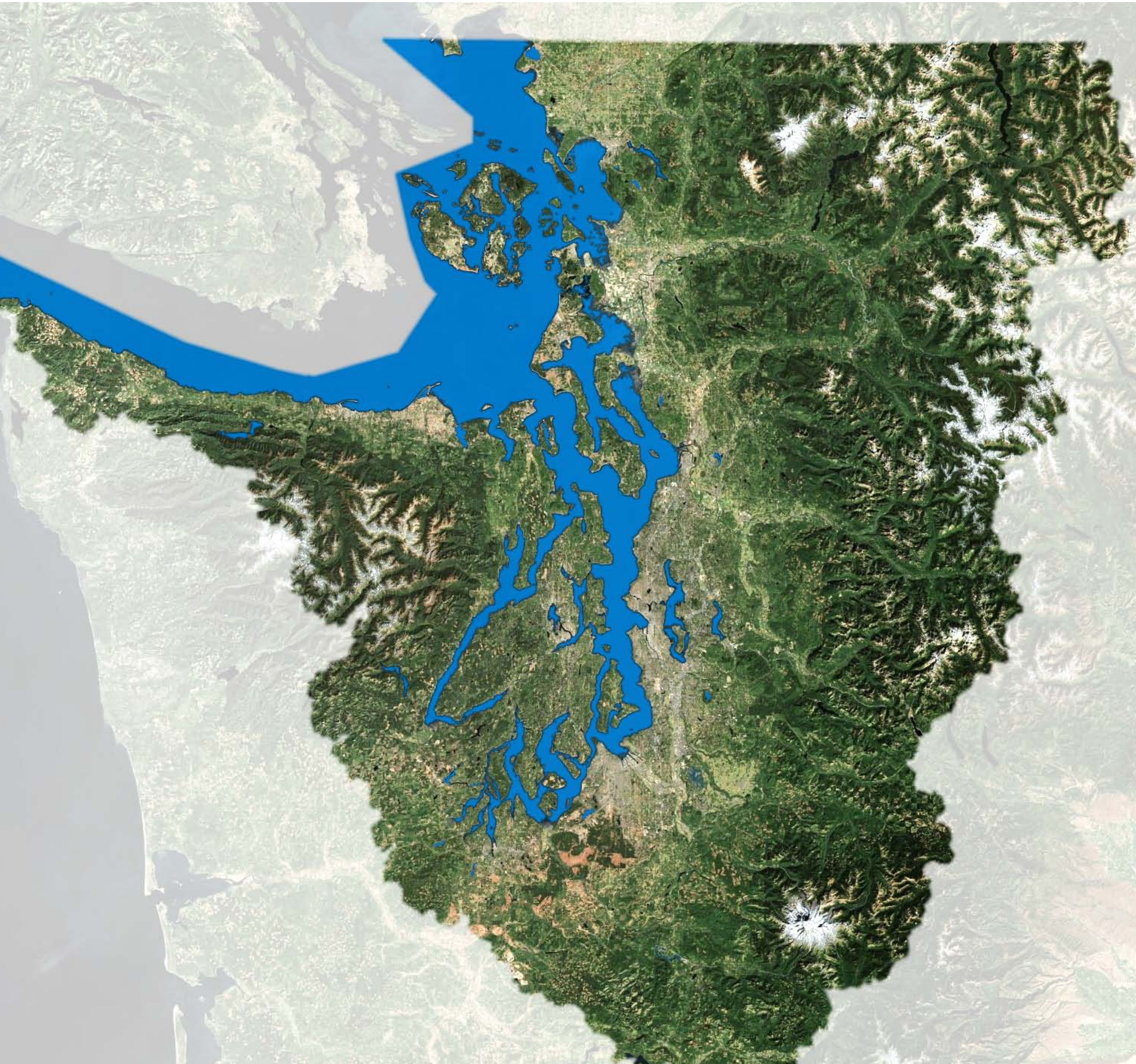

Control of Toxic Chemicals in Puget Sound

Quality Assurance Project Plan for Phase 3: Characterization of Loadings via Surface Runoff

HERRERA ENVIRONMENTAL CONSULTANTS

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DEPARTMENT OF ECOLOGY
State of Washington

Quality Assurance Project Plan

Control of Toxic Chemicals in Puget Sound Phase 3: Characterization of Loadings via Surface Runoff

Prepared by

Herrera Environmental Consultants
2200 Sixth Avenue, Suite 1100
Seattle, Washington 98121

Ecology and Environment, Inc.
720 Third Avenue, Suite 1700
Seattle, Washington 98104

Practical Stats
9278 Lark Sparrow Drive
Highlands Ranch, Colorado 80126-5232

Washington State Department of Ecology
P.O. Box 47600
Olympia, Washington 98504-7600

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For more information, contact:

Washington Department of Ecology
Water Quality Program
P.O. Box 47600
Olympia, WA 98504
Phone: (360) 407-6400

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Distribution List:

James M. Maroncelli, Washington Department of Ecology
Stuart A. Magoon, Washington Department of Ecology
John Lenth, Herrera Environmental Consultants, Inc.
Joy Michaud, Herrera Environmental Consultants, Inc.
Andrew Hafferty, Ecology and Environment, Inc.

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Quality Assurance Project Plan
Phase 3: Characterization of Loadings via Surface Runoff

July 2009

Approved by:

Signature | Date 7-7-09

John Lenth, Project Manager, Herrera Environmental Consultants, Inc.

Signature | Date 23 July 2009

Joy Michaud, Principal-in-Charge, Herrera Environmental Consultants, Inc.

Signature | Date 7-21-09

Andrew Hafferty, Water Quality Data QA Lead, Ecology and Environment, Inc.

Signature | Date 7-16-09

Dylan Ahearn, Flow Data QA Lead, Herrera Environmental Consultants, Inc.

Signature | Date 21 July 2009

David Ikeda, Water Quality Data Management Lead, Ecology and Environment, Inc.

Signature | Date 7-15-09

Peter Steinberg, Flow Data Management Lead, Herrera Environmental Consultants, Inc.

Signature James M. Maroncelli | Date 7-23-09

James M. Maroncelli, Project Manager, Washington Department of Ecology

Signature Date

7/27/09

Stuart A. Magoon, Laboratory Director, Washington Department of Ecology

Signature Date

7/30/09

Robert Duff, Environmental Assessment Program Manager, Washington Department of Ecology

Signature Date

7/30/09

Bill Kammin, QA Officer, Washington Department of Ecology

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List of Abbreviations and Acronyms

BNAs	base/neutral/acid extractable compounds
CVAA	cold-vapor atomic adsorption
DEM	digital elevation model
E & E	Ecology and Environment, Inc.
Ecology	Washington State Department of Ecology
ECD	electron capture detector
ELCD	electrolytic conductivity detector
EIM	Environmental Information Management database
FIA	flow injection analyzer
GC	gas chromatograph
GC/ECD	gas chromatography/electron capture detector
GC/FID	gas chromatograph/flame ionization detector
GC/HRMS	gas chromatography/high resolution mass spectrometry
GC/MS	gas chromatography/mass spectrometry
GIS	geographic information system
HEM	N-hexane extractable material
Herrera	Herrera Environmental Consultants
HRMS	high resolution mass spectrometry
ICP-AES	inductively coupled plasma-atomic emission spectroscopy
ICP-MS	inductively coupled plasma-mass spectrometry
L	liter
LC/MS/MS	liquid chromatography-tandem mass spectrometry
LCS	laboratory control sample
LiDAR	Light Detection and Ranging
ml	milliliter
MS	matrix spike
MSD	matrix spike duplicate
MEL	Manchester Environmental Laboratory

PAHs	polycyclic aromatic hydrocarbons
PFOAs	perfluoroorganic acids
PFOSs	perfluorosulfonates
PBDEs	polybrominated diphenyl ethers
PCBs	polychlorinated biphenyls
PSBM	Puget Sound Box Model
PSOEP	Puget Sound Ocean Exchange Project
SOP	standard operating procedure
SGT-HEM	silica gel treated N-hexane extractable material
SIM	selected ion monitoring
QA	quality assurance
QAPP	quality assurance project plan
QC	quality control
TPH	total petroleum hydrocarbons
U.S. EPA	United States Environmental Protection Agency
USGS	United States Geological Survey

Introduction

The Washington Department of Ecology (Ecology) is collaborating with the Puget Sound Partnership and other state and federal agencies to conduct scientific studies on toxic chemicals discharged to Puget Sound from surface runoff. Phase 3 of this effort includes a monitoring project to characterize toxic loadings to Puget Sound from surface runoff. This document is the Quality Assurance Project Plan (QAPP) for that monitoring project. It was jointly prepared by Ecology and a consultant team led by Herrera Environmental Consultants (Herrera), and supported by Ecology and Environment, Inc. (E & E) and Practical Stats.

This QAPP documents procedures used for data collection, processing, and analysis to ensure all results obtained from this monitoring project are scientifically and legally defensible. It meets requirements of Ecology's *Guidelines for Quality Assurance Project Plans* (Ecology, 2004), and includes the following:

- **Background** – An explanation of why the project is needed.
- **Project Description** – Project goals and objectives, and the information required to meet the objectives.
- **Organization and Schedule** – Project roles and responsibilities, and the schedule for completing the work.
- **Quality Objectives** – Performance (or acceptance) thresholds for collected data.
- **Sampling Process Design** – The sampling process design for the study, including sample types, monitoring locations, and sampling frequency.
- **Sampling Procedures** – A detailed description of sampling procedures and associated equipment requirements.
- **Measurement Procedures** – Laboratory procedures that will be performed on collected samples.
- **Quality Control** – Quality control (QC) requirements for both laboratory and field measurements.
- **Data Management Procedures** – How data will be managed from field or laboratory recording to final use and archiving.
- **Audits and Reports** – The process that will be followed to ensure this QAPP is being implemented correctly and the quality of the data is acceptable.

- **Data Verification and Validation –** The data evaluation process, including the steps required for verification, validation, and data quality assessment.

- **Data Quality (Usability) Assessment –** The procedures that will be used to determine if collected data are of the right type, quality, and quantity to meet project objectives.

Background

Puget Sound is the largest fjord-like estuary in the continental United States. Located between the Cascade and Olympic mountain ranges in Washington State (Figure 1), the Puget Sound Basin covers more than 43,400 square kilometers (16,800 square miles) of land and water (Hart Crowser *et al.*, 2007). The basin is made up of a series of interconnected underwater basins with an average depth of 140 meters (460 feet), separated by shallow ridges or "sills." These basins include the deep Main Basin (up to 280 meters [920 feet] deep) and the shallower South Sound, Hood Canal, and Whidbey Basins. Admiralty Inlet connects Puget Sound to the Pacific Ocean through the Strait of Juan de Fuca. For the purposes of this project, the term "Puget Sound" includes all of Puget Sound, Hood Canal, and the Straits of Georgia and Juan de Fuca within the state of Washington.

Over the past 150 years, human activity has introduced a wide range of toxic chemicals into Puget Sound at levels that are harmful to aquatic life (Puget Sound Partnership, 2006). Despite a ban of some harmful chemicals in the 1970s and numerous cleanup efforts, toxic chemicals continue to persist and circulate throughout Puget Sound and are still being introduced via stormwater runoff, municipal sewage treatment plants, and atmospheric deposition. These pollutants accumulate as they move through the food chain, showing up in key forage fish (like herring) and bottom fish species (like English sole) and ultimately affect salmon, seals, and orcas. These pollutants are also a significant concern for human health, especially for those who frequently consume fish with high contaminant levels.

Recognizing these concerns, Ecology is now collaborating with the Puget Sound Partnership and other state and federal agencies to conduct three phases of scientific studies of toxic chemicals discharged to Puget Sound. Phase 1 was completed in October 2007, and included an initial estimate of loadings to Puget Sound for 17 toxic chemicals of concern that use the following pathways for contaminant transport:

- Surface runoff
- Atmospheric deposition
- Wastewater loading
- CSO loading
- Direct spill

In the Phase 1 study report (Hart Crowser *et al.*, 2007), these loading estimates were provided for the entire Puget Sound Basin and the 14 upland study areas (Figure 2) that link to Ecology's Puget Sound Box Model (PSBM), a computerized tool for predicting contaminant movement within the Puget Sound ecosystem. The report also provides loading estimates for the surface runoff pathway for the following land use categories in each study area: commercial/industrial, residential, agricultural, and forest/field/other. In this analysis, "surface runoff" consists of stormwater, nonpoint source overland flow, and groundwater discharge to surface waters that flow to Puget Sound.

Ecology completed the Phase 2 study in 2008, with the goal of refining toxic chemical loadings from the Phase 1 study by incorporating information on toxic chemical loadings from roadways. As a first step, the project team performed a Geographic Information System (GIS) analysis to delineate and map roadway areas in the upland study areas linked to the PSBM (Figure 2). The project team also updated the Phase 1 land use/land cover dataset (based on the 1992 National Land Cover Dataset [MRLC, 1992]), using the more current 2001 version (MRLC, 2001).

Finally, the project team performed a focused literature review to obtain information about toxic chemicals in roadway runoff. Review results indicated there were sufficient data available to characterize some toxic chemicals in runoff from highways; however, adequate data were lacking for arterial and collector roads, side streets, and parking lots. Therefore, the report prepared for the Phase 2 study (EnviroVision et al., 2008) presented updated toxic chemical loading estimates for the four land use categories targeted in the Phase 1 analysis, based on the more current national land cover dataset. Where sufficient data were available for specific parameters, the report also provided toxic loading estimates for highways. Similar to the Phase 1 project, these loading estimates were provided for the entire Puget Sound Basin and each of the 14 upland study areas for the PSBM (Figure 2).

Results from both the Phase 1 study and Phase 2 studies indicated surface runoff is the largest single contributor of toxic chemicals to Puget Sound. However, these studies also suggested that there are substantial differences in absolute and unit area toxic chemical loadings between the four land use categories. These differences are primarily because of two controlling factors: the relative magnitude of the toxic chemical concentrations for each land use category, and the total amount of land area represented by each land use category in the Puget Sound Basin.

For example, unit area loading rates for toxic chemicals of concern are generally greatest for commercial/industrial, and highway areas within the Puget Sound Basin because the representative toxic chemical concentrations used in the loading analyses for these land use categories were relatively high. However, since commercial/industrial and highway areas are only a small portion of the total land area of the Puget Sound Basin, these areas are relatively minor sources of absolute toxic chemical loading. In absolute terms, residential areas are the largest source of toxic chemical loadings because they represent a relatively large proportion of the total land area in the Puget Sound Basin. These results are generally consistent with other regional studies of toxic loading (Herrera, 2007).

Despite these conclusions, the rough estimates of the quantities of toxic chemicals released from different land uses and roadway areas were still not sufficiently precise to form the basis for recommending specific source control policies to reduce releases of toxic chemicals to Puget Sound. This imprecision was due to the numerous assumptions that were required in their derivation and the wide ranges in the underlying concentration data. Therefore, Ecology began to collect additional information during the Phase 3 studies to further improve estimates and link the toxics threats from surface runoff to Puget Sound with the sources of toxic chemicals.

Project Description

Ecology is performing this Phase 3 study to accomplish the following:

- Obtain concentration data for toxic chemicals in surface runoff from multiple well-defined locations in the Puget Sound Basin at various times throughout the year.

- Obtain concentration data for toxic chemicals in surface runoff from multiple, well-defined areas that represent specific land uses.

- Obtain concentration data for toxic chemicals in surface runoff that illustrate the attenuation effects of the various natural landscape and constructed features located between the original sources of surface runoff and the point of its final discharge to Puget Sound.

These goals were identified after one of the Phase 2 study (EnviroVision *et al.*, 2008) as important for advancing current knowledge on toxic loadings to Puget Sound.

Working with its consultant team during the project planning phase, Ecology identified two detailed study objectives to be accomplished in conjunction with these broader goals:

- Perform an in-depth study within two pilot watersheds to determine the relative contributions of toxic chemicals in surface runoff from the four major land uses identified above (i.e., residential, commercial/industrial, agricultural, and forest/field/other) based on unit area loading estimates.

- Reduce the uncertainty of the total loading estimates for toxic chemicals that are discharged to Puget Sound via surface runoff relative to the estimates determined in the Phase 1 and Phase 2 studies.

To meet these objectives, the project team will conduct water quality sampling and flow monitoring at representative locations within the two pilot watersheds. Samples of surface runoff will be analyzed for selected toxic chemicals and pollutants of concern, including:

- Polycyclic aromatic hydrocarbons (PAHs)
- Base/neutral/acid extractables (BNA) (semi-volatile organic compounds)
- Pesticides
- Herbicides
- Polybrominated diphenyl ethers (PBDEs [congeners])
- Polychlorinated biphenyls (PCBs [congeners])
- Petroleum hydrocarbons
- Oil and grease, N-hexane extractable material (HEM)

- Heavy metals
- Nutrients

Sampling will be timed to measure concentrations of these pollutants during both base flow and storm flow conditions. Upon completion of this monitoring, the project team will use the concentration data and flow monitoring data to calculate both absolute (*i.e.*, kilograms per year) and unit area (*i.e.*, kilograms per acre per year) toxic chemical loading estimates. The unit area loading estimates will then be compared to determine which land use categories are primary sources for specific toxic chemicals. Also, unit area loading estimates for base and storm flow conditions will be compared to determine if the primary transport pathway for each toxic chemical is via groundwater or stormwater and overland flow (including shallow interflow).

In the Phase 1 and 2 studies of toxic chemical loading to Puget Sound, loading estimates were calculated for the 14 study areas that provide input to the PSBM (Figure 2). However, these loading estimates were derived using data compiled from numerous regional and national studies with varying objectives that were not necessarily related to this specific application. In contrast, the data obtained through this study will be collected using a highly controlled experimental design from monitoring locations that are representative of local land use conditions. Therefore, this study will also provide more accurate data for calculating loading estimates for these 14 study areas.

Finally, monitoring for this study is being coordinated with the Phase 3 Puget Sound Ocean Exchange Project (PSOEP). Ecology is implementing the PSOEP to evaluate toxic chemical concentrations in the marine waters of Puget Sound, and the exchange of those chemicals between Puget Sound and the Pacific Ocean. In connection with this project, Ecology will collect samples seasonally from the mouths of five major rivers discharging to Puget Sound. These samples will be analyzed for the same parameters that are targeted in this study. The project team will use data obtained from this study and the PSOEP to evaluate potential attenuation of toxic chemicals between their point of origin and the point of final discharge to Puget Sound.

Organization and Schedule

This section identifies the project team, their roles and responsibilities, and the schedule for completing the work.

Organization

Ecology is collaborating with the Puget Sound Partnership and other state and federal agencies to conduct this project. Ecology is assisted in this effort by a consultant team led by Herrera and supported by E & E and Practical Stats. Key staff members are identified in Table 1 with their roles and responsibilities.

Schedule

The project will occur between May 2009 and October 2010. Key project milestones and deliverables are summarized in Table 2.

Quality Objectives

The goal of this QAPP is to ensure that data collected during this study are scientifically and legally defensible. To meet this goal, data will be evaluated using the following data quality indicators (Ecology, 2004):

- **Precision**
  A measure of the variability in the results of replicate measurements due to random error.

- **Bias**
  The constant or systematic distortion of a measurement process, different from random error, which manifests itself as a persistent positive or negative deviation from the known or true value. This can result from improper data collection, poorly calibrated analytical or sampling equipment, or limitations or errors in analytical methods and techniques.

- **Representativeness**
  The degree to which the data accurately describe the condition being evaluated, based on the selected sampling locations, sampling frequency and duration, and sampling methods.

- **Completeness**
  The amount of valid data obtained from the measurement system.

- **Comparability**
  A qualitative term that expresses the measure of confidence that one data set can be compared to another and can be combined for the decision(s) to be made. Data are comparable if sample collection techniques, measurement procedures, analytical methods, and reporting are equivalent for samples within a sample set.

Measurement Quality Objectives (MQOs) are performance or acceptance criteria established for the data. The specific MQOs that will be used in the assessment of water quality and hydrologic data are presented in the following sections.

Measurement Quality Objectives for Water Data

QA objectives for water quality data are expressed in terms of precision, bias, representativeness, completeness, and comparability. The associated MQOs are defined in the subsections below and summarized in Table 3.

Precision

Precision will be assessed based on the analyses of laboratory and field duplicates, and matrix spike duplicates (MSD). Precision in these duplicate samples will be evaluated based on their relative percent difference (RPD):

$$RPD = \frac{(C_1 - C_2) \text{ x } 100\%}{(C_1 + C_2) / 2}$$

Where: RPD = relative percent difference

C_1 = larger of two values

C_2 = smaller of two values

Specific MQOs for MSD are defined for each analysis method in Table 3.

Bias

Bias will be assessed based on analyses of method blanks, matrix spikes (MS), and laboratory control samples (LCS). Bias in MS and LCS will be quantified based on percent recovery or the average (arithmetic mean) of the percent recovery. Percent recovery for MS will be calculated using the following equation:

$$\%R = \frac{(S - U) \text{ x } 100\%}{C_{sa}}$$

Where: %R = percent recovery

S = measured concentration in spike sample

U = measured concentration in unspiked sample

C_{sa} = actual concentration of spike added

Percent recovery for LCS will be calculated using the following equation:

$$\%R = \frac{M}{T} \times 100\%$$

Where: %R = percent recovery

M = measured value

T = true value

Specific MQOs for MS and LCS are defined in Table 3 for each analysis method.

Representativeness

This project will assess a range of water quality conditions, both seasonally and during periods of base and storm flow. Sample representativeness will be ensured by employing consistent and standard sampling procedures. A stratified random sampling process will be used to identify individual monitoring locations that sufficiently represent the specific land use categories targeted in this study.

Completeness

Completeness will be assessed based on the percentage of specified samples (listed in this QAPP) collected. The completeness goal shall be 90 percent. Completeness for acceptable data is defined as the percentage of acceptable data out of the total amount of data generated. Acceptable data is either data that passes all QC criteria, or data that may not pass all QC criteria but has appropriate corrective actions taken.

Comparability

Standard sampling procedures, analytical methods, units of measurement, and reporting limits will be applied in this study to meet the goal of data comparability. The results will be tabulated in standard spreadsheets to facilitate comparison with other study results and water quality threshold limits (e.g., WAC 173-201A).

Measurement Quality Objectives for Hydrologic Data

Hydrologic monitoring will include measurements of water levels at individual monitoring locations. These measurements will then be converted to estimates of discharge using stream discharge rating curves (see next section). QA objectives for these measurements are expressed in terms of precision, bias, representativeness, completeness, and comparability.

Precision

Because it is difficult to obtain repeat measurements from hydrologic monitoring equipment during continuously changing site conditions, precision of the hydrologic data will be assessed based on a controlled test that is performed prior to installing the monitoring equipment in the field. This test will specifically involve the following steps:

1. Place a pressure transducers obtained for this project into a large bucket.
2. Fill bucket with 1 foot of water.
3. Seal bucket tightly to reduce/eliminate evaporation, but leave small gap for pressure equilibration.

4. Zero the pressure transducer.
5. Run the test for 24 hours, collecting data at 5-minute intervals.
6. Repeat the test with 3.0 feet of water in the bucket.

The MQO for precision is less than 5 percent change in water level readings from one measurement to the next over the duration of two tests performed at different water levels (*i.e.*, 1 and 2 feet).

Bias

The bias of hydrologic monitoring data will be assessed based on comparisons of monitoring equipment readings to an independently measured "true" value. In this case, the true value will be derived from manual measurements of water level that are obtained from a staff gauge at each monitoring location. These manual measurements will be made every 2 weeks in conjunction with routine visits to each monitoring location (see next section).

If the monitoring equipment is not affected by drift or other operational problems, the difference between the equipment reading and the manual measurement of water level ("instrument drift") should remain at zero over time and varying water depths. Therefore, bias in these data will be assessed based on the change in the instrument drift value relative to all previous measurements. Specifically, a change in the instrument drift value of plus or minus 2 standard deviations relative to the mean from all previous measurements will trigger an assessment of the monitoring equipment to determine proper functioning.

Completeness

Completeness will be assessed based on the occurrence of gaps that may occur in the data record for all monitoring equipment. The associated MQO is less than 10 percent of the total data record missing due to equipment malfunctions or other operational problems. Completeness will be ensured through routine maintenance of all monitoring equipment and immediate implementation of corrective actions if problems arise.

Comparability

Standard monitoring procedures, units of measurement, and reporting conventions will be applied to meet the goal of data comparability.

Sampling Process Design

The project team will conduct surface runoff monitoring at 16 different locations: 8 in the Snohomish River Watershed, and 8 in the Puyallup River Watershed. Watershed locations are shown in Figure 1.

Each monitoring location will represent a drainage basin where one of the following land use categories is the dominant condition: commercial/industrial, residential, agricultural, or forest/field/other. Two separate drainage basins within each watershed will represent each land use type. For example, two drainage basins selected in the Puyallup River watershed and two in the Snohomish River watershed will represent agricultural land use (a total of four).

The project team will conduct sampling at these locations during eight events. Two events will be scheduled to represent base flow conditions; one base flow event will occur in the summer and the other in the winter. The remaining six events will occur during storm flow events spread out over the monitoring year. Samples from both types of events will be analyzed for selected toxic chemicals and pollutants of concern. The project team will use the data obtained from these samples to evaluate differences (if any) in the toxic chemical concentrations in relation to land use, watershed, and base/storm flow.

The project team will also establish stream gauging stations at each of the 16 monitoring locations to obtain a continuous record of discharge over a 1-year period, from August 2009 through July 2010. The team will then use water quality and discharge data obtained from each sampling location to calculate absolute and unit area loadings from each drainage basin. These data will be compared by land use, watershed, and base/storm flow conditions.

Monitoring Locations

The Snohomish River and Puyallup River watersheds were selected for monitoring based on the following considerations:

- Each has a diverse land use.
- Each has a USGS gauging station(s) at or near its mouth that can provide a continuous record of flow during the sampling period. (The gauging network in each watershed is shown in Appendix A.)
- Each has available land use/land cover data to support the required analyses for this study.
- Each will be sampled in connection with Ecology's PSOEP.

- Collectively, these watersheds represent some of the geographic diversity within the Puget Sound Basin and yet are fairly centrally located to reduce travel time and sampling logistics. For example, the Snohomish River Watershed is located in the central region of the basin, while the Puyallup River Watershed is located in the southern region (Figure 1).

The monitoring locations within these watersheds will receive runoff from smaller drainage areas with land use corresponding to one of the four primary land use categories. In order to ensure the land use in these smaller drainage basins is sufficiently representative of a particular category, the project team used a stratified random sampling process to identify the individual monitoring locations. The specific goal of this process was to eliminate bias in the monitoring location selection process to the extent possible. The general steps that were used in this process are summarized below:

1. Using a 10-meter digital elevation model (DEM), the project team used the ArcGIS Hydrology Toolbox to delineate the stream channel network in each watershed. The resulting stream layer was then compared against publicly available GIS hydrology data as a QC measure.

2. The project team used the stream network and 10-meter DEM topography to delineate the drainage basins for all second-order streams within each watershed.

3. The project team screened all the smaller drainage basins in each watershed to identify a subset of drainage basins for which their entire land area was below 2,200 feet in elevation. Drainage basins above this threshold were eliminated from further consideration. (This step was performed to ensure the drainage basins selected for monitoring would not be rendered inaccessible because of winter snow conditions.)

4. Using the most recent version of the National Land Cover Dataset (MRLC 2001), the project team screened the subset of drainage basins obtained from Step 3 to identify representative drainage basins for each land use category based on the following criteria:

    - <u>Commercial/Industrial</u>: At least 30 percent of the drainage basin must be classified as commercial/industrial land use. (Initially a minimum of 50 percent was targeted for this land use category. However, this limited the available drainage basins to only a few that largely represented only one commercial or industrial facility, which did not meet the intent of the study.)

    - <u>Residential</u>: At least 50 percent of the drainage basin must be classified as residential land use; and no more than 10 percent may be classified as commercial/industrial land use.

- <u>Agricultural</u>: At least 50 percent of the drainage basin must be classified as agricultural land use.

- <u>Forest/Field/Other</u>: At least 90 percent of the drainage basin must be classified as forest/field/other land use.

5. Using the subset of drainage basins that met these criteria, the project team randomly selected five drainage basins for each land use category within each of the two watersheds. The project team then performed field reconnaissance on these randomly selected drainage basins to evaluate their suitability for actual monitoring relative to the following criteria:

    - Traffic and water safety
    - Ease of access
    - Property access restrictions
    - Representativeness for the targeted land use
    - Suitability for gauging (channel morphology, diversions, dams, *etc*.)

6. Drainage basins that were not suitable for monitoring based on observations from the field reconnaissance were eliminated from further consideration. If fewer than two drainage basins for any given land use were identified as being suitable for monitoring through this process, the project team randomly selected five additional drainage basins for that land use. The project team then performed field reconnaissance on these additional drainage basins as described in Step 5. This process continued until at least two drainage basins for each land use were identified as being suitable for monitoring in each of the two watersheds.

7. The project team acquired higher-resolution topographic data (*i.e.*, Light Detection and Ranging [LiDAR]) for the drainage areas identified for sampling through Step 6. These data were used to confirm the accuracy of the delineated boundaries and to identify any possible topographic variations that might not be identifiable at the 10-meter DEM scale.

More detailed descriptions of the GIS analyses performed during this process are provided in Appendix B. A complete list of all monitoring locations that were evaluated through the site reconnaissance process described above is provided in Appendix C. Appendix C also presents the rationale for selecting a monitoring location for this project. Finally, standardized forms documenting observations made during field reconnaissance are presented in Appendix D.

Table 4 provides information on the 16 monitoring locations that were identified through this process. Included in this table are the GIS coordinates for each monitoring location and detailed information on the associated drainage basin (e.g., size and land use breakdown). The relative positions of each drainage basin within the Snohomish River Watershed and Puyallup River

Watershed are also shown in Figures 3 and 4, respectively. More detailed maps are provided in Appendix E for each monitoring location that show the following information:

- Monitoring locations relative to delineated basin boundaries
- Land use breakdown within the delineated basin boundaries
- Stream channel network within the delineated basin boundaries

A photograph of each monitoring location is provided in Appendix F.

For the purpose of this study, the project team will compute toxic chemical loading estimates for each monitoring location based on the assumption that the <u>entire</u> drainage basin is representative of the targeted land use, even though Table 4 indicates there is actually a mix of land uses present. However, as noted above, the land use breakdown in each drainage basin was determined from relatively low resolution data that were obtained from the National Land Cover Dataset (MRLC, 2001). In general, the maps provided in Appendix E suggest actual land use in the drainage basins is more representative of the targeted land use for each monitoring location than Table 4 would suggest. In the presentation of results from this study, the project team will discuss any discrepancies between the land use data presented in Table 4 and the actual land use for each drainage basin.

Water Quality Sampling

The project team will conduct surface runoff sampling at the 16 monitoring locations identified in Table 4 during two base flow events. One event will occur in August 2009 to represent summer base flow conditions, and the other will occur in January or February 2010 to represent winter base flow conditions. In each case, the project team will conduct base flow sampling following a period of at least 1 week without rain. Base flow samples will consist of a single grab that is collected from each monitoring location. The project team will deliver the grab samples to the Manchester Environmental Laboratory (MEL) where they will be analyzed for selected toxic chemicals and pollutants of concern that are identified in Table 5.

The project team will also conduct surface runoff sampling at the 16 monitoring locations identified in Table 4 during six separate storm events over the period extending from August 2009 through July 2010. Efforts will be made to spread the storm event sampling out over this period as follows:

- First Fall Flush: One event in September or October 2009.
- Winter Storm Flow: Three events in October 2009 through February 2010.
- Spring Storm Flow: Two events in March through May 2010.

The project team will attempt to collect samples from the first storm event of the fall season to capture the first seasonal flush. Thereafter, the sampling team will attempt to sample the required number of storms as early as possible in the winter and spring storm flow periods to ensure that the required number of storm events are captured within each time window.

Across all the storm sampling periods, the following conditions will serve as guidelines for defining the acceptability of individual storm events for sampling:

- **Target storm depth**: Minimum of 0.25 inches of precipitation in a 24-hour period.
- **Antecedent conditions**: A period of at least 12 hours preceding the event with less than 0.01 inches of precipitation.

Samples will likely be collected from only one watershed during any given storm event due to staffing and equipment limitations. During storm event sampling, the project team will collect two separate grab samples from each monitoring location, in consecutive rounds. The project team will collect one grab sample from each of its assigned monitoring locations traveling a predetermined route from one location to the next, return to the first location to collect the second grab sample, and then follow the same route for the remaining locations.

Following the collection of samples, the project team will then composite these grab samples into a single sample in proportion to the flow measured when the two individual samples were collected. For parameters that cannot be composited (see description below), the project team will collect only a single grab sample during the first round of sampling for subsequent analyses. Following the compositing process, the project team will deliver both composite samples and single grab samples to the laboratory where they will be analyzed for those analytes listed in Table 5.

The project team will also make *in situ* measurements for the field parameters identified in the following section. These measurements will be made immediately following the collection of grab samples during both the base and storm flow events. Results obtained during consecutive rounds of sampling during storm flow events will be averaged to obtain a single value for each event.

Monitoring Parameters

The project team will submit samples to the MEL where they will be analyzed for the toxic chemicals and pollutants of concern that are identified in Table 5. Table 5 also identifies parameters that will be measured *in situ* by the project team during both types of events.

The water quality sampling design described above will result in a total of 128 samples for any given parameter if sampling occurs at all 16 monitoring locations across all the base and storm flow events (16 locations × 8 events total = 128 samples). However, due to cost considerations, some parameters will be analyzed for only a subset of the locations, while others will be analyzed for only a subset of the events. In either case, sampling for these parameters will be targeted at conditions that have the most chance of producing a detectable concentration. The project team may also decide to suspend monitoring of any given parameter if results from early monitoring indicate no useful information is being obtained (e.g., if all the data are non detects). Table 5 also identifies the number of samples that will be collected for each parameter based on the associated number of monitoring locations and sampling events that are anticipated at this stage of the project. Finally, Table 5 also identifies the parameters that will be collected only as single grab sampled during the first round of storm event sampling.

Stream Gauging

The project team will establish stream gauging stations at each of the monitoring locations identified in Table 4 to obtain a continuous record of discharge over a 1-year period, from August 2009 through July 2010. At each gauging station, the project team will install a staff gauge for obtaining a manual measurement of water level at a fixed location within the stream channel. The project team will also install a data logger and pressure transducer at each gauging station to facilitate the continuous collection of water level data with a 5-minute logging interval. The pressure transducer will be housed in a vandal-resistant stilling well submerged within the stream channel. Specifications for the pressure transducer and data logger that will be used for this application (*i.e.*, Instrumentation Northwest, AquiStar® PT2X) are provided in Appendix G. Typical installation configurations for both the staff gauge and stilling well/pressure transducer combination are provided in Appendix H. The specific configuration of this equipment at each monitoring location will be documented by the project team on standardized forms that will be provided as an Addendum to this QAPP.

The project team will perform site visits every 2 weeks to check the operational status of the data loggers at each monitoring location and to upload the associated water level data. The uploaded data will be immediately transferred to a secure server located in Herrera's Seattle office that is backed-up on a daily basis. The project team will then use the AQUARIUS Time-Series software for all subsequent tasks related to the processing and analysis of the compiled water level data.

To convert the water level data to estimates of discharge, the project team will develop stream discharge rating curves for each monitoring location based on manual measurements of discharge that are made during each of the biweekly site visits and the site visits performed for water quality sampling during base and storm flow events. In addition, the project team will collect manual measurements of discharge during up to six additional storm events to facilitate development of these rating curves. Based on this schedule, it is anticipated that a minimum of 20 discharge measurements will be obtained for each site to facilitate rating curve development. The project team will subsequently use the AQUARIUS Rating Curve software to develop stream discharge rating curves using USGS protocols from the manual measurements of discharge at each monitoring location. The project team will also collect channel cross-section information from each monitoring location on a quarterly basis to determine if there have been substantial changes in channel geometry due to scour or other fluvial processes that would warrant development of a new rating curve.

Data Analysis

The project team will perform the following analyses using the data compiled through the monitoring activities described above and the data obtained from the PSOEP. Note that these statistics and computations may be developed for only a subset of the parameters tested if the data are not adequate to support the effort for all the parameters (e.g., if there are too many non-detect values for a given parameter):

- Calculate summary statistics for toxic chemical concentrations by monitoring location, land use, watershed, and flow type (*i.e.*, base and storm).
- Compare toxic chemical concentrations to applicable water quality criteria.
- Perform statistical analyses to evaluate differences in toxic chemical concentrations by land use, watershed, and flow type.
- Compute absolute (*i.e.*, Kg/year) and unit area (Kg/year/hectare) toxic chemical loading rates for the four primary land use categories targeted in this study based on data obtained from the monitoring locations identified in Table 4.
- Compute "land use" based toxic loading estimates at the watershed scale for comparison to loading estimates measured at river mouths. Based on this comparison, evaluate potential attenuation of toxic chemicals between their point of origin and the point of final discharge to Puget Sound.
- Compute absolute and unit area toxic chemical loading estimates for the 14 study areas that provide the input to the PSBM (Figure 2).

Sampling Procedures

To collect samples during base flow events, separate two-person sampling teams will be deployed to the two watersheds targeted for sampling. Each sampling team will then progressively sample the eight monitoring locations in each watershed. At each monitoring location, the sampling team will perform the following tasks, in the order shown:

1. Collect water quality samples.
2. Field filter water quality samples.
3. Make *in-situ* measurements.

Using this approach, it is anticipated that all monitoring locations will be sampled in an 8- to 10-hour period. Upon completion of base flow sampling, sampling teams assigned to the Snohomish River Watershed will transport the collected samples to Herrera's office in Seattle, while teams assigned to the Puyallup River Watershed will transport the collected samples to Herrera's office in Olympia. In both cases, all collected samples will be immediately processed and transported to the laboratory for further analysis at the earliest opportunity.

Sampling teams will be deployed during storm events to sample all monitoring locations within a single watershed in the shortest amount of time. To meet this goal, it is anticipated that only one watershed will be sampled during a particular storm event due to staffing and equipment limitations. To sample a single watershed, two 2-person sampling teams will be simultaneously deployed during each storm event. Each team will be assigned to sample four monitoring locations in the watershed based on their geographic proximity. Each sampling team will collect one grab sample from each monitoring location traveling a predetermined route, return to the first location to collect the second grab sample, and then follow the same route for the remaining locations. At each monitoring location, the sampling team will conduct the three tasks described above for base flow events. Using this approach, it is anticipated that successive grab samples from each monitoring location can be collected within a 4- to 6-hour interval, and all sampling can be completed in an 8- to 12-hour period.

During storm sampling, each sampling team will maintain communication with weather monitoring personnel at Herrera's offices in Seattle and/or Olympia who have access to real-time Doppler radar images showing the distribution of rainfall in the watershed and the surrounding region. If rainfall appears to be unevenly distributed among the sampling locations in the watershed, or if the rainfall appears to be dissipating prior to the completion of the required sampling, the Consultant Project Manager (Table 1) will be notified. The Consultant Project Manager will then consult with the Project Manager (Table 1) to determine whether the sampling event should be aborted.

Upon completion of storm flow sampling, sampling teams assigned to the Snohomish River Watershed will transport the samples to Herrera's office in Seattle, while teams assigned to the Puyallup River Watershed will transport the samples to Herrera's office in Olympia. In either case, all samples will be immediately composited and processed by separate teams than those who performed the field work. After compositing and processing, the project team will transport the samples to the laboratory for further analysis at the earliest opportunity.

The following sections provide more detailed descriptions of the following activities related to this process:

- Collection of grab samples.
- Field filtering.
- Measurements for *in situ* parameters.
- Sample compositing and processing.

Collection of Grab Samples

Table 6 identifies the specific bottles that will be filled as grab samples during base flow events and in successive rounds of sampling during storm events. All of the identified bottles will be pre-cleaned in advance of sampling using the following procedure:

1. Wash with Alconox soap and rinse with tap water.
2. Rinse with 20 percent hydrochloric acid and rinse with tap water.
3. Rinse with distilled water.
4. Rinse with ultra-grade acetone and allow to air dry.

As shown in Table 6, the sampling teams will use one of two methods to fill the each type of bottles: either direct immersion of the bottle in stream, or transfer the sample from the stream to the bottle with a stainless steel pitcher. In both cases, the field sampling teams will use "clean hands, dirty hands" procedures to ensure samples are not biased by contamination during the collection process. Standard Operating Procedures (SOPs) for these sampling procedures are provided in Appendix I.

The separate subsections below provide a general description of the respective procedures that will be used to collect grab samples by direct immersion and by transfer using a stainless steel pitcher. Grab sample labeling conventions are then presented in a subsequent subsection.

Grab Sample Collection Procedure by Direct Immersion

To prepare for grab sampling, one sampling team member will be designated "dirty hands" and the other "clean hands". Prior to sample collection, both team members will put on new gloves (i.e., clean, powder-free gloves made of Nitrile). The collection procedure will then proceed as follows:

1. Dirty hands team member:

    a. Open the cooler with sample bottles. For un-bagged sample bottles, proceed to Step 2 below.

    b. For double bagged samples, remove double-bagged sample bottle from cooler.

    c. Unseal outer bag.

2. Clean hands team member:

    a. For un-bagged samples, remove the sample bottle from the cooler.

    b. For double bagged samples, unseal the inner bag containing the sample bottle.

    c. Remove bottle and unscrew cap, keeping the sample bottle upwind and away from technician exhalation pathway (do not breathe near sample bottle).

    d. Fill bottle by submerging the sample bottle 6 inches below the water surface (or at mid-depth if the water depth is less than 1 foot) at a point near the center of the stream channel and upstream of the sampler.

    e. Orient the sample bottle opening down as it is initially submerged and then slowly oriented upstream (against flow) of the sampler while filling at the proper depth.

    f. Rinse bottle three times in water to be sampled (if sample contains no preservative).

    g. Under low flow conditions (*e.g.*, velocity less than 0.1 feet per second), move the sample bottle slowly upstream while filling.

    h. After removal of the bottle from the water, discard a small portion of the sample (leaving a small headspace) to allow for proper mixing before analysis (except for the three 40-ml gasoline sample bottles [Table 6] that are to be collected with zero head-space).

    i. Return sample bottles to inner bag (or cooler for un-bagged samples).

j. Reseal inner bag.

k. Reseal outer bag (either team member).

l. Return double-bagged sample to cooler (either team member).

Grab samples obtained at each monitoring location through the process described above will be documented on standardized field forms (see example in Appendix J).

Grab Sample Collection Procedure by Transfer with Stainless Steel Pitcher

As shown in Table 6, this procedure will be used to fill the 12-liter (L) stainless steel sample bottle because it to too cumbersome to fill by direct immersion. To prepare for grab sampling, designate one team member “dirty hands” and one team member “clean hands”. Prior to sample collection, both team members will put on new gloves (*i.e.*, clean, powder-free gloves made of Nitrile). The specific steps that will be used to implement the procedure are as follows:

1. Dirty hands team member:

    a. Open the outer plastic bag containing the stainless steel pitcher.

2. Clean hands team member:

    a. Open the inner plastic bag and removes the stainless steel pitcher.

3. Dirty hands team member:

    a. Open the cooler containing the 12-L stainless steel sample bottle.

4. Clean hands team member:

    a. Remove the 12-L stainless steel sample bottle.

    b. Rinse stainless steel pitcher three times in stream.

    c. At a point near the center of the stream channel and upstream of the sampler, submerge the stainless steel pitcher 6 inches below the water surface (or at mid-depth if the water depth is less than 1 foot) with pitcher opening oriented down.

    d. Slowly orient stainless steel pitcher opening up and allow to fill. Under low flow conditions (e.g., velocity less than 0.1 feet per second), move the pitcher slowly upstream while filling.

e. Removes the cap from the 12-L stainless steel sample bottle and pour the sample into the bottle.

f. Repeat steps 4.c through 4.d until 12-L stainless steel sample bottle is full.

g. Replace the cap on the 12-L stainless steel sample bottle and put the filled bottle back into the cooler.

Grab samples obtained at each monitoring location through the process described above will be documented on standardized field forms (see example in Appendix J).

Grab Sample Labeling Conventions

Samples will be will be labeled using the following convention:

"Monitoring Location ID" – "date" – "time" - "event type" – "sample type" – "QC type"

Where:	"Monitoring Location ID"	=	Name of the basin.
	"date"	=	Date when sampling was completed (mm/dd/yyyy).
	"time"	=	Time when sampling was completed (24-hour clock time).
	"event type"	=	B for base flow event; S1 for round one of storm event sampling; and S2 for round two of storm event sampling.
	"sample type"	=	UB for unfiltered bulk sample; UBM for unfiltered metals bulk sample; FB for filtered bulk sample; GS for gasoline sample; LB for diesel/lube oil sample; OG1 for the oil & grease, HEM/diesel & lube oil sample; and OG2 for the low detection limit oil & grease, HEM sample.
	"QC type"	=	B for rinsate blank and D for field duplicate.

Using this convention, an example label is "FB203-08242009-15:00-S1-FB-D"for a grab sample with the following attributes:

- Monitoring Location ID: Forest Basin 203
- Sample collection date: August 24, 2009
- Sample collection time: 3:00 p.m.
- Event type: Grab sample collected during first round of storm event sampling
- Sample type: Bulk sample for dissolved parameters
- QC type: Duplicate sample

Field Filtering

As shown in Table 6, dissolved metals, dissolved organic carbon, and orthophosphate phosphorus samples will be filtered in the field immediately after collection. To filter the sample, the field sampling teams will use a peristaltic pump to draw the unfiltered sample through a 0.45-micron filter. The peristaltic pump will be fitted with new Teflon tubing prior to filtering the sample from each monitoring location. The filtered sample will be deposited into a separate, 2-liter Teflon bottle that has been pre-cleaned using the procedure described above.

The field sampling teams will use "clean hands, dirty hands" procedures to ensure samples are not biased by contamination during the filtering process. To prepare for filtering, one sampling team member will be designated "dirty hands" and the other "clean hands". Prior to sample collection, both team members will put on new gloves (*i.e.*, clean, powder-free gloves made of Nitrile). The collection procedure will then proceed as follows:

1. Dirty hands team member:
    a. Set up the peristaltic pump.
    b. Open bag containing new pump tubing and filter.
2. Clean hands team member:
    a. Remove pump tubing and filter from bag.
3. Dirty hands team member
    a. Insert the silicon tubing into the peristaltic pump (while clean hands holds polyethylene tubing and filter).
    b. Remove the original full double-bagged 2-L Teflon sample bottle for dissolved metals from cooler and unseal outer and inner bag.
4. Clean hands team member
    a. Remove bottle and unscrew cap of original sample bottle.
    b. Insert the intake end (the tubing without the filter attached) of the Teflon lined polyethylene tubing into the original 2-L Teflon sample bottle.
    c. Attach the discharge end of the polyethylene pump tubing to the filter stand with a clamp (while dirty hands handles the clamp),

such that the filter outlet is suspended at a height that will allow filling of the 2-L Teflon bottle for the filtered sample.

5. Dirty hands team member

    a. Remove the empty double-bagged 2-L Teflon sample bottle for dissolved metals from cooler and unseal outer and inner bag.

    b. Turn the pump on to a maximum rate not to exceed 1 liter/minute.

6. Clean hands team member:

    a. Remove empty 2-L Teflon sample bottle and unscrew cap.

    b. Once water begins discharging from the filter, discard the initial 250 ml of filtrate.

    c. Rinse empty 2-L Teflon sample bottle and cap three times with filtered sample water and fill sample bottle.

    d. Return 2-L Teflon sample bottle to inner bag.

7. Dirty hands team member

    a. Reseal inner and outer bag and return double-bagged 2-L Teflon sample bottle to cooler.

Measurements for *in Situ* Parameters

As shown in Table 5, field sampling teams will measure the following suite of parameters *in situ* during base flow events and in successive rounds of sampling during storm events: dissolved oxygen, temperature, conductivity, pH, and discharge. To facilitate development of stream discharge rating curves, field sampling teams will also make additional discharge measurements at each monitoring location during the routine site visits to upload water level data from stream gauging equipment and during larger storm events. The specific procedures that will be used to collect *in situ* measurements for water quality and discharge are described in the following subsections, respectively.

Water Quality Measurements

The field sampling team will use a YSI 556 multi-parameter meter to make *in situ* measurements for dissolved oxygen, pH, conductivity, and temperature at each monitoring location. The meter will be calibrated in accordance with the SOP provided in Appendix K prior to making measurements at the first monitoring location. The meter will then be recalibrated after measurements have been made at four successive monitoring locations. Finally, the meter calibration will be checked upon completion of the monitoring activities for any given base or storm flow event. All calibration information will be documented on standardized field forms (see example in Appendix J).

To make *in situ* water quality measurements, field sampling teams will directly submerge the sensing probe in the stream at each monitoring location. Because oxygen is consumed by the sensor during measurement, the probe will be placed in an area within the stream where the water is moving at rate of at least one foot per second to avoid false low readings. If stagnant water is encountered at a particular monitoring location, field sampling teams will artificially generate current around the probe by rapidly moving the probe tip through the water. When the meter readings have stabilized, field sampling teams will record the measurements for each water quality parameter on standardized field forms (see example in Appendix J).

Discharge Measurements

Field sampling teams will make discharge measurements at each monitoring location using a Marsh McBirney Flo-Mate electromagnetic velocity meter or a Swoffer model 2100 current meter. Standard operating procedures for measuring discharge are included in Appendix L, and a general description of the procedures is provided below.

Whenever possible, field sampling teams will make discharge measurements in culvert outlets; otherwise, the measurements will be made within the stream channel in an area that best approximates uniform flow and has minimum turbulence. To ensure discharge measurements made in stream channels are consistent from one site visit to the next, field sampling teams will drive steel rods in each stream bank at the onset of monitoring to serve as reference points for all subsequent discharge measurements.

To measure discharge, field sampling steams will stretch a surveyor's tape between the steel rods. Channel depth, water depth, and current velocity will then be recorded at each of 10 to 25 intervals along the cross-section (approximately one measurement per 0.5 feet). Velocity will be recorded according to the six-tenths-depth method (USBR 2001) using a Marsh McBirney Flo-Mate electromagnetic velocity meter or a Swoffer model 2100 current meter. Stream depths measured on the in-stream staff gage will be read at the beginning and end of each discharge measurement to aid in correcting measurements made during changing conditions, and to facilitate the development of stream discharge rating curves. Field sampling teams will record velocity and water depth measurements on standardized field forms (see example in Appendix J). Stream discharge will then be calculated by multiplying the velocity measurement by the cross-sectional area of each interval and summing the results.

In general, field sampling teams will make discharge measurements in smaller streams by straddling the channel and inserting the velocity meter into the stream. For larger streams, field sampling teams will don hip boots or chest waders and then enter the stream with the velocity meter to make discharge measurements. If high flows create conditions that are too dangerous for field sampling teams to enter the stream, discharge measurements will be made by inserting the velocity meter into the stream from an overhanging structure (e.g., a nearby bridge) if possible, or by inserting the velocity meter into the stream from the bank.

Sample Compositing and Processing

As shown in Table 6, some of the samples collected in successive rounds of sampling during storm events will be composited into single, flow weighted composite sample. Sampling teams assigned to the Snohomish River Watershed will complete the compositing process at Herrera's office in Seattle, while the teams assigned to the Puyallup River Watershed will complete the compositing process at Herrera's office in Olympia. Both locations have suitable facilities for processing samples without significant risk of contamination.

As a first step in the compositing process, field sampling teams will process data obtained from discharge measurements to determine the flow rate in each stream during each round of sampling. Using these results, the proportion of sample to be composited from each round of sampling will be determined based on the following equations:

$$P_1 = F_1/(F_1 + F_2)$$

$$P_2 = F_2/(F_1 + F_2)$$

Where: P_1 = Proportion of sample from Round 1.
P_2 = Proportion of sample from Round 2.
F_1 = Flow rate measured during Round 1.
F_2 = Flow rate measured during Round 2.

Field sampling teams will then complete the compositing process using the following steps:

1. The bottle obtained from the first round of sampling (hereafter referred to as B1) will be placed on a scale that can read up to 15 kilograms to the nearest gram. The weight of B1 will be recorded.

2. The appropriate mass of sample for compositing in proportion to flow will be determined based on the following formula:

$$M_f \times P_1 = M_1$$

Where: M_f = Desired mass of sample in the final composite bottle, assuming the samples have a density of 1 gram/centimeter^3.

M_1 = Appropriate mass of sample for compositing from B1.

3. Sample will be incrementally poured out of B1 until the appropriate mass (M_1) for compositing remains in the bottle (to within ±10 grams for 2-L bottles, and ±100 grams for 12-L bottles). Prior to each incremental pouring of sample, B1 will be inverted three times to ensure the sample is thoroughly mixed.

4. The bottle obtained from the second round of sampling (hereafter referred to as B2) will be placed on the scale and its weight recorded.

5. The appropriate mass of sample for compositing in proportion to flow will be determined based on the following formula:

$$M_f \text{ x } P_2 = M_2$$

Where: M_f = Desired mass of sample in the final composite bottle, assuming the samples have a density of 1 gram/centimeter^3.

M_2 = Appropriate mass of sample for compositing from B2.

6. Sample will be incrementally poured out of B2 until the appropriate mass (M_2) for compositing remains in the bottle (to within ±10 grams for 2-L bottles, and ±100 grams for 12-L bottles). Prior to each incremental pouring of sample, B2 will be inverted three times to ensure the sample is thoroughly mixed.

7. The remaining sample contained in B2 will be poured into B1 in order to obtain the final composite sample.

Once the compositing process is complete, field sampling teams will transfer sample from the appropriate composite bottle for each parameter (Table 6) to the appropriate laboratory bottle for the respective analysis (Table 7). Laboratory bottles will be pre-cleaned by the laboratory for the analysis as necessary (Table 7). Prior to transferring sample to each laboratory bottle, the composite sample bottle will be inverted three times to ensure the sample is thoroughly mixed. After the sample has been transferred to the laboratory bottle, the appropriate preservative will be added as necessary (Table 7). The laboratory bottles will then be packed in a cooler with ice (at 4°C) and transported to the laboratory.

Measurement Procedures

Ecology will arrange for MEL to analyze samples for the majority of toxic chemicals listed in Appendix M. Ecology and MEL will subcontract directly with specialty laboratories for testing not performed by MEL.

Analytical methods and reporting limits for all target analytes are also shown in Appendix M. Detailed information on specific analytical procedures that will be used for this project are provided below.

BNAs and Herbicides
Analyzed using USEPA SW-846 Method 8270
Samples will be analyzed by gas chromatography/mass spectrometry (GC/MS) following extraction and, if necessary, appropriate sample cleanup and derivatization procedures. Sample extracts are injected into a gas chromatograph (GC) equipped with a capillary column, which utilizes a temperature program to separate analytes which are then detected with a mass spectrometer. Analytes are identified by comparing electron impact spectra to the spectra of known standards. Analytes are quantified by comparing the response of a major ion relative to an internal standard using a calibration curve developed for each GC/MS instrument.

PAHs
Analyzed using USEPA SW-846 Method 8270 SIM
Method 8270 SIM is a modification of method 8270. Selected ion monitoring (SIM) enhances sensitivity by setting the mass spectrometer to detect specific ions rather than a range of ions. Sensitivity is generally increased by a factor of ten over standard mass spectrometer measurements. The primary disadvantage of SIM is a loss of qualitative information (unable to compare spectra).

Pesticides
Analyzed using USEPA SW-846 Method 8081
Samples will be analyzed by gas chromatography/electron capture detector (GC/ECD) following extraction and, if necessary, appropriate sample cleanup procedures. Sample extracts are injected into a GC, equipped with a capillary column, which utilizes a temperature program to separate analytes which are then detected with either an electron capture detector (ECD) or electrolytic conductivity detector (ELCD). Analytes are identified by comparing the retention time of target compounds with retention times of known standards on two dissimilar columns. Analytes are quantified by comparing the sample peak response using a calibration curve developed for each target compound.

PBDEs
Analyzed using EPA method GC/HRMS 1614
Samples will be analyzed using gas chromatography/high resolution mass spectrometry (GC/HRMS) following extraction and, if necessary, appropriate sample cleanup procedures. Sample extracts are injected into a GC equipped with a capillary column, which utilizes a

temperature program to separate analytes which are then detected with a HRMS. Congeners are identified by comparing the retention time and ion-abundance ratio of target compounds and associated labeled analog compounds with retention times and ion-abundance ratio of known standards. Congeners are quantified using the isotopic dilution quantitation technique, comparing the area of the quantification ion to that of the 13C-labelled standard and correcting for response factors.

PCBs

Analyzed using EPA method GC/HRMS 1668

Samples will be analyzed using GC/HRMS following extraction and, if necessary, appropriate sample cleanup procedures. Sample extracts are injected into a GC, equipped with a capillary column, which utilizes a temperature program to separate analytes which are then detected with a HRMS. Congeners are identified by comparing the retention time and ion-abundance ratio of target compounds and associated labeled analog compounds with retention times and ion-abundance ratio of known standards. Congeners are quantified using the isotopic dilution quantitation technique, comparing the area of the quantification ion to that of the 13C-labelled standard and correcting for response factors.

PFOAs and PFOSs

Analyzed using AXYS method MLA-060

Samples will be analyzed by liquid chromatography-tandem mass spectrometry (LC/MS/MS) following solid phase extraction and selective elution procedures. Sample extracts are analyzed on a high performance liquid chromatograph coupled to a triple quadruple mass spectrometer. Target compounds are quantified using the internal standard method, comparing the area of the quantification ion to that of the 13C-labelled standard and correcting for response factors.

Metals

Analyzed using USEPA Method 200.8

Samples will be analyzed for dissolved metals following filtration of the whole water samples using a 0.45-micron fiber filter. Total metals analyses will be conducted using unfiltered water samples.

Metals analyzed using Method 200.8 include: aluminum, arsenic, barium, beryllium, cadmium, cobalt, copper, lead, manganese, nickel, selenium, thallium, tin, and zinc. Samples will be analyzed by inductively coupled plasma-mass spectrometry (ICP-MS) following acid extraction. Sample extracts injected into the ICP-MS are quantified by comparing instrument response to a calibration curve developed for each analyte. Results will be reported for total (unfiltered) and filtered metals.

Calcium and Magnesium

Analyzed using USEPA Method 200.7

Samples will be analyzed for dissolved calcium and magnesium following filtration of the whole water samples using a 0.45-micron fiber filter. Total calcium and magnesium analyses will be conducted using unfiltered water samples.

Samples will be analyzed by inductively coupled plasma-atomic emission spectroscopy (ICP-AES) following acid extraction. Sample extracts injected into the ICP-AES are quantified by comparing instrument response to a calibration curve developed for each analyte. Results will be reported for total (unfiltered) and filtered calcium and magnesium.

Mercury
Analyzed using either EPA Method 245.7 or EPA Method 7470
Samples will be analyzed for dissolved mercury following filtration of the whole water samples using a 0.45-micron fiber filter. Total mercury analyses will be conducted using unfiltered water samples.

Samples may be analyzed using Method 245.7 "Mercury in Water by Cold Vapor Atomic Fluorescence Spectrometry". Samples are oxidized and the ionic mercury is then reduced to form volatile mercury. Volatile mercury is purged from the sample solution into a cold-vapor atomic adsorption (CVAA). Concentration is determined by measuring sample fluorescence against the fluorescence of known standards.

Samples may also be analyzed using Method 7470 "Mercury in Liquid Waste (Manual Cold Vapor Technique)". This technique is similar to Method 245.7 but uses different reagents to oxidize and then reduce the mercury. Instead of measuring fluorescence, this method measures absorbance using an atomic absorption spectrophotometer. Concentration is determined by measuring sample absorbance against the absorbance of known standards.

Total Petroleum Hydrocarbons (as gasoline)
Analyzed using Washington Department of Ecology Method NWTPH-Gx
Samples are purged using a purge/trap concentrator and analyzed by gas chromatograph using a flame ionization detector (GC/FID). Volatile petroleum hydrocarbon concentrations as gasoline are measured by integrating sample responses (e.g., peak areas) to responses from a calibration curve developed using a regular unleaded gasoline standard. The range of peaks associated with gasoline generally includes compounds in the molecular weight range of benzene to naphthalene.

Total Petroleum Hydrocarbons (as diesel and as lube oil)
Analyzed using Washington Department of Ecology Method NWTPH-Dx
Samples are solvent extracted and analyzed by GC/FID. Semi-volatile petroleum hydrocarbon concentrations as diesel are measured by integrating sample responses (e.g., peak areas) to responses from a calibration curve developed using a #2 diesel standard. The range of peaks associated with diesel generally includes compounds in the molecular weight range of jet fuels through #2 diesel. Semi-volatile petroleum hydrocarbon concentrations as lube oil are measured by integrating sample responses (e.g., peak areas) to responses from a calibration curve developed using a non-synthetic SAE 30 weight motor oil standard. The range of peaks associated with lube oil generally includes compounds such as lubricating oils, heavy fuel oils and mineral oils.

Oil and Grease, HEM

Analyzed using USEPA Method 1664, Rev. A

This method measures oil and grease, HEM by extracting a sample with N-hexane then desiccating the extract and weighing the residue. The materials extracted include: non-volatile hydrocarbons, vegetable oils, animal fats, waxes, soaps, greases and related materials.

Silica gel treated HEM (SGT-HEM; non-polar material) may be analyzed by re-dissolving the residue and using silica gel to remove polar compounds, then desiccating the sample and weighing the residue. Lower reporting limits may be achieved by increasing the volume of the water sample. In addition to the standard analysis described here, a "Diesel [& Lube Oil] Extract of Oil and Grease, HEM" will be conducted. The final weighed residue of the gravimetric Oil and Grease, HEM analyses will be re-suspended in methylene chloride and the material analyzed using the GC portion of the NWTPH-Dx method described above.

Hardness

Measured using Standard Methods method 2340 B

Total hardness will be calculated after determining calcium and magnesium concentrations in the sample. Calcium and magnesium will be analyzed following USEPA Method 200.8 (see above).

Ammonia Nitrogen

Measured using Standard Methods method 4500-NH3 H

A water sample is injected into a flow injection analyzer (FIA) and following reaction with various reagents, produces a blue-colored dye. The intensity of the dye's absorbance is measured with an absorbance detector. Concentration is measured by comparing sample absorbance to a standard curve of absorbance determined from known ammonia standard concentrations.

Nitrate and Nitrite Nitrogen

Measured using Standard Methods method 4500-NO3 I

A water sample is passed through a copperized cadmium column to reduce nitrate (NO3) to nitrite (NO2). The sample is then injected into a FIA and following reaction with various reagents, produces a magenta-colored dye. Total NO3 + NO2 concentration is measured by comparing sample absorbance to a standard curve of absorbance determined from known nitrate standard concentrations.

Total Nitrogen

Measured using Standard Methods method 4500-N B

A water sample is injected into a FIA. In-line ultraviolet/persulfate digestion and oxidation followed by reaction with various reagents, produces a pink-colored dye. The intensity of the dye's absorbance is measured with an absorbance detector. Concentration is measured by comparing sample absorbance to a standard curve of absorbance determined from known standard concentrations of nitrate and nitrite compounds. This method measures nearly all forms of organic and inorganic nitrogen.

Dissolved Organic Carbon
Measured using Standard Methods method 5310 B
There are several options for measuring dissolved organic carbon in this method; all of which are similar to the description below.

A field-filtered water sample is first treated by acidification and purging to remove inorganic carbon. The sample is then injected into a high temperature reaction chamber containing an oxidative catalyst. Organic carbon is oxidized to carbon dioxide (CO_2) which is carried in a gas stream to a non-dispersive infrared analyzer which measures the concentration of the CO_2. Concentration is determined by comparing measured CO_2 sample concentration to a standard concentration curve determined from known standard concentrations of potassium biphthalate.

Total Organic Carbon
Measured using Standard Methods method 5310 B
The method is the same as for dissolved organic carbon above; only the filtering step is eliminated.

Orthophosphate Phosphorus
Measured using Standard Methods method 4500-P G
Water sample is injected into a FIA and following reaction with various reagents, produces a blue complex. The intensity of the complex's absorbance is measured with an absorbance detector. Orthophosphate (PO_4) concentration is measured by comparing sample absorbance to a standard curve of absorbance determined from known orthophosphate standard concentrations.

Total Phosphorus
Measured using Standard Methods method 4500-P F
A water sample is digested using acid and persulfate to convert the phosphate in organic and inorganic compounds to orthophosphate. Following neutralization the sample is injected into a FIA and following reaction with various reagents produces a complex that is reduced with ascorbic acid to form a new blue complex. The intensity of the complex's absorbance is measured with an absorbance detector. Total phosphorus concentration is measured by comparing sample absorbance to a standard curve of absorbance determined from known orthophosphate standards that have been carried through the entire procedure.

Total Suspended Solids
Measured using Standard Methods method 2540 D
Water sample is filtered through a weighed glass-fiber filter. The filter and residue are dried at 103 to 105^{o}C. The increase in weight is the mass of the total suspended solids.

Field Parameters (dissolved oxygen, pH, specific conductance, and temperature)
Measured using a YSI 556 meter
The YSI 556 multi-parameter meter is a hand held instrument. Dissolved oxygen is measured using an internal polarographic sensor. pH is measured using a glass combination electrode. Specific conductance is measured using a 4-electrode conductivity cell. Temperature is determined with a precision thermistor. The meter is calibrated according to manufacturer specifications prior to use.

Quality Control

To ensure the data quality objectives for this study are met, the project team will implement the procedures specified in the following subsections for field and laboratory QC.

Field Quality Control Procedures

QC procedures used for field activities are described in the following sections. The frequency and type of quality control samples to be collected in the field are summarized in Table 8.

Field Logbooks and Data Forms

The project team will document daily observations on standardized field forms. Documentation will be sufficient to enable participants to accurately and objectively reconstruct events that occurred during the project at a later time. Entries will be made in waterproof ink, dated, and signed. Project-specific field data forms/sheets will be used to capture field operations and observations (see example in Appendix J). If corrections are necessary, these corrections will be made by drawing a single line through the original entry (so that the original entry is legible) and writing the corrected entry alongside. The correction will be initialed and dated. Corrected errors may require a footnote explaining the correction.

Custody Procedures

The primary objective of chain-of-custody procedures is to provide an accurate written or computerized record that can be used to trace the possession and handling of a sample from collection to completion of all required analyses. A sample is in custody when any of the following conditions are true:

- The sample is in someone's physical possession.
- The sample is in someone's view.
- The sample is locked up.
- The sample is kept in a secured area that is restricted to authorized personnel.

Field Custody Procedures

The project team will use the following guidance to ensure proper control of samples while in the field:

- As few people as possible will handle the samples.

- The sample collector will be responsible for the care and custody of collected samples until they are transferred to another person or dispatched properly under chain-of-custody rules.

- The sample collector will record sample data on standardized field data forms/sheets (see example in Appendix J).

- The sampling team leader will determine whether proper custody procedures were followed during the fieldwork and will decide if additional samples are required.

MEL personnel will be responsible for packaging and shipping samples to outside laboratories. When transferring custody (*i.e.*, releasing samples to a shipping agent), the following rules will apply:

- The container in which samples are packed will be sealed and accompanied by two copies of the chain-of-custody records. When transferring samples, the individuals relinquishing and receiving them must sign, date, and note the time on the chain-of-custody record. This record will document sample custody transfer.

- Samples will be dispatched to the laboratory for analysis with separate chain-of-custody records accompanying each shipment. Shipping containers will be sealed with custody seals for shipment to the laboratory. The chain-of-custody records will be signed by the relinquishing individual, and the method of shipment, name of courier, and other pertinent information will be entered on the chain-of-custody record before placement in the shipping container.

- All shipments will be accompanied by chain-of-custody records identifying their contents. The original record will accompany the shipment. The other copies will be distributed appropriately to the site team leader and site manager.

- If sent by common carrier, a bill of lading will be used. Freight bills and bills of lading will be retained as part of the permanent documentation.

Laboratory Custody Procedures

A designated sample custodian at the laboratory will accept custody of the shipped samples from the carrier and enter preliminary information about the package into a package or sample receipt log, including the initials of the person delivering the package and the status of the custody seals on the coolers (*i.e.*, broken versus unbroken). The custodian responsible for sample log-in will follow the laboratory's SOP for opening the package, checking the contents, and verifying that the information on the chain-of-custody agrees with samples received. The laboratory will follow its internal chain-of-custody procedures as stated in the laboratory QA Manual.

Field Quality Control Samples

Field QC samples for this project vary by analysis, but generally include one field (equipment rinsate) blank and one field duplicate for collection of sufficient sample volume, to allow the laboratories to conduct the QC analyses identified in Table 8 for each sampling event. In this context, a "sampling event" is completed when samples have been collected from all 16 monitoring locations identified in Table 4. A separate sample container for the MS/MSD and duplicate is not required for metals, mercury, hardness, ammonia nitrogen, nitrate & nitrite nitrogen, total nitrogen, orthophosphate phosphorus, and total phosphorus since the sample container for the native sample contains sufficient volume for both the sample analysis and QC testing. The field/rinsate blank is used to evaluate potential contamination from sampling equipment. Analyses conducted using isotopic dilution will not require MS/MSD samples. Analytical accuracy is evaluated using isotope dilution data for samples analyzed using this methodology. Precision will be defined using the duplicate analysis.

The matrix spike and matrix spike duplicate taken from the duplicate sample is a co-located sample collected sequentially with one sample which the laboratory uses to measure analytical precision and accuracy.

Rinsate blanks are not required for several of the conventional analytes (Table 8). Field QC samples will not be required for measurements made in the field using the YSI 556 handheld meter.

Laboratory Quality Control Procedures

Laboratory QC samples are summarized in Table 9. Detailed QC procedures are documented in the Manchester Environmental Laboratory Quality Assurance Manual (MEL, 2006) and each subcontracted laboratory's quality assurance manual. One QC goal for this project is for each lab to extract and analyze all the samples collected during each event in a single batch. By doing this, a single set of QC parameters will be applicable to all samples collected during each sampling event.

PCBs, aluminum, barium, beryllium, cobalt, manganese, nickel, selenium, thallium, tin, and low detection limit oil and grease, HEM will be collected only during two sampling events and from a subset of monitoring locations (see Table 5) due to budget constraints.

The diesel extract of oil and grease, HEM will be analyzed during the fall first flush event and first winter storm flow event (see Table 5). Monitoring may be suspended after the first winter storm flow event depending on the results of the first two events.

At a minimum, oil and grease, HEM with be analyzed with a lower detection limit during the fall first flush event and first winter storm flow event (see Table 5). At the discretion of the project team, additional samples may also be analyzed at select locations during additional events.

The method blank is used to assess potential contamination from sample handling in the laboratory.

The laboratory control sample (LCS) is sometimes referred to as a blank spike. The LCS is used to measure the accuracy of the laboratory by determining the ability of the laboratory to recover known amounts of target analytes in the absence of matrix effects.

Isotopic dilution provides recovery data for labeled analytes that relate directly to the native compound recoveries.

The matrix spike and matrix spike duplicate are samples that have known amounts of target analytes added to them in the laboratory. The laboratories measure the percent recovery of these compounds to estimate accuracy. Analytical precision is estimated by comparing the MS and MSD recoveries. The matrix spikes allow the laboratory to assess matrix interferences. Precision is also impacted by field variability since separate samples are being collected.

LCS and MS/MSD tests are not required for several of the conventional analytes. Laboratory blanks and laboratory duplicate analyses provide sufficient QC data to meet the data quality objectives for this project. Field QC samples will not be required for measurements made in the field using the YSI 556 handheld meter.

Data Management Procedures

MEL will provide sample and QC data in a standardized electronic format that is suitable for evaluating the study data. The project team will input data obtained from MEL and all field data obtained through the study into a Microsoft Excel spreadsheet to facilitate all subsequent data management, analysis, and archiving activities. All field data entries will be independently verified for accuracy. After completing the verification and review process (see description below), the project team will submit all acceptable data to Ecology for incorporation into the Environmental Information Management (EIM) system.

The project team will also perform site visits every 2 weeks to check the operational status of the data loggers at each monitoring location and upload the associated water level data using a portable field computer. The uploaded water level data will be immediately transferred to a database (SQL server with Aquarius Time Series Software) for all subsequent data management tasks. Manual measurements of water level obtained from the staff gauges at each monitoring location will be used to correct pressure transducer readings for drift.

Audits and Reports

The project will perform routine audits of water quality and hydrologic data to ensure this QAPP is being implemented correctly. In addition, data obtained from this study will be presented in a final summary report after the completion of monitoring activities. These activities are described in more detail in the following subsections.

Audits

The Manchester Environmental Laboratory conducts performance and system audits of their procedures. MEL will make those audits available upon written request from the project team. Ecology's Accreditation Program determines if external laboratories may be used to analyze samples. Since Ecology has not yet approved the method identified for PFOA and PFOS analyses, the Ecology Quality Assurance Officer will waive the requirement for accreditation of the method for this project.

Audits for hydrologic data will occur on a monthly basis. In connection with these audits, the project team will examine the data collected from each monitoring location over the previous month in relation to data from prior months to identify potential QA issues. This audit will specifically include an examination of the data record for gaps, anomalies, or inconsistencies in the water level. Any data generated from calibration checks that were performed at a particular monitoring location will also be entered into control charts and reviewed to detect potential instrument drift or other operational problems. In the event that QA issues are identified on the basis of these audits, the project team will immediately perform a site visit to troubleshoot the problem and to implement corrective actions if possible. The project team will document any QA issues that are detected through these audits in the electronic data record.

No audits will be required for other field measurements since the meter(s) used will be calibrated before and after each monitoring event.

Reports

During the implementation of this project, the project team will forward QA summary memoranda (see description in the *Data Verification and Validation* section) for each batch of samples that are submitted to the laboratory within 1 week of their completion by the Water Quality Data QA Lead (Table 2). The project team will also provide interim progress reports to Ecology on quarterly basis with the following information:

- Channel cross-section information from each monitoring location that has been sampled to determine whether there have been substantial changes in channel geometry that would warrant development of a new rating curve (see description in the *Stream Gauging* section).

- Raw and corrected water level data from each monitoring location.
- Control charts used to track calibration checks for pressure transducers installed at each monitoring location.
- Most recent current stream discharge rating curve that has been developed for each monitoring location.

Upon completion of field activities for this project, the project team will summarize results from this study in a draft summary report that will be submitted to Ecology for review and comment. The project team will prepare a final report based on the comments that are received on the draft. The summary report will present the following information:

- An overview of the study's goals and objectives.
- The study's analytical, sampling, and statistical methods.
- A formal evaluation of data quality based on field duplicates, laboratory duplicates, and matrix spikes.
- A summary of statistical and computation results for each of the six topics of interest described above in the *Data Analysis* section.
- Conclusions and recommendations regarding land use effects on toxics in runoff, differences between the Phase 2 and Phase 3 results, and limitations of the Phase 3 results.
- Hardcopy and electronic graphical and tabular summaries of toxic chemical loading estimates.
- Hardcopy and electronic copies of gauging station data.

The schedule for completing the draft and final summary report is presented in Table 2.

Data Verification and Validation

The following subsections describe the data verification and validation processes that will be used for water quality and hydrologic data, respectively.

Water Quality Data Verification and Validation

The project team will record field data and observations on standardized field forms. MEL and all subcontracted laboratories will provide both electronic and hard copy data packages for data from each sampling event. Each data package will include a case narrative discussing any problems with the analyses, alterations, if any, made to the methods, and an explanation of data qualifiers. The data package will include all relevant QC results. QC information will be used to evaluate the accuracy and precision of the data and to determine if measurement data quality objectives were met.

The project team will conduct a Quality Assurance level 1 (QA1) analytical data review following the process outlined in Ecology QA1 review guidelines (PTI, 1989). QA1 includes review of case narratives and laboratory data. Reviews verify that methods specified in this QAPP were followed, calibrations and QC checks are provided for all samples, and data are correct and complete. Evaluation criteria include: holding times, calibrations, blanks, detection limits, control samples, spike recoveries and relative percent differences, and laboratory applied data qualifiers.

Significant laboratory findings will be discussed with the applicable laboratory project managers. QA summary memoranda will be prepared for the record. Field data will also be evaluated for quality assurance. Impacts to the data (if any) will be summarized and addressed in the final report. All laboratory data reviews will be completed by the Water Quality Data QA lead (Table 2), and checked by the project manager.

The project team will validate analytical data to verify they meet project data quality objectives and to identify any limitations of the data, following the process outlined in Ecology QA1 review guidelines (PTI, 1989). The validation process will involve comparing calibration, accuracy, and precision results to the MQOs listed in the method, the laboratory standard operating procedure (SOP), and this QAPP. If no QA guidelines exist for specific analytes, then appropriate U.S. Environmental Protection Agency (EPA) National and Regional Data Review guidelines will be used.

Hydrologic Data Verification and Validation

The project team will perform the steps identified below to verify and validate hydrologic data collected through this project:

1. The available water level data from each monitoring location will be verified based on visual screening of the associated hydrographs relative to hyetographs from USGS rain gauges in the immediate vicinity. The specific gauges that will used for this purpose are indentified in Appendix N. Gross anomalies (e.g., spikes, dropouts, drift), gaps, or inconsistencies that are identified through this review will be investigated to determine if there are quality assurance issues associated with the data. If minor quality assurance issues are identified through this review, that portion of the data will be considered an estimate and flagged accordingly. If major quality assurance issues are identified, that portion of the data will be rejected an excluded from all subsequent analyses.

2. Calculated instrument drift values (see description in Measurement Quality Objectives for Hydrologic Data section) for each monitoring location will be examined to determine if they conform to the MQO specified in this QAPP for bias. Where there are minor deviations from this MQO, a correction factor for the drift will be applied to the data, and the individual corrected values will be flagged as estimates. Where there are major deviations from this MQO, that portion of the data will be rejected and excluded from all subsequent analyses.

Data Quality (Usability) Assessment

Procedures that will be used to assess the usability of the data and then analyze the data are described in the following sections.

Data Usability Assessment

The project team's Water Quality QA Lead and Flow Data QA Lead (Table 1) will review the compiled QA data for water quality and flow monitoring, respectively, using the MQOs that have been identified in this QAPP. Review results will be presented in a separate data quality assessment report for water quality and flow data, to be prepared after all monitoring activities are complete. These reports will summarize quality control results, identify when data quality objectives were not met, and discuss the resulting limitations (if any) on the use or interpretation of the data. Specific quality assurance information that will be noted in the data quality assessment reports includes the following:

- Changes in and deviations from the monitoring and quality assurance plan.
- Results of performance and/or system audits.
- Significant quality assurance problems and recommended solutions.
- Data quality assessment results in terms of precision, bias, representativeness, completeness, comparability, and reporting limits.
- Discussion of whether the quality assurance objectives were met and the resulting impact on decision-making.
- Limitations on use of the measurement data.

Data Analysis Procedures

The project team will perform the following analyses and computations using the data compiled through the monitoring activities described above and from the PSOEP:

- Calculation of summary statistics for toxic chemical concentrations for each monitoring location, land use, watershed, and flow type (i.e., base and storm).
- Statistical analyses to evaluate differences in toxic chemical concentrations for each land use, watershed, and flow type.

- Computation of toxic chemical loading estimates at each monitoring location.

- Comparison of land use based loading estimates at the watershed scale with loading estimates based on measurements at river mouths.

- Computation of toxic chemical loading estimates for the 14 study areas that provide the input to the Ecology PSBM (Figure 2).

Procedures to be used in conjunction with these analyses are described in the following subsections. However, the project team may employ alternate procedures if they are necessary, depending on the nature of the data that are obtained through this study.

Calculation of Summary Statistics for Toxic Chemical Concentrations

The project team will calculate summary statistics from the compiled data for each monitoring location to characterize toxic chemical concentrations in surface runoff. For each toxic chemical, these summary statistics will be calculated for every possible combination of monitoring location, land use, watershed, and flow type (i.e., base and storm). Table 10 identifies the specific combinations of grouping variables that will be used to generate these statistics with an associated example subset of data. The specific summary statistics that will be calculated for each subset of data will include: mean, minimum, maximum, standard deviation, 95 percent confidence interval for the mean, and percentage of non-detects.

These calculations will be straightforward for toxic chemicals without non-detect values. Where non-detect values are present in a dataset, the project team will use the following approaches for calculating the summary statistics:

- If less than 65 percent of the values in any given subset of data are non-detect values, the project team will use regression on order statistics to calculate the summary statistics listed above. This method involves using observed data above the detection limit to extrapolate below detection limit values based on an assumed distributional shape for the data (Helsel, 2005). These extrapolated values are then used in combination with the above detection limit values for estimating summary statistics. However, these extrapolated values are computed for the sole purpose of estimating summary statistics and are not estimates to replace specific non-detect values for use in other analyses.

- If more than 65 percent of the values in any given subset of data are non-detects, the project team will report only the percentage of non-detect values. All other summary statistics identified above will be reported as "ND" to indicate that these quantities cannot be accurately estimated due to the high frequency of non-detect values.

The project team will also calculate summary statistics for classes of chemicals (*e.g.*, PAHs) based on the summary statistics computed from their individual congeners. For example, the mean value for PAHs will be computed by summing the means for the individual PAH congeners. The standard deviation for PAHs will be computed by summing the variances for the individual PAH congeners, then calculating the square root of this value.

Statistical Analyses of Toxic Chemical Concentrations

The project team will analyze the data from all monitoring locations using a three-factor analysis of variance (ANOVA) test to determine if there are differences in measured toxic chemical concentrations in relation to land use, major watershed, and flow type (*i.e.*, base and storm). In order to reduce the sensitivity of the ANOVA test to violations of its underlying assumptions (*i.e.*, group means are normally distributed and have homogeneous variances), these tests will be performed on the ranks of the data as opposed to the raw concentrations. This test cannot be performed if there are multiple reporting limits in the dataset. Therefore, if a particular dataset for a toxic chemical has multiple reporting limits, all non-detect values will be assigned the highest reporting limit before computing the ranks of the data. Furthermore, this test will be performed for a given parameter only if less than 65 percent of the associated values are non-detects. In all cases, interaction effects among factors will not be investigated in these analyses due to the low numbers of sample in each group. In all tests, statistical significance will be assessed based on an alpha level of 0.05.

Calculation of Toxic Chemical Loading Estimates at Each Monitoring Location

The project team will calculate absolute and unit area loading rates for each toxic chemical measured at a particular monitoring location. These data will be compared to determine the relative contribution of specific toxic chemicals in surface runoff from the four major land use categories. In addition, loading rates calculated from base and storm flow samples will be compared to determine if the transport pathway for each toxic chemical is primarily via groundwater inputs to each monitored stream or via wash off from impervious surfaces in the surrounding drainage basin during storm events.

The following procedures will be used to calculate absolute and unit area loading rates for each toxic chemical in base and storm flow both separately and combined:

1. Flow data obtained from each monitoring location will be processed using the Hysep hydrograph separation algorithm (USGS, 1996) to estimate the volume of base flow and storm flow over the monitoring period for this study (*i.e.*, August 2009 through July 2010). This algorithm identifies local minima in the flow data and then linearly interpolates between these local minima to differentiate base flow from storm flow.

2. An absolute storm flow loading rate (kilograms per year) will be estimated for each monitoring location by multiplying the storm flow volume derived from Step 1 by the mean concentration from storm event samples that were collected from <u>all</u> monitoring

locations representing that land use in the same watershed. To provide some estimate of the uncertainty in these estimates, the storm flow volume will also be multiplied by the upper and lower 95 percent confidence limits for this mean.

3. A unit area storm flow loading rate (kilograms per hectare per year) will be estimated by dividing the absolute loading rates obtained from Step 2 by the contributing basin area for the monitoring station.

4. For each toxic chemical, an absolute base flow loading rate (kilograms per year) will be estimated for each monitoring location by multiplying the base flow volume derived from Step 1 by the mean concentration from base flow samples that were collected from all monitoring locations representing that land use in both watersheds. To provide some estimate of the uncertainty in these estimates, the base flow volume will also be multiplied by the upper and lower 95 percent confidence limits for this mean.

5. An absolute loading rate (kilograms per year) will be estimated for each monitoring location by summing the absolute storm and base flow loading rates from Step 2 and Step 4, respectively.

6. A unit area total loading rate (kilograms per hectare per year) will be estimated for each monitoring location by summing the unit area storm and base flow loading rates from Step 3 and Step 5, respectively.

These computations will be performed for each toxic chemical only if less than 65 percent of the values in the dataset for that toxic chemical are non-detect values. If greater than 65 percent of the values in the dataset are non-detect values, the project team will report the absolute and unit area loading rates as "ND" to indicate these quantities cannot be accurately estimated due to the high frequency of non-detect values.

Comparison of Land Use Based Loading Estimates at the Watershed Scale with Loading Estimates Based on Measurements at River Mouths

The project team will calculate "land use" based toxic chemical loading estimates for the Snohomish River and Puyallup River watersheds using data obtained from each of the 16 monitoring locations in this study. These values will be representative of loadings near each toxic chemical's point of origin. The project team will also calculate separate toxic loading estimates for the Snohomish River and Puyallup River watersheds using data obtained from the PSOEP. These latter values will be representative of loadings at each toxic chemical's point of discharge to Puget Sound. The project team will then compare the two sets of loading estimates to evaluate potential attenuation that may occur between a toxic chemical's point of origin and point of discharge to Puget Sound.

The methodologies that will be used to calculate each set of loading estimates are described in the following subsections.

Calculation of Land Use Based Loading Estimates

The project team will calculate the land use based toxic chemical loading estimates for the Puyallup River and Snohomish River watersheds using a similar methodology to the one used in the Phase 1 and 2 analyses of toxic chemical loadings to Puget Sound. Specifically, the project team will calculate the runoff volume associated with each land use category based on the runoff coefficient method (Chow, 1964) using the following equation:

$$q_{i,j} = r_{i,j} f_{i,j} Q_i$$

Where:
- $q_{i,j}$ = Total discharge rate (volume/time) from land use category j within watershed i
- $r_{i,j}$ = Relative runoff rate for land use category j within watershed i
- $f_{i,j}$ = Fraction of total watershed represented by land use category j within watershed i
- Q_i = average discharge rate for watershed i

The project team will compute the values for $r_{i,j}$ using the following equations:

$$r_1 f_1 + r_2 f_2 + r_3 f_3 + r_4 f_4 + r_5 f_5 = 1$$

and:

$$r_1 / r_2 = (RC)_1 / (RC)_2$$

$$r_1 / r_3 = (RC)_1 / (RC)_3$$

$$r_1 / r_4 = (RC)_1 / (RC)_4$$

$$r_1 / r_5 = (RC)_1 / (RC)_5$$

Where: $(RC)_i$ = Runoff coefficient (fraction between 0 and 1) for land use category i

The project team will compute toxic chemical loading estimates for each land use in the Snohomish River and Puyallup River watersheds using the following equation:

$$m_i = q_i c_i$$

Where: m_i = Toxic chemical loading estimate for land use category *i*

c_i = Representative toxic chemical concentration in the runoff from land use category i

The toxic chemical loading estimates for all four land use categories will subsequently be summed to provide an estimate of the toxic chemical loading from the entire watershed.

Unlike the analyses performed for the Phase 1 and 2 studies of toxic chemical loading to Puget Sound, this study will use Monte Carlo simulations to quantify the potential error in the loading estimates that stems from uncertainties in the equation inputs described above. Monte Carlo simulation is a method that estimates possible outcomes from a set of random variables by simulating a process a large number of times and observing the outcomes. Using Monte Carlo simulation, the project team will calculate multiple loading estimate scenarios for each watershed by repeatedly sampling (or picking) values for specific input variables from computer-generated probability distributions. In this way, distributions can be derived for the loading estimates that indicate which predicted values have a higher probability of occurrence. In this analysis, the project team will use Monte Carlo simulations to determine the median, 10th percentile, and 90th percentile values for toxic chemical loadings in each watershed near the point of origin. The project team will then compare these values to the loading estimates for each toxic chemical at their point of discharge to Puget Sound to assess potential attenuation within the intervening receiving waters.

The sections below describe how each of the specific inputs to the equations described above will be developed and applied.

Fraction of Total Watershed Area Represented by Land Use Category

The fraction of total watershed area represented by each land use category ($f_{i,j}$) will be derived from land use data that are obtained from the National Land Cover Dataset (MRLC, 2001). This is the same dataset that was used in the Phase 2 study of toxic chemical loadings to Puget Sound.

Watershed Discharge Rate

The average surface runoff discharge rates for each watershed (Q_i) will be derived from USGS gauging station(s) that are located at or near the mouth of each watershed. (The gauging network in each watershed is shown in Appendix A.) The average discharge rate for each watershed will be computed based on data that were collected over the monitoring period for this study (*i.e.*, August 2009 through July 2010).

Runoff Coefficient for Land Use Category

The runoff coefficients ($RC_{i,j}$) will be varied in this analysis using Monte Carlo simulations based on their anticipated range of uncertainty. For reference, the default values for each land use category that were used in the previous Phase 2 study of toxic chemical loadings to Puget Sound were as follows:

$(RC)_{i,\text{highway}}$ = 0.90
$(RC)_{i,\text{commercial/industrial}}$ = 0.85
$(RC)_{i,\text{residential}}$ = 0.70
$(RC)_{i,\text{agricultural}}$ = 0.35
$(RC)_{i,\text{forest/field/other}}$ = 0.20

For this analysis, the project team will use available literature (*e.g.*, Chow, 1964; Dunne and Leopold, 1978) to derive a representative range of values for each land use category. (This study will not consider highways as a land use separate from the other four.) To the extent possible, this range of values will reflect predominant soil types in each watershed. This range of values will then be fitted to an appropriate probability distribution (*e.g.*, uniform, triangular, *etc.*) for repeated sampling during the Monte Carlo simulations. Using this approach, probability distributions will be obtained for the toxic chemical loading estimates that reflect uncertainty in the runoff coefficients for each land use category.

Best Estimate of Representative Toxic Chemical Concentrations

The representative toxic chemical concentration in the runoff from each land use category (c_i) will be varied in this analysis using Monte Carlo simulations based on their measured uncertainty from the sampling conducted in connection with this study. Specifically, the mean and standard deviation for each toxic chemical in runoff from a particular land use will be calculated from pooled base flow and storm flow samples (n = 16) that were collected in each watershed. In these calculations, non-detect values will be handled using the approach described above in the section titled "Calculation of Summary Statistics for Toxic Chemical Concentrations." The mean and standard deviation will then be used to derive an appropriate probability distribution (*e.g.*, lognormal) for each toxic chemical that will be repeatedly sampling during the Monte Carlo simulations. Using this approach, probability distributions will be obtained for the toxic chemical loading estimates that reflect uncertainty in the toxic chemical concentrations for each land use category.

Calculation of Toxic Chemical Loading Estimates at River Mouths

As described above, the project team will calculate loading estimates for the Snohomish River and Puyallup River watersheds using data obtained from the PSOEP. These values will be representative of loadings at each toxic chemical's point of discharge to Puget Sound. To calculate these values, the project team will determine the flow at the mouth of each watershed over the monitoring period for this study (*i.e.*, August 2009 through July 2010) based on data obtained from USGS gauging stations (see Appendix A). An absolute loading rate (kilograms per year) will be estimated for each river by multiplying this flow volume by a representative concentration for each toxic chemical. It is anticipated that this representative concentration will be derived based on the mean concentration from the three samples that will be collected at the mouth each river through the PSOEP. However, to avoid potential bias introduced by the treatment of non-detect values in the dataset, the mean concentration will be calculated using only the detected values in the dataset.

Computation of Toxic Chemical Loading Estimates for the 14 Study Areas

The project team will compute toxic chemical loading estimates for the 14 study areas that provide the input to the Ecology PSBM (Figure 2) using the same approach described above for calculating land use based toxic chemical loadings at the watershed scale (see section titled "*Calculation of Land Use Based Loading Estimates*"). However, in this case, a separate analysis will be performed for each of the 14 study areas.

The following sections indicate how the required inputs for this analysis will be developed and applied.

Fraction of Total Study Area Represented by Land Use Category

In each study area, the fraction of the total study area represented by each land use category ($f_{i,j}$) will be derived from land use data that are obtained from the National Land Cover Dataset (MRLC, 2001). This is the same dataset that was used in the Phase 2 study of toxic chemical loadings to Puget Sound.

Study Area Discharge Rate

Surface runoff discharge rates from each study area (Q_i) will be varied in this analysis using Monte Carlo simulations based on their measured uncertainty from compiled historical data. Specifically, the mean and standard deviation for surface runoff discharge rates within each study area will be calculated from historical data that are compiled from available USGS gauging stations. These values will then be used to derive an appropriate probability distribution (*e.g.*, normal or lognormal) for surface runoff discharge rates from each study area that will be repeatedly sampling during the Monte Carlo simulations. Using this approach, probability distributions will be obtained for the toxic chemical loading estimates that reflect uncertainty in the surface discharge rates for each study area.

Runoff Coefficient for Land Use Category

The runoff coefficients ($RC_{i,j}$) will be varied in this analysis using Monte Carlo simulations based on their anticipated range of uncertainty. For this analysis, the project team will use available literature (*e.g.*, Chow, 1964; Dunne and Leopold, 1978) to derive a representative range of values for each land use category. To the extent possible, this range of values will reflect regional differences in soil characteristics across the 14 study areas. This range of values will then be fitted to an appropriate probability distribution (*e.g.*; uniform, triangular, *etc.*) for repeated sampling during the Monte Carlo simulations. Using this approach, probability distributions will be obtained for the toxic chemical loading estimates that reflect uncertainty in the runoff coefficients for each land use category and study area.

Best Estimate of Representative Toxic Chemical Concentrations

The representative toxic chemical concentrations in the runoff from each land use category (c_i) will be varied in this analysis using Monte Carlo simulations based on their measured uncertainty from the sampling conducted in connection with this study. Specifically, the mean and standard deviation for each toxic chemical in runoff from a particular land use will be calculated from pooled base flow and storm flow samples that were collected from both watersheds (n = 32). In these calculations, non-detect values will be handled using the approach described above in the section titled "Calculation of Summary Statistics for Toxic Chemical Concentrations." The mean and standard deviation will then be used to derive an appropriate probability distribution (*e.g.*, lognormal) for each toxic chemical that will be repeatedly sampling during the Monte Carlo simulations. Using this approach, probability distributions will be obtained for the toxic chemical loading estimates that reflect uncertainty in the toxic chemical concentrations for each land use category.

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TABLES

Table 1. Key staff assigned to the Phase 3 characterization of toxic loadings via surface runoff study.

Name	Organization	Role	Responsibilities	Phone
James Maroncelli	Ecology	Project Manager	Responsible for overall monitoring program including fiscal resources and personnel. Approves QAPP.	Office: (360) 407-6588
John Lenth	Herrera	Consultant Project Manager	Responsible for ensuring tasks and other requirements of this QAPP are executed on time. Responsible for verifying the QAPP is followed and the study is producing data of known and acceptable quality. Ensures adequate training and supervision of all monitoring and data collection activities. Supervises all assigned study personnel. Tracks project schedule and budgets. Provides regular status updates to the Ecology project manager.	Office: (206) 441-9080 x144 Mobile: (206) 245-7539
Joy Michaud	Herrera	Principal-in-charge	Provides senior quality assurance review of all project technical work and deliverables.	Office: (360) 754-1344 Mobile: (360) 790-5789
Andy Hafferty	E & E	Water Quality Data QA Lead	Responsible for coordinating the sampling events with the laboratory. Oversees the review of all analytical laboratory data to verify they meet quality objectives specified in this QAPP.	Office: (206) 624-9537
Dylan Ahearn	Herrera	Flow Data QA Lead	Responsible for coordinating field work related to continuous flow monitoring. Oversees the review of all flow monitoring data to verify they meet quality objectives specified in this QAPP. Coordinates the development of discharge rating curves for individual monitoring locations.	Office: (206) 441-9080 x190 Mobile: (206) 407-9538
David Ikeda	E & E	Water Quality Data Management Lead	Responsible for processing analytical data obtained from the laboratory for subsequent analyses and entry into the EIM.	Office: (206) 624-9537
Peter Steinberg	Herrera	Flow Data Management Lead	Responsible for processing continuous flow data. Applies corrections to these data as necessary based on routine calibration checks.	Office: (206) 441-9080 x256
Jennifer Schmidt	Herrera	GIS Analysis Support	Provides GIS support during QAPP development and preparation of the final project report.	Office: (206) 441-9080 x184
Dennis Helsel	Practical Stats	Statistical Analysis Support	Provides statistical analysis support during QAPP development and preparation of the final project report.	Office: (303) 870-4921

Table 1 (continued). Key staff assigned to the Phase 3 characterization of toxic loadings via surface runoff study.

Name	Organization	Role	Responsibilities	Phone
Stuart A. Magoon	Ecology	Laboratory Director	Responsible for supervision of laboratory personnel involved in generating analytical data for this study. Responsible for ensuring that laboratory personnel involved in generating analytical data have adequate training and a thorough knowledge of the QAPP and all SOPs specific to the analyses or task performed and/or supervised. Responsible for oversight of all operations, ensuring that all QA/QC requirements are met, and documentation related to the analysis is completely and accurately reported. Enforces corrective action, as required. Develops and facilitates monitoring systems audits.	Office: (360) 871-8801

Ecology = Washington State Department of Ecology
E & E = Ecology and Environment, Inc.
EI = Environmental Information Management database
GIS = Geographic information system
Herrera = Herrera Environmental Consultants
QA = Quality assurance
QAPP = Quality assurance project plan
QC = Quality control
SOP = Standard operating procedure

Table 2. Schedule of key project milestones and deliverables for the Phase 3 characterization of toxic loadings via surface runoff study.

	Project Milestone/Deliverable	Date
1.	GIS Analysis to Support Monitoring Location Selection	Apr - May, 2009
2.	Reconnaissance of Monitoring Locations	May 2009
4.	Draft QAPP Submitted	June 5, 2009
5.	Final QAPP	July 20, 2009
6.	Install and Test Equipment for Continuous Flow Monitoring	July 2009
7.	Initiate Surface Runoff Sampling and Continuous Flow Monitoring	August 1, 2009
8.	Complete Surface Runoff Sampling and Continuous Flow Monitoring	July 31, 2010
9.	Data Analysis	August 2010
10.	Draft Data Report	September 15, 2010
11.	Final Data Report	October 31, 2010

Table 3. Analytical methods, reporting limits, and quality control limits.

Priority Pollutant Scans for 10 POTWs – Laboratory Quality Control Limits									
Analysis Method	**Preparation Method**	**Parameter**	**Reporting Limit (ug/L)**	**MS/MSD %R (%)**	**MS/MSD RPD (%)**	**Calibration %RSD††† (%)**	**CCV (%)**	**LCS (%)**	**Others (specify) Surrogate %Recovery (%)**
8270 SIM	3510	PAHs	0.01	** see below	** see below	† see below	±15	40-140	20-200
8270	3510	BNAs	0.25 - 5	50-150	40	† see below	±20	50-150	*see below
8270	3535 or 3510	Herbicides	0.062	40-130	40	† see below	±20	40-130	40-130
GC/HRMS 1614	GC/HRMS 1614	PBDEs	0.00001–0.0001	** see below	** see below	±20 target, ±35 labeled	70-130 target, 50-150 labeled	50-150 target, 30-140 labeled	10-150
8081	3535 or 3510	Pesticides	0.002 – 0.025	50-150	40	††	±15	50-150	50-150
MLA060 (AXYS 2008)	MLA060 (AXYS 2008)	PFOAs and PFOSs	0.0001	** see below	** see below	R^2 > 0.990	±30 for a maximum of three compounds; remainder ±20	80-120, 70-130 depending on analyte	20-150, 40-150 depending on analyte
GC/HRMS 1668	GC/HRMS 1668	PCBs	0.0001	** see below	** see below	±20 target, ±35 labeled	70-130 target, 50-150 labeled	50-150 target, 30-140 labeled	10-150
200.8	200.8	Metals	0.002 - 50	75-125	20	†††	±10	85-115	NA
245.7	245.7	Mercury	0.002	75-125	20	†††	±10	85-115	NA
NWTPH-Gx	NWTPH-Gx	Gasoline	140	70-130	40	R^2 > 0.99	±15	70-130	70-130
NWTPH-Dx	NWTPH-Dx	Diesel	150	70-130	40	R^2 > 0.99	±15	70-130	50-150
NWTPH-Dx	NWTPH-Dx	Lube Oil	380	NA	NA	R^2 > 0.99	±20	NA	50-150
1664, Rev. A.	1664, Rev. A	Oil & Grease, HEM	5,000 (MDL = 1,400)	78-114	20	NA	NA	RPD 18 %R 78-114	NA
NWTPH-Dx	1664, Rev. A	Oil & Grease, HEM	150	NA	NA	NA	NA	NA	70-130
1664, Rev. A	1664, Rev. A Large sample	Oil & Grease, HEM	1,250 (MDL = 350)	78-114	20	NA	NA	RPD 18 %R 78-114	NA
2340B	200.7	Hardness	300 as $CaCO_3$	75-125	20	NA	NA	85-115	NA
4500-NH3 H	4500-NH3 H	Ammonia Nitrogen	10	75-125	20	10	10	80-120	NA
4500-NO3 I	4500-NO3 I	Nitrate & Nitrite Nitrogen	10	75-125	20	10	10	80-120	NA
4500-N B	4500-N B	Total Nitrogen	25	75-125	20	10	10	80-120	NA
5310 B	5310 B	Dissolved Organic Carbon	1,000	75-125	20	10	10	80-120	NA
5310 B	5310 B	Total Organic Carbon	1,000	75-125	20	10	10	80-120	NA
4500-P G	4500-P G	Orthophosphate Phosphorus	3	75-125	20	10	10	80-120	NA
4500-P F	4500-P F	Total Phosphorus	5	75-125	20	10	10	80-120	NA
2540 D	2540 D	Total Suspended Solids	1,000	NA	NA	NA	NA	RPD 20 %R 80-120	NA
YSI 556 meter	NA	Dissolved Oxygen	0.1 mg/L	NA	NA	NA	NA	NA	NA
YSI 556 meter	NA	pH	NA	NA	NA	NA	NA	NA	NA

Table 3 (continued). Analytical methods, reporting limits, and quality control limits.

Priority Pollutant Scans for 10 POTWs – Laboratory Quality Control Limits									
Analysis Method	**Preparation Method**	**Parameter**	**Reporting Limit (ug/L)**	**MS/MSD %R (%)**	**MS/MSD RPD (%)**	**Calibration %RSD††† (%)**	**CCV (%)**	**LCS (%)**	**Others (specify) Surrogate %Recovery (%)**
YSI 556 meter	NA	Specific Conductivity	1 µS	NA	NA	NA	NA	NA	NA
YSI 556 meter	NA	Temperature	NA	NA	NA	NA	NA	NA	NA

Key to Table 3:
* 1,2-Dichlorobenzene-D4 16-110%
* 2-Fluorobiphenyl 43-116%
* 2-Fluorophenol 21-110
* D4-2-Chlorophenol 33-110%
* D5-Nitrobenzene 35-114%
* D5-Phenol 10-110%
* Pyrene-D10 50 -150%
* Terphenyl-D14 33-141%
** These are isotopic dilution methods: no MS/MSD required.
† Calibration ModelRequirement
Average response %RSD < 15%
Linear curve $r^2 > 0.995$; %RSD < 20%
Quadratic curve coefficient of determination (cod) > 0.99, at least six calibration points
†† Calibration ModelRequirement
Average response %RSD < 20%
Linear curve $r^2 > 0.99$; %RSD < 20%
Quadratic curve coefficient of determination (cod) > 0.99, at least six calibration points
††† Calculated concentration of each standard must be ±20% (lowest cal may be ±50%); except for PFOA/PFOS: ±25 % of actual (lowest cal may be ±30%) and metals ±10% of actual (lowest cal may be ±20%)

Appendix M includes detailed list of RLs for each individual analyte/congener.

Acronyms and Abbreviations:
%R percent recovery
BNAs Base/Neutral/Acid Extractable Compounds (semivolatiles)
CCV Continuing Calibration Verification
GC Gas Chromatograph
HRMS High Resolution Mass Spectrometry
LCS Laboratory Control Sample
MDL Method Detection Limit
MS Matrix Spike
MSD Matrix Spike Duplicate
NA Not Applicable
PAHs Polycyclic aromatic hydrocarbons
PBDEs Polybrominated diphenyl ethers
PCBs Polychlorinated biphenyls
PFOAs Perfluoroorganic acids
PFOSs Perfluorosulfonates
RL Reporting Limit
RPD Relative Percent Difference
RSD Relative Standard Deviation
SIM Selected Ion Monitoring
ug/L micrograms per liter (parts per billion [ppb])

Table 4. Summary information for selected monitoring locations and their associated drainage basins in the Snohomish River Watershed and Puyallup River Watershed.

Monitoring Location ID	Monitoring Location Coordinates (UTM)	Drainage Basin Representative Land Use	Drainage Basin Area (hectares)	Land Use Breakdown (%)			
				Commercial/ Industrial	Residential	Agricultural	Forest/Field/ Other
Snohomish River Watershed							
CB335	554063.007943, 5309759.47667	Commercial/Industrial	213.4	62.7%	29.2%	0.0%	7.5%
CBX	555672.035262, 5309703.98759	Commercial/Industrial	224.2	29.6%	62.4%	0.0%	6.4%
RB111	569272.049652, 5311659.65829	Residential	581.2	0.2%	58.2%	4.2%	37.3%
RB202	568128.858768, 5299271.84088	Residential	334.3	0.4%	64.0%	0.0%	35.6%
AG174	569159.774363, 5302333.92985	Agricultural	360.5	0.0%	11.5%	49.6%	38.9%
AGG	559517.099173, 5330755.76999	Agricultural	249.4	0.0%	25.9%	49.7%	24.5%
FB200	577693.601262, 5317990.38049	Forest/Field/Other	174.2	0.0%	9.3%	0.0%	90.7%
FB203	588160.264358, 5299898.50836	Forest/Field/Other	1657.6	0.0%	2.9%	0.0%	95.8%
Puyallup River Watershed							
CBA	557031.022208, 5234338.21891	Commercial/Industrial	655.9	31.8%	62.1%	0.0%	6.2%
CBB	551510.941536, 5238021.81523	Commercial/Industrial	435.3	38.1%	48.4%	0.0%	13.4%
RB53	551196.567944, 5231447.99943	Residential	375.5	5.1%	81.7%	1.1%	9.8%
RB209	548616.293597, 5228040.37359	Residential	548.7	4.5%	81.6%	0.0%	13.9%
AG143	576361.877304, 5224874.67739	Agricultural	337.5	0.2%	9.5%	53.1%	37.2%
AG62	570811.016618, 5233122.35979	Agricultural	330.9	0.1%	24.0%	50.0%	25.9%
FB130	590803.841674, 5225041.38736	Forest/Field/Other	80.4	0.0%	3.5%	0.0%	96.5%
FB372	563044.272399, 5214256.61906	Forest/Field/Other	528.0	0.0%	2.5%	0.0%	97.5%

Table 5. Monitoring parameters and associated sampling frequency for the Phase 3 characterization of toxic loadings via surface runoff study.

Parameter	Analysis Method	Monitoring Locations	Number of Base Flow Events	Number of Storm Flow Events	Total Number of Events	Total Number of Samples (a)	Comment
PAHs	Laboratory	16	2	6	8	128	
BNAs (plus Bisphenol A and 4-Nonyphenol)	Laboratory	16	2	6	8	128	
Pesticides	Laboratory	16	2	6	8	128	
Herbicides (plus Triclopyr)	Laboratory	16	2	6	8	128	
PBDE (35 congeners)	Laboratory	16	2	6	8	128	
PFOAs and PFOSs	Laboratory	TBD	TBD	TBD	TBD	TBD	The decision of whether, when, and where to analyze for this parameter will be based in part on the available funding.
TPH – Gas	Laboratory	16	2	6	8	128	During storm events, a single grab sample will be collected during the first round of sampling for subsequent analysis.
TPH – Diesel	Laboratory	16	2	6	8	128	During storm events, a single grab sample will be collected during the first round of sampling for subsequent analysis.
Oil & Grease, HEM	Laboratory	16	2	6	8	128	During storm events, a single grab sample will be collected during the first round of sampling for subsequent analysis.
– Diesel Extract of O&G	Laboratory	16	1	6	7	112	During storm events, a single grab sample will be collected during the first round of sampling for subsequent analysis. Grab samples will be analyzed during the Fall first flush event and first Winter storm flow event (see description above). Monitoring may be suspended after the first Winter storm flow event if results from the first two events provide no special value.
– Oil &Grease, HEM – Low Detection Limit	Laboratory	16	1	1	2	32	During storm events, a single grab sample will be collected during the first round of sampling for subsequent analysis. Grab samples will be analyzed during the Fall first flush event and first Winter storm flow event (see description above). Additional samples may be analyzed from select locations during additional events.
Total Hardness	Laboratory	16	2	6	8	128	
Ammonia Nitrogen	Laboratory	16	2	6	8	128	
Nitrate & Nitrite Nitrogen	Laboratory	16	2	6	8	128	
Total Nitrogen	Laboratory	16	2	6	8	128	
Dissolved Organic Carbon	Laboratory	16	2	6	8	128	
Total Organic Carbon	Laboratory	16	2	6	8	128	
Orthophosphate Phosphorus	Laboratory	16	2	6	8	128	
Total Phosphorus	Laboratory	16	2	6	8	128	
Total Suspended Solids	Laboratory	16	2	6	8	128	
Total Mercury	Laboratory	16	2	6	8	128	
Dissolved Mercury	Laboratory	16	2	6	8	128	

Table 5 (continued). Monitoring parameters and associated sampling frequency for the Phase 3 characterization of toxic loadings via surface runoff study.

Parameter	Analysis Method	Monitoring Locations	Number of Base