Different scales at the bottom of the figure are used to better depict analyte concentrations within each sample matrix.

4.0 Project Description

4.1 Project goal

The overall goal of this study is to identify, characterize, and prioritize the major pathways and sources of PFAS to Lake Washington.

4.2 Project objectives

The objective of Phase 1 was to identify and characterize PFAS concentrations in the lake (water and sediment samples) and potential pathways to the lake (stormwater, tributary, groundwater, and bulk atmospheric deposition).

The objectives of Phase 2 are to (1) focus on source tracing efforts in the subbasins where some of the highest PFAS concentrations or loads were observed in samples collected during Phase 1, and (2) characterize PFAS in potential diffuse sources including stormwater runoff, road dust, and atmospheric deposition.

4.4 Tasks required

Main tasks for Phase 2 are as follows:

- Coordinate any permissions needed for site access and sampling.
- Scout field sites before sampling to determine feasibility of access and sampling.
- Coordinate with laboratories prior to sampling.
- Prepare and decontaminate field equipment.
- Conduct sampling according to QAPP addendum (See Sections 7–8 of this addendum).
- Ship samples to labs for analysis of PFAS and general chemistry.
- Review and assess lab data quality.
- Enter Phase 2 data into Ecology's s Environmental Information Management (EIM) database.
- Conduct data analysis and write final report documenting both Phase 1 and 2 results.

5.0 Organization and Schedule

5.4 Proposed project schedule

Field sampling for Phase 2 is anticipated to begin during summer 2022. Estimated due dates for Phase 2 project tasks are provided in Tables 3-5.

Table 3. Schedule for completing field and laboratory work.

Task	Due date	Lead staff
Field work completed	May 1, 2023	Siana Wong/Diane Escobedo
Lab analyses completed	June 15, 2023	MEL/Contract Lab
Data validation completed	Nov. 30, 2023	MEL QA Coordinator/Data Validation Chemist

Table 4. Schedule for data entry

Task	Due date	Lead staff
EIM data loaded*	May 31, 2024	Siana Wong/Diane Escobedo
EIM QA	June 30, 2024	Diane Escobedo
EIM complete	July 31, 2024	Siana Wong

*EIM Project ID: SWON0003
EIM: Environmental Information Management database

Table 5. Schedule for final report

Task	Due date	Lead staff
Draft to supervisor	March 31, 2024	Siana Wong
Draft to client/ peer reviewer	April 30, 2024	Siana Wong
Final draft to publications team	May 31, 2024	Siana Wong
Final report due on web	July 31, 2024	Siana Wong

5.5 Budget and funding

Table 6. Estimated laboratory costs for Phase 2.

Contract Lab Samples Total:	$33,375
Contract Lab Fee Total (30%):	$10,013
MEL Samples Total:	$169,100
MEL Level 4 Data Validation Fee (20%):	$30,500
GRAND TOTAL:	**$242,988**

Table 7. Estimated lab costs by parameter and sample matrix.

Parameter	Sample Type	Sample Matrix	Number of Samples	Number of Field QC Samples[1]	Number of Billable Lab QC Samples[2]	Cost Per Sample	Subtotal	Laboratory
PFAS	Surface Water	Water	84	17	10	$500	$55,500	MEL
PFAS	Groundwater	Water	98	20	12	$500	$65,000	MEL
PFAS	Stormwater	Water	2	2	0	$500	$2,000	MEL
PFAS	Surface Runoff	Water	13	2	2	$500	$8,500	MEL
PFAS	Bulk Atmospheric Deposition	Water	12	18	3	$500	$16,500	MEL
PFAS	All Water[3]	Water	30	NA	NA	$500	$15,000	Contract Lab
PFAS	Biofilm	Tissue	6	1	NA	$500	$3,500	Contract Lab
PFAS	Macroinverte brate	Tissue	6	1	NA	$500	$3,500	Contract Lab
PFAS	Suspended Sediment	Solids/ Sediment	6	1	NA	$500	$3,500	Contract Lab
PFAS	Road Dust	Solids/ Sediment	13	1	NA	$500	$7,000	Contract Lab
PFAS	Opportunistic	Water	10	0	NA	$500	$5,000	MEL
Grain Size	Suspended Sediment	Solids/ Sediment	6	1	NA	$125	$875	Contract Lab
TSS	Water	Water	69	7	NA	$15	$1,140	MEL
DOC	Water	Water	167	17	NA	$45	$8,280	MEL
TOC	Water	Water	69	7	NA	$35	$2,660	MEL
TOC	Suspended Sediment/ Road Dust	Solids/ Sediment	18	2	NA	$50	$1,000	MEL
Ash-Free Dry Weight	Biofilm	Tissue	6	1	NA	$40	$280	MEL
Chloride	Groundwater	Water	98	10	NA	$15	$1,620	MEL
Sulfate	Groundwater	Water	98	10	NA	$15	$1,620	MEL

[1] Field quality control (QC) samples refer to: Field duplicate and field blank for PFAS in water; field duplicate for PFAS in solid/sediment and tissue; field duplicate, equipment blank, and rinsate blank for PFAS in Bulk Atmospheric Deposition; and field duplicate for total suspended solids (TSS), total organic carbon (TOC), dissolved organic carbon (DOC), grain size, and ash-free dry weight.

[2] Billable Lab QC for PFAS samples refer to Matrix Spike and Matrix Spike Duplicate.

[3] Split samples will be collected and analyzed for PFAS by a contract lab for about 10% of water samples analyzed by MEL by sample type and event.

6.0 Quality Objectives

6.2 Measurement quality objectives

Phase 2 of this project will require laboratory analysis of PFAS using EPA Draft Method 1633 (EPA 2021), which is a change from what was planned in the original QAPP. Quality control (QC) criteria for Phase 2 will not require compliance with Table B-15 of the U.S. Department of Defense (DoD) Quality System's Manual (QSM) Version 5.3 (DoD/DoE 2019), as had been required for the original QAPP. The analytical lab should be able to meet QC criteria as described in Draft Method 1633.

The reason for the change is the development of a standardized method by the EPA and DoD for analyzing 40 PFAS analytes in non-potable water and other matrices. The method is in draft because it is still undergoing a multi-laboratory validation study. For this reason, QC criteria within Draft Method 1633 are subject to revision after the method validation study is completed.

Lab analysis of PFAS samples collected during Phase 1 was performed by SGS AXYS, using their in-house method for analyzing 40 PFAS analytes by LC-MS/MS with isotopic dilution. The lab's in-house method was used to develop Draft Method 1633. We do not anticipate that the change to requiring Draft Method 1633 will hinder our Phase 2 study goal and objectives. Project-specific measurement quality objectives remain unchanged from Phase 1; these are summarized in Table 8.

Table 8. Project-specific measurement quality objectives (MQOs).

These are unchanged from Phase 1, with the exception that DoD QSM 5.3 criteria are not required for Phase 2, and changes made to surrogate recovery for the specified PFAS compounds in water matrix.

Parameter	Sample Matrix	Lab Duplicate Samples (RPD)	Matrix Spike/ Matrix Spike Duplicate (% Recovery)	Matrix Spike/ Matrix Spike (RPD)	Method Blank	Lab Control Sample (LCS) (% Recovery)	Surrogate Standards (% Recovery)	Limit of Detection
PFAS-Analytes	Water	≤40	50-150	≤30	no analytes detected > ½ LOQ	50-150	50-150[1]	0.1-4.0 ng/L
PFAS-Analytes	Solids/ Sediment	≤40	50-150	≤30	no analytes detected > ½ LOQ	50-150	50-150	0.01-0.4 ng/g dw
PFAS-Analytes	Tissue	≤40	50-150	≤30	no analytes detected > ½ LOQ	50-150	50-150	0.03-1.2 ng/g ww
TSS	Water	≤20	NA	NA	≤RL	80-120	NA	1.0 mg/L (RL)
DOC	Water	≤20	75-125	20	≤RL	80-120	NA	0.5 mg/L (RL)
TOC	Water	≤20	75-125	20	≤RL	80-120	NA	0.5 mg/L (RL)
TOC-440	Solids/ Sediment	≤20	NA	NA	≤RL	80-120	NA	0.10% dw (RL)
Grain Size	Solids/ Sediment	≤20	NA	NA	NA	NA	NA	0.10% (RL)
Ash Free Dry Weight	Biofilm	≤20	NA	NA	NA	NA	NA	10 mg/L (RL)
Chloride	Water	≤20	75-125	20	≤RL	90-110	NA	0.1 mg/L (RL)
Sulfate	Water	≤20	75-125	20	≤RL	90-110	NA	0.3 mg/L (RL)

[1] Surrogate recovery for the following compounds is 40-150%:
13C5-PFBA, 13C5-PFPeA, D5-NEtFOSA, D9-NEtFOSE, D3-NMeFOSA, D2-NMeFOSE, 13C2-PFTeDA, and 13C2-PFDoA

LCS = Laboratory Control Sample

LOQ = Limit of Quantitation

RL = Reporting Limit

RPD = Relative Percent Difference

7.0 Study Design

7.2 Field data collection

7.2.1 Sampling locations and frequency

The overall Phase 2 sampling design is summarized below and described further in this section:

- Source Tracing
  - Conduct intensive sampling in three "focus" tributary subbasins in which among the highest PFAS concentrations or loads were found during Phase 1.
  - Conduct one-time surface water grab sampling in four additional subbasins in which among the highest PFAS concentrations or loads were found during Phase 1.
  - Conduct focused groundwater sampling in one additional subbasin not included in Phase 1 sampling.
  - Conduct focused groundwater sampling in lake shoreline areas where among the highest PFAS concentrations were found during Phase 1.
- Diffuse Source Characterization
  - Sample runoff and road dust in the three focus subbasins and the 520 bridge.
  - Sample bulk atmospheric deposition in two locations.
- Additional Sampling
  - Revisit three open water sites in Lake Washington to collect surface water samples.
  - Conduct follow-up sampling of two stormwater sites from Phase 1.
  - Collect up to 10 opportunistic samples to assess impacts from potential PFAS sources within the watershed.

Subbasin and Site Selection

Because of our available resources, we selected seven subbasins for sampling (Table 9). Although the Sammamish River had the highest tributary instantaneous loads to Lake Washington during our Phase 1 sampling, we chose not to include this subbasin in Phase 2 because of its large geographic size and complexity. Instead, we chose to sample seven smaller subbasins, which collectively represented appreciable PFAS instantaneous load contributions to the lake. Future assessments may be necessary to address PFAS sources entering the lake from the Sammamish River.

Within each subbasin, our final site selection will be based on a combination of desktop research of potential PFAS sources within the watershed, local knowledge about feasible sampling locations, satellite imagery to evaluate site accessibility, publicly available land use and zoning maps, and field scouting. We are planning for sampling locations to be (1) upstream near tributary headwaters, (2) downstream near the outlet to Lake Washington, (3) upstream/downstream of potential sources, and (4) midpoint between tributary headwaters and outlet to Lake Washington. This plan will increase the resolution of sampling sites in each tributary and bracket where PFAS loads may be coming from. We also plan to sample the original Phase 1 sampling sites within each subbasin.

A list of Phase 2 sampling sites and rationale for sampling is shown in Appendix B, and a map of sites is provided in Appendix C. Groundwater sampling sites will generally coincide with surface water sites for select subbasins, with adjustments based on local hydrogeology and further field reconnaissance. If the planned site cannot be sampled because of accessibility or other issues, we will find a suitable alternative site.

Table 9. List of selected subbasins to be sampled during Phase 2, and general land use characteristics (Source: King County Stream Report[1]). Qualitative descriptions of major developed land uses are also provided.

Subbasin	Agricul-ture	Developed	Forest	Scrub	Wet-lands	Other	Approximate Subbasin Area (acres)
Cedar River	<1%	13% (Commercial, industrial, residential downstream)	70% (mostly upstream)	10%	2%	>4%	120,320
Juanita Creek	0%	88% (Residential, Commercial)	10%	<1%	1%	<1%	4,000
Thornton Creek	0%	96% (N. Branch – mostly residential; S. Branch – mostly commercial upstream, mostly residential downstream)	3%	<1%	<1%	<1%	7,402
Fairweather Creek	na*	na (Commercial, residential)	na	na	na	na	600
Kelsey Creek	0%	86% (Commercial, residential)	12%	<1%	<2%	<1%	10,870
McAleer Creek	0%	92% (Residential)	6%	<1%	<1%	<2%	5,700
Ravenna Creek	na	na	na	na	na	na	na

*na: Reference source could not be found

Source Tracing

Focus Tributary Subbasins: Cedar River, Juanita Creek, and Thornton Creek

The Cedar River, Juanita Creek, and Thornton Creek subbasins were selected as our three focus tributary subbasins because PFAS concentrations and/or loads within these subbasins were among the highest of samples collected during Phase 1 (Figure 4, Appendix A), and also because they have characteristics of various land use categories (Table 9) that are important to investigate in Phase 2.

In these subbasins, we will use an intensive and holistic approach, similar to our approach in Phase 1, that includes (1) sampling different media during multiple sampling events, and (2) measuring ancillary parameters. In addition to source tracing, the purpose of using a broader sampling approach in these subbasins is to gain a better understanding about fate and transport of PFAS in the environment.

[1] King County Stream Report: https://green2.kingcounty.gov/streamsdata/WaterShedInfo.aspx

In these subbasins, we will collect tributary surface water samples, suspended sediment samples, and groundwater samples during one summer low-flow event and one spring high-flow event (Table 10). Groundwater samples will be co-located at a subset of surface water sites if the site is located in a groundwater discharge area. We will also consider alternative groundwater sampling locations such as nearby springs, monitoring wells, or water supply wells. Suspended sediment samples will be collected from one suitable location in each of the three tributaries. This will be determined during field scouting.

Table 10. General schedule of Phase 2 sampling activities.

Sampling Activity	Aug-Sept 2022	Oct-Dec 2022	Jan-Mar 2023	Apr-May 2023
Tributary (Focus subbasins)	Surface water (24 sites) Groundwater (35 sites) Suspended sed. (3 sites) Biofilm (6 sites) Invertebrates (6 sites)	Surface water (3 sites; 1 storm event)	Surface water (3 sites; 2 storm events)	Surface water (24 sites) Groundwater (35 sites) Suspended sed. (3 sites)
Tributary (one-time grab samples)	Surface water (24 sites)	None	None	None
Lake Washington	Surface water (3 sites)	None	None	None
Stormwater Runoff & Road Dust	Road dust (13 sites)	Stormwater runoff (13 sites)	None	None
Bulk Atmospheric Deposition	2 sites	2 sites; 2 events	2 sites; 2 events	2 sites
Groundwater (Shoreline)	7 sites	None	None	7 sites
Groundwater (Ravenna subbasin)	6 sites	None	None	6 sites

In the Cedar River, we plan to collect biofilm and invertebrate samples once during the summer at a subset of six surface water locations. The purpose of sampling the biota is to provide information on potential bioaccumulation of PFAS analytes in food sources of fish. Although we sampled biofilm during Phase 1, we plan to resample this media because it may be useful as a source tracing tool as part of our Phase 2 objective in the Cedar River, where surface water concentrations were relatively low. If biofilm and invertebrates are not available to sample at a planned site on the Cedar River, we will select an alternative site. If there are no suitable alternative sites that can be sampled for biofilm or invertebrates, we will not collect the sample.

We will not sample biofilm or invertebrates in Juanita and Thornton Creeks because we had difficulty finding biofilm at our sampling sites in these tributaries during Phase 1.

During three storm events, we will collect surface water grab samples at the outlet locations of the Cedar River, Juanita Creek, and Thornton Creek, as was done in Phase 1, in order to compare and assess PFAS concentrations and loads during storm events.

Water samples for analyses of conventional parameters will be collected concurrently with PFAS samples to provide supporting environmental data. These parameters include total organic carbon (TOC), dissolved organic carbon (DOC), and total suspended solids (TSS). Also, water temperature, conductivity, pH, and dissolved oxygen will be measured at each tributary site using a multiparameter sonde. For suspended sediment, we will collect concurrent samples for TOC and grain size analyses (if there is sufficient substrate). For biofilm, we will collect additional samples for analysis of ash-free dry weight to estimate biomass.

One-time Grab Sampling: Fairweather, Kelsey, McAleer, and Ravenna Creek Subbasins

We will conduct sampling in four additional subbasins in which relatively high PFAS concentrations and/or loads were detected during Phase 1: Fairweather, Kelsey, McAleer, and Ravenna Creek subbasins. In these subbasins, we will collect only surface water samples for PFAS analysis during one sampling event in summer (with the exception of Ravenna Creek, in which groundwater samples will also be collected).

Although a less holistic sampling approach will be used, we included these four subbasins for one-time grab sampling because there is good opportunity to bracket and identify potential PFAS sources through upstream-downstream water sample collection.

Groundwater Sampling

We will sample about 30-40 sites in the three focus subbasins (Cedar River, Juanita Creek, and Thornton Creek), depending on discharge zone variability, difficulty of piezometer/PushPoint sampler insertion, groundwater flow patterns, and access to existing monitoring and/or supply wells. Sampling locations will generally coincide with tributary surface water sampling sites if sites are located in an area of groundwater discharge. However, additional groundwater sampling sites will be selected within the higher density urban corridor of the lower Cedar River, where relatively higher PFAS concentrations were detected in surface water during Phase 1.

In addition to the focus subbasin sampling, we will include groundwater sampling in the Ravenna Creek subbasin. Groundwater samples were not collected in this subbasin during Phase 1. Groundwater sampling is included in Phase 2 because (1) previous results and historic land use suggest a potential source near the outlet of the Ravenna Creek, and (2) we have received permission to access and sample monitoring wells on-site. We will sample a subset of tributary surface water sampling sites, existing monitoring wells located in the presumed upgradient direction of Ravenna Creek, and one site from Sulfur Spring in Ravenna Park. Samples will be collected once during the late summer/early fall and once in the spring to capture seasonal variability.

We will conduct groundwater sampling along the Lake Washington shoreline at two Seattle locations: Madrona Beach and Wetmore Slough (Figure 2), in which relatively high PFAS concentrations were observed in groundwater during Phase 1. We will resample the two Phase 1 sites to capture inter-annual variability. We will bracket Phase 1 sample sites along the shoreline and collect an upland sample if feasible. Sampling will occur once during the late summer/early fall and once in the spring to capture seasonal variability. Also, we will sample two springs discharging upland of the shoreline in the Madrona Beach area.

Groundwater geochemistry could affect PFAS sorption to aquifer solids and, therefore, could affect PFAS mobility in the aquifer. A 2019 study evaluating PFAS occurrence in drinking water in the eastern United States found concentrations of DOC, sulfate, and chloride, among other geochemical parameters, to be significantly higher in samples containing PFAS detections (McMahon et al 2022). We will collect samples for analysis of DOC, chloride, and sulfate, as well as PFAS samples to evaluate the relationship between the geochemistry of the aquifer and PFAS detections. Groundwater temperature, conductivity, pH, dissolved oxygen, oxidation reduction potential, and turbidity will be measured at each groundwater sampling site using a multiparameter sonde.

Diffuse Source Characterization

Stormwater Runoff and Road Dust

The purpose of collecting stormwater runoff and road dust samples is to document PFAS concentrations and composition in these sample types, which will be collected from four different land use categories within the three focus subbasins. These data will help us to further characterize and evaluate stormwater runoff from paved surfaces as a pathway of PFAS to Lake Washington.

In each of the three focus subbasins, Cedar River, Juanita Creek, and Thornton Creek, we will collect stormwater runoff and road dust samples from paved surfaces, such as parking lots, in public access areas representing different land use categories: commercial, industrial, high-density residential, and low-density residential. We will also collect one runoff and road dust sample from the 520 bridge. Runoff samples and road dust samples will be collected from generally the same locations. The specific locations will be determined after scouting suitable sites and before sampling begins.

We will collect four road dust samples once during the summer in each of the three subbasins at the selected sites and from the 520 bridge (13 total samples). We plan to sample just prior to scheduled municipal street sweeping surrounding the selected sites to capture materials that have accumulated before street sweeping. Samples for analysis of TOC will be collected concurrently with PFAS road dust samples.

We will collect four stormwater runoff samples in each of the three focus subbasins and from the 520 bridge (13 total samples). Water samples for analysis of TOC, DOC, and TSS will be collected concurrently with PFAS samples. We will keep the same criteria for stormwater events as was used for Phase 1. Conditions for a qualifying storm event will be defined as at least 0.2 inches of rainfall, following a minimum antecedent dry period of <0.05 inches rainfall in the last 48 hours. As much as practical, we plan to sample during the first flush period, or within 12 hours of the storm event. If this is not possible for all 13 sample sites, we propose to sample different storm events for each subbasin.

Bulk Atmospheric Deposition

Bulk atmospheric deposition samples will be collected from two locations, Ecology's Beacon Hill air monitoring station in Seattle and Ecology's air monitoring station in North Bend. The Beacon Hill site is the same site used for bulk atmospheric deposition sampling during Phase 1. For Phase 2, we added a second site in North Bend to compare PFAS concentrations in samples from outside the urban growth boundary surrounding Lake Washington. For reference, North Bend's urban growth area is about 6 square miles (City of North Bend 2015), a fraction of King County's total urban growth area of about 460 square miles (King County 2021). Most of these 460 square miles includes the urban areas surrounding Lake Washington and along the Interstate-5 and 405 corridors.

As during Phase 1, bulk atmospheric deposition samplers will be deployed for about 7-21 days during a total of six deployments from summer 2022 through spring 2023. The length of deployment will depend on the amount of precipitation received during the deployment period; this will ensure the collection containers do not overfill.

Additional Sampling

Lake Sampling

We will collect surface water samples from three Lake Washington basin sites that were sampled during Phase 1: Lake-North, Lake-Mid, and Lake-South (Figure 1). During Phase 2, these samples will be collected once during the summer.

Follow-Up Stormwater Sampling

We will sample two Phase 1 stormwater sampling sites that had relatively high PFAS concentrations. One site, located in Bellevue, drains a small single and multi-family residential zoning area directly to the lake in Meydenbauer Bay (total PFAS 115 ng/L). The second site drains runoff from an area of the Renton airport (total PFAS 50 ng/L) to the Cedar River. We will sample these sites once during a qualifying storm event.

Opportunistic Sampling

We will also collect up to 10 “opportunistic” samples to assess impacts from potential PFAS sources and pathways within the watershed. Opportunistic sampling will be based on a feasible opportunity to sample, as well as new information such as recent aqueous film forming foam (AFFF; generally known as one of the major sources of PFAS to the environment) use or spill reports that may impact surface water or groundwater.

Examples of opportunistic samples include:

- Stormwater runoff from the Interstate-90 bridge.
- Water sample collection following a reported AFFF usage or spill. Ecology’s Environmental Report Tracking System will be used to track reports within the Lake Washington watershed. Other sources of information may also be used.
- Stormwater runoff from artificial-turf athletic fields.

7.2.2 Field parameters and laboratory analytes to be measured

The primary analytes of interest continue to be the 40 PFAS analytes, with the analyte list as discussed in the original QAPP (Wong and Mathieu 2021). Conventional parameters will be measured as part of our Phase 2 sampling, as described previously in Section 7.1.1.

7.4 Assumptions underlying design

During Phase 1, we sampled various pathways and environmental media in the Lake Washington watershed over a broad area during the course of one year. Our sampling design for Phase 2 uses several approaches to follow up on results from Phase 1. An underlying assumption is that the data and information collected during both phases will provide multiple lines of evidence to help us identify the significant transport pathways and sources of PFAS to Lake Washington.

7.5 Possible challenges and contingencies

7.5.1 Logistical problems

Logistical challenges for sampling during Phase 2 remain the same as for Phase 1 and are described in more detail in the original QAPP (Wong and Mathieu 2021) and groundwater addendum (Escobedo 2021).

Site access is one challenge. Before sampling, we will conduct field scouting to ensure that planned sampling sites are publicly accessible. For sites that need permission to access and sample, we will obtain permissions before sampling. If permission is denied, we will select an alternative sample site.

During Phase 1, one of the big logistical challenges was timing sampling during a qualifying storm event. Part of this challenge involved the physical distance between Ecology Headquarters in Olympia and the sampling locations in King County. Even with multiple weather forecasts and radar information, it was difficult to predict and time the sampling of a storm event that was occurring 50–70 miles north of Olympia. One solution for Phase 2 may be to stay overnight in King County during the week of an anticipated storm event. This will allow us to (1) visibly see what the weather is doing on location prior to sampling, and (2) be closer to our sampling sites so that we are ready to sample when the storm approaches.

7.5.2 Practical constraints

Practical constraints during Phase 1 included uncertainties associated with the COVID-19 pandemic. During Phase 1, we will follow Ecology guidelines for conducting field work during the pandemic, if pandemic conditions worsen.

7.5.3 Schedule limitations

Coordination with well owners may require adjustment to the sampling schedule for any monitoring well or supply well sampling. Permitting and property access approvals for piezometer installation may cause sampling delays; therefore, the sampling schedule will be adjusted if necessary.

8.0 Field Procedures

We will follow the same Ecology standard operating procedures (SOPs) that we used during Phase 1 for field sampling and guidance for avoiding PFAS cross-contamination. Additional field sampling procedures are described in Section 8.2. Details of field procedures for the following sampling activities are provided in the original QAPP (Wong and Mathieu 2021) and groundwater addendum (Escobedo 2021):

- Steps to minimize the spread of invasive species
- Water sampling in tributaries and lake
- Biofilm sampling
- Bulk atmospheric deposition sampling
- Groundwater sampling using a PushPoint sampler
- Sample containers, preservation, and holding times
- Equipment decontamination
- Sample ID assignments, chain of custody, and field log requirements

8.2 Measurement and sampling procedures

Groundwater Sampling

Monitoring Wells

Groundwater samples will be collected from monitoring wells, using field sampling methods described in Ecology SOP for purging and sampling monitoring wells (Marti 2016). Static water levels will be measured in each well using an electric water level meter prior to sampling. Monitoring wells will be purged and sampled using either a decontaminated stainless steel bladder pump or a peristaltic pump, depending on depth of the well. The intake of the bladder pump or HDPE tubing (for peristaltic pump) will be placed at the midpoint of the saturated screened interval of the well. Purging and sampling will be conducted as described in the groundwater QAPP addendum (Escobedo 2021).

Piezometers

Groundwater samples will be collected from a decontaminated piezometer, using field sampling methods described in Ecology's SOP for installing, monitoring and decommissioning hand driven piezometers (Sinclair and Pitz 2018). Piezometers will be hand driven with a fence post driver or comparable tool in the streambed or riverbed about 1 to 2 meters below the sediment/water interface. Water depth of selected sample sites must be wadeable, safely accessed during all but flood periods, and not be dry during baseflow periods. The piezometers will either be 1/4" inner diameter HDPE polyethylene tubing attached to a steel drive point via a barbed fitting or a 1" diameter galvanized pipe crimped and perforated at the bottom, with HDPE tubing inserted for development, purging, and sampling. The tubing piezometer will be used if it is determined that a lower profile option would be beneficial based on public access to and use of the area.

After installation, a peristaltic pump will be attached to the tubing, and the piezometer will be developed using a surge and pump technique until no sediment appears in the discharge water. This will ensure a good hydraulic connection with the streambed sediments. The piezometers will be allowed to equilibrate for a minimum of one week prior to sampling. Surface-water stage and instream piezometer water levels will be measured using a calibrated electric water level meter or a manometer board, as appropriate. The water level difference between the piezometer and river provides an indication of vertical hydraulic gradient. When the piezometer water level is higher than the river stage, it can be inferred that groundwater is discharging to the river.

Samples will be collected only if groundwater is discharging to the river. Purging and sampling details using a peristaltic pump will be conducted as described the groundwater QAPP addendum (Escobedo 2021). Piezometers will be removed after the spring 2023 sampling.

Water Supply Wells

Groundwater samples will be collected from water supply wells using field sampling methods described in Ecology's SOP for collecting groundwater samples for organic compounds from water supply wells (Marti, *in publication*). Water supply well samples will be collected as close to the wellhead as possible. If possible, the sample will be collected before passing through any storage tank or treatment system. The wells will be purged using a decontaminated Y-fitting attached to a spigot. One outlet of the fitting will be connected to a garden hose and set to a high discharge rate so that the well can be purged quickly. The other outlet will be connected to a flow-cell set to a low flow rate of about 300-400 milliliters per minute.

Field measurements will be collected using a flow-through cell and multiparameter sonde. Stabilization parameters are included in Table 7 of the 2021 groundwater QAPP addendum (Escobedo 2021). After purging is complete, the flow cell will be disconnected and the sample will be collected using a decontaminated connector and new high density polyethylene (HDPE) tubing.

Macroinvertebrate Sampling

Macroinvertebrates will be collected by picking them from rocks or substrate at a subset of water and biofilm sampling sites along the Cedar River. If this method is inefficient for obtaining sufficient sample, an alternative approach will be to use a standard kicknet (Adams 2010). The number and location of macroinvertebrate samples will be based on whether enough sample can be collected at the site. We plan to target the same genus at each collection site, likely within the order *Trichoptera* (caddisflies).

A field scale will be used to measure at least 2 grams of soft issue for lab analysis of PFAS. Samples will be scooped into a PFAS-free wide-mouth HDPE jar provided by the lab. Tissue samples will be homogenized before freezing and shipping them to the lab.

Road Dust Sampling

Road dust samples will be collected from paved surfaces using field sampling methods adapted from Van Metre et al. (2008). A decontaminated PFAS-free brush and dust pan (stainless steel, or lined with clean Reynolds ® heavy duty aluminum foil) will be used to collect samples. A new brush will be used for each site. Samples will be collected as a composite of at least 10 spots within the vicinity of the sample site. At each spot, a pre-determined area will be swept. An apparatus with an area of 1 or 4 square meters will be used to estimate and document the area swept. The composited sweepings will be poured through a decontaminated 0.5 mm stainless steel mesh sieve into a decontaminated stainless steel bowl to remove course sand, gravel, and other debris. The composited sweepings (at least 5 grams) will be mixed using a decontaminated stainless steel spoon, and then scooped into one PFAS-free wide-mouth HDPE jar provided by the lab. Sample material will also be scooped into a separate container for TOC analysis.

Stormwater Runoff Sampling

Stormwater runoff samples will be collected during a qualifying storm event from the same general locations and paved surfaces in which road dust samples are collected. Sampling procedures will be adapted from Ecology SOP and guidance documents for stormwater sampling (Lowe et al. 2009, Ecology 2015). If there is an on-site catch basin that is feasible to sample, water will be collected directly from the catch basin using the sample bottle. Alternatively, sheet runoff may be collected by capturing and funneling water using heavy duty aluminum foil, or by capturing water using a decontaminated stainless steel dust pan or foil-lined dust pan. Water will then be poured into a PFAS-free HDPE sample bottle, and separate containers for TOC, DOC, and TSS analysis.

Suspended Sediment Sampling

Suspended sediment samples will be collected using a decontaminated Hamlin trap deployed in the water over time. Field sampling procedures for the Hamlin trap will follow guidance in Ecology's SOP for collecting stormwater solids (Lubliner et al. 2018). The trap will be deployed in a secure spot, hidden from view and away from popular areas. The traps will be deployed for about four weeks to ensure that enough sediment has accumulated. A mid-point check will be conducted to see if the traps are still secured and are accumulating sediment. Upon retrieval, the accumulated sediment will be scooped into a PFAS-free HDPE wide-mouth sampling container using a decontaminated spoon. If necessary, samples will be decanted or centrifuged back at Ecology Headquarters. If there is sufficient substrate, samples will also be scooped into separate containers for TOC and grain size analyses.

Storing and Shipping of Samples

All PFAS samples will be stored on ice in a cooler during field sampling. When back to Ecology Headquarters, the samples will be stored frozen (-20°C) until shipped to the contract lab for analysis. Samples will be shipped within 60 days of collection.

9.0 Laboratory Procedures

9.1 Lab procedures table

Parameter	Parameter Group	Expected Range of Results	Sample Preparation/ Cleanup	Analytical Method
PFAS Analytes	Water	<0.8-60 ng/L per analyte	SPE[1] / EnviCarb®	EPA Draft Method 1633 (EPA 2021)
PFAS Analytes	Solids/ Sediment	<0.08-10 ng/g per analyte	Methanol shake / EnviCarb® and SPE	EPA Draft Method 1633 (EPA 2021)
PFAS Analytes	Tissue	<0.2-300 ng/g ww per analyte	Methanol shake / EnviCarb® and SPE	EPA Draft Method 1633 (EPA 2021)
TSS	Water	1-300 mg/L	Gravimetric, Dried 103-105C	SM2540D
DOC	Water	<1-10 mg/L	NA	SM5310B
TOC	Water	<1-10 mg/L	NA	SM5310B
TOC	Solids/ Sediment	<0.1-40%	NA	TOC-440/ PSEP 1986
Grain Size	Solids/ Sediment	Gravel: 0-100% Sand: 0-100% Silt: 0-100% Clay: 0-75%	NA	PSEP 1986
Ash-Free Dry Weight	Biofilm	10,000-50,000 mg/L	NA	SM10300C
Chloride	Water	0.1-140 mg/L	NA	EPA 300.0
Sulfate	Water	0.3-170	NA	EPA 300.0

9.4 Labs accredited for methods

As described in Section 6.2, Phase 2 of this project will require the lab to use EPA Draft Method 1633 for analysis of PFAS in non-potable water, solids, and tissue samples; this is a change from the original QAPP. A laboratory waiver will be obtained for analysis of PFAS in water, solid/sediment, and tissue samples using Draft Method 1633 because no labs are currently accredited through Ecology's Laboratory Accreditation Unit for this method.

10.0 Quality Control Procedures

10.1 Table of field and laboratory quality control

Parameter	Sample Matrix	Field Duplicate	Field / Equipment Blank	Lab Duplicate	Laboratory Control Sample (LCS)	Matrix Spike/ Matrix Spike Duplicate (MS/MSD)	Method Blank (MB)	Surrogates
PFAS-Analytes	Water	10% of samples	10% of samples	1/batch	1/batch[1]	1/batch	1/batch	All samples
PFAS-Analytes	Solids/Sediment	10% of samples	10% of samples	1/batch	1/batch	1/batch	1/batch	All samples
PFAS-Analytes	Tissue	10% of samples	10% of samples	1/batch	1/batch	1/batch	1/batch	All samples
TSS	Water	10% of samples	NA	2/batch	1/batch	NA	2/batch	NA
DOC	Water	10% of samples	10% of samples[2]	1/batch	1/batch	1/batch	1/batch	NA
TOC	Water	10% of samples	NA	1/batch	1/batch	1/batch	1/batch	NA
TOC	Solids/Sediment	10% of samples	NA	1/batch	1/batch	NA	1/batch	NA
Grain Size	Solids/Sediment	10% of samples	NA	1/batch	NA	NA	NA	NA
Ash-Free Dry Weight	Biofilm	10% of samples	NA	NA	1/batch	NA	NA	NA
Chloride	Water	10 % of samples	10% of samples	1/batch	1/batch	1/batch	1/batch	NA
Sulfate	Water	10% of samples	10% of samples	1/batch	1/batch	1/batch	1/batch	NA

[1]A batch is a group of 20 or fewer samples of similar matrix, which are prepared and analyzed together.
[2]Groundwater only.

11.0 Data Management Procedures

11.2 Laboratory data package requirements

A Tier 4 data package will be required for Phase 2 of this project. The data package requirements remain the same as the original QAPP, except that DoD QSM Table B-15 criteria will not be required for Phase 2 data.

13.0 Data Verification

13.3 Validation requirements, if necessary

A Stage 4 data validation is required for Phase 2. Data validation will be conducted based on EPA National Functional Guidelines and will use EPA data qualifiers and criteria from EPA Draft Method 1633. Criteria from Table B-15 of DoD QSM version 5.3 will not be required. The data validator will prepare a case narrative that assesses data quality and usability based on EPA National Functional Guidelines, requirements of EPA Draft Method 1633, and also the QAPP for this project (Wong and Mathieu 2021).

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16.0 Appendices

Appendix A. Phase 1 Total PFAS Results for Tributary Surface Water Grab Samples and Groundwater

Location	Location ID	Total PFAS (ng/L) Summer	Total PFAS (ng/L) Spring	Location Type
Coal Creek	CC-MOUTH	14.0	9.5	Tributary
Coal Creek	CC-NEWCASTLE	21.9	2.5	Tributary
Cedar River	CR-CGNA	0.24	0.71	Tributary
Cedar River	CR-LANDSBURG	ND	3.8	Tributary
Cedar River	CR-MOUTH	1.5	1.5	Tributary
Cedar River	CR-USGS GAGE	1.5	1.4	Tributary
Denny Creek	DC-MOUTH	14.3	22.3	Tributary
Forbes Creek	FC-108TH	68.0	43.1	Tributary
Fairweather Creek	FWC-MOUTH	134	79.1	Tributary
Juanita Creek	JC-MOUTH	42.2	32.6	Tributary
Juanita Creek	JC-WINDSOR	40.8	30.8	Tributary
Kelsey Creek	KC-405	54.5	31.4	Tributary
Kelsey Creek	KC-KCP	55.1	36.8	Tributary
Lyons Creek	LC-MOUTH	20.1	18.1	Tributary
Lyons Creek	LC-TERRACE	39.9	28.0	Tributary
Mapes Creek	MAPES-MOUTH	14.9	22.2	Tributary
May Creek	MAY-MOUTH	26.2	13.5	Tributary
May Creek	MAY-NILE	27.7	12.3	Tributary
McAleer Creek	MC-196TH	43.3	34.8	Tributary
McAleer Creek	MC-MOUTH	29.9	27.4	Tributary
Mercer Slough	M-SLOUGH	81.9	35.4	Tributary
Ravenna Creek	RC-WAHKIAKUM	49.8	18.1	Tributary
Sammamish River	SR-145TH	12.7	12.5	Tributary
Sammamish River	SR-96TH	23.2	23.0	Tributary
Sammamish River	SR-MARYMOOR	15.0	12.2	Tributary
Sammamish River	SR-MOUTH	20.9	18.0	Tributary
Taylor Creek	TC-LAKERIDGE	45.8	48.5	Tributary
Thornton Creek	TC-MOUTH	35.5	25.2	Tributary
Thornton Creek	TC-N-10TH	32.6	22.0	Tributary
Thornton Creek	TC-S-5TH	68.9	41.8	Tributary
Yarrow Creek	YC-101ST	27.5	24.5	Tributary
Yarrow Creek	YC-34TH	10.7	9.8	Tributary
Chism Beach	CHISM	-	12.5	Groundwater
Cedar River	CR-1	-	54.8	Groundwater
Cedar River	CR-2	-	39.3	Groundwater
Cedar River	CR-3	-	12.3	Groundwater
Gene Coulon Beach	GC2	-	45.1	Groundwater
Houghton Beach	HBP	-	19.6	Groundwater

Location	Location ID	Total PFAS (ng/L) Summer	Total PFAS (ng/L) Spring	Location Type
Juanita Beach	JBP	-	68.9	Groundwater
Kennydale Beach	KENNYDALE	-	0.23	Groundwater
Log Boom Beach	LB	-	49.9	Groundwater
Lyons Creek Waterfront Preserve	LCWP	-	28.5	Groundwater
Lake Forest Park Water District (artesian wells)	LFPWD	-	1.9	Groundwater
Madrona Beach	MADRONA	-	105	Groundwater
Matthews Beach	MB	-	32.6	Groundwater
Meydenbauer Bay Beach	MBAY	-	60.8	Groundwater
Newcastle Beach	NEWCASTLE	-	19.6	Groundwater
Saint Edwards Beach	SE1	-	6.9	Groundwater
Saint Edwards Beach	SE2	-	1.7	Groundwater
Saint Edwards Beach	SE3	-	2.8	Groundwater
Wetmore Slough	WETMORE	-	37.0	Groundwater

Appendix B. Phase 2 Planned Tributary, Lake, and Bulk Atmospheric Deposition Sampling Sites

Subbasin	Location Name	Location ID	Location Type	Approximate Coordinates (WGS84)	Sample Type	Phase 1 Sampling Site
Cedar River	Cedar River-USGS Gage	CR-USGS-Gage	Tributary	47.482306, -122.202778	Surface Water, Biofilm, Invertebrates	x
Cedar River	Cedar River-Riverview Park	CR-RVP	Tributary	47.476822, -122.179810	Surface Water, Biofilm, Invertebrates	
Cedar River	Cedar River-Ron-Regis Park	CR-RRP	Tributary	47.4696330, -122.1504774	Surface Water	
Cedar River	Cedar River-Cedar River Park	CR-CRP	Tributary	47.465538, -122.125549	Surface Water	
Cedar River	Cedar River-Cedar Grove Natural Area	CR-CGNA	Tributary	47.462542, -122.089053	Surface Water, Biofilm, Invertebrates	x
Cedar River	Cedar River-Larry Phillips Natural Area	CR-LPNA	Tributary	47.439825, -122.064098	Surface Water	
Cedar River	Cedar River-Fred V. Habenicht Rotary Park	CR-FVHRP	Tributary	47.405517, -122.038204	Surface Water, Biofilm, Invertebrates	
Cedar River	Cedar River-Landsburg Park	CR-Landsburg	Tributary	47.374945, -121.971843	Surface Water, Biofilm, Invertebrates	x
Cedar River	Cedar River-Chester Morse Lake	CR-CML	Tributary	47.369907, -121.624436	Surface Water, Biofilm, Invertebrates	
Juanita Creek	Juanita Creek-Mouth	JC-Mouth	Tributary	47.705022, -122.216747	Surface Water	x
Juanita Creek	Juanita Creek-NE 129th Dr	JC-NE129th	Tributary	47.716194, -122.207317	Surface Water	
Juanita Creek	Juanita Creek-NE 132nd	JC-NE132nd	Tributary	47.719294, -122.203153	Surface Water	
Juanita Creek	Juanita Creek-Windsor Vista Park	JC-Windsor	Tributary	47.730768, -122.194051	Surface Water	x
Juanita Creek	Juanita Creek-Source	JC-Source	Tributary	47.73546, -122.17933	Surface Water	
Thornton Creek	Thornton Creek-Mouth	TC-Mouth	Tributary	47.695957, -122.275806	Surface Water	x
Thornton Creek	Thornton Creek-Below Meadow Brook Pond	TC-Below MBP	Tributary	47.704678, -122.285424	Surface Water	

Subbasin	Location Name	Location ID	Location Type	Approximate Coordinates (WGS84)	Sample Type	Phase 1 Sampling Site
Thornton Creek	Thornton Creek-North Branch-Above Meadow Brook Pond	TC-N-Above MBP	Tributary	47.708299, -122.289946	Surface Water	
Thornton Creek	Thornton Creek-North Branch-10th Ave NE	TC-N-10TH	Tributary	47.725131, -122.319932	Surface Water	x
Thornton Creek	Thornton Creek-North Branch-Twin Ponds	TC-N-Twin	Tributary	47.7385022, -122.3294508	Surface Water	
Thornton Creek	Thornton Creek-North Branch-Ronald Bog	TC-N-Ronald	Tributary	47.7549110, -122.3323479	Surface Water	
Thornton Creek	Thornton Creek-South Branch-Above MBP	TC-S-Above MBP	Tributary	47.70689, -122.29608	Surface Water	
Thornton Creek	Thornton Creek-South Branch-Kingfisher Natural Area	TC-S-KNA	Tributary	47.7032554, -122.3095756	Surface Water	
Thornton Creek	Thornton Creek-South Branch-5th Ave NE	TC-S-5TH	Tributary	47.704162, -122.322302	Surface Water	x
Thornton Creek	Thornton Creek-South Branch-Barton Woods	TC-S-Barton	Tributary	47.70302, -122.33197	Surface Water	
Fairweather Creek	Fairweather Creek-Mouth	FWC-Mouth	Tributary	47.636766, -122.230779	Surface Water	x
Fairweather Creek	Fairweather Creek-NE 24th	FWC-NE24th	Tributary	47.632801, -122.230560	Surface Water	
Fairweather Creek	Fairweather Creek-Overlake	FWC-Overlake	Tributary	47.630767, -122.228764	Surface Water	
McAleer Creek	McAleer Creek-Mouth	MC-Mouth	Tributary	47.752079, -122.281876	Surface Water	x
McAleer Creek	McAleer Creek-196th St	MC-196th	Tributary	47.7705851, -122.3114713	Surface Water	x
McAleer Creek	McAleer Creek-Ballinger Outlet	MC-Ballinger Outlet	Tributary	47.775879, -122.316052	Surface Water	
Hall Creek	Hall Creek-Ballinger Inlet	HC-Ballinger Inlet	Tributary	47.787032, -122.330015	Surface Water	
Hall Creek	HC-Hall Lake Outlet	HC-Hall Lake Outlet	Tributary	47.807753, -122.311697	Surface Water	
Kelsey Creek	Mercer Slough	M. Slough	Tributary	47.582100, -122.186264	Surface Water	x

Subbasin	Location Name	Location ID	Location Type	Approximate Coordinates (WGS84)	Sample Type	Phase 1 Sampling Site
Kelsey Creek	Kelsey Creek-405	KC-405	Tributary	47.6015134, -122.1845170	Surface Water	x
Kelsey Creek	Kelsey Creek-Kelsey Creek Park	KC-KCP	Tributary	47.6060245, -122.1623475	Surface Water	x
Kelsey Creek	Kelsey Creek-Above KCP	KC-Above KCP	Tributary	47.6195237, -122.1616649	Surface Water	
Kelsey Creek	Kelsey Creek-Above Valley Creek	KC-Above VC	Tributary	47.62419, -122.15300	Surface Water	
Kelsey Creek	Kelsey Creek-Below Larsen Lake	KC-Larsen	Tributary	47.606030, -122.140508	Surface Water	
Kelsey Creek	Kelsey Creek-Phantom	KC-Phantom	Tributary	47.596390, -122.129501	Surface Water	
Valley Creek	Valley Creek-Mouth	VC-Mouth	Tributary	47.62438, -122.15340	Surface Water	
Valley Creek	Valley Creek-Below Bellevue Golf Course	VC-Below BGC	Tributary	47.6459559, -122.1519895	Surface Water	
Valley Creek	Valley Creek-Above Bellevue Golf Course	VC-Above BGC	Tributary	47.6557439, -122.1534627	Surface Water	
Ravenna Creek	Ravenna Creek-Mouth	RC-Mouth	Tributary	47.65602, -122.29699	Surface Water	
Ravenna Creek	Ravenna Creek-Wahkiakum	RC-Wahkiakum	Tributary	47.658005, -122.296513	Surface Water	x
Ravenna Creek	Ravenna Creek-Montlake Blvd NE	RC-Montlake	Tributary	47.660877, -122.297846	Surface Water	
Ravenna Creek	Ravenna Creek-Ravenna Park	RC-RP	Tributary	47.6719792, -122.3065025	Surface Water	
Ravenna Creek	Ravenna Creek-Carp Pond	RC-Carp	Tributary	47.654697, -122.295149	Surface Water	
Ravenna Creek	Ravenna Creek-Central Pond	RC-Central	Tributary	47.654835, -122.293093	Surface Water	
Lake Washington	Lake Washington-North Basin	Lake-North	Lake	47.686750, -122.235278	Surface Water	x
Lake Washington	Lake Washington-Mid Basin	Lake-Mid	Lake	47.636500, -122.268611	Surface Water	x
Lake Washington	Lake Washington-South Basin	Lake-South	Lake	47.575444, -122.267222	Surface Water	x

Subbasin	Location Name	Location ID	Location Type	Approximate Coordinates (WGS84)	Sample Type	Phase 1 Sampling Site
West Lake Washington	Beacon Hill-Atmospheric Deposition	BH-ATM	Bulk Atmospheric Deposition	47.568228, -122.308639	Bulk Atmospheric Deposition	x
South Fork Snoqualmie River	North Bend-Atmospheric Deposition	NB-ATM	Bulk Atmospheric Deposition	47.489468, -121.774028	Bulk Atmospheric Deposition	

Appendix C. Phase 2 Map of Planned Tributary, Lake, and Bulk Atmospheric Deposition Sampling Sites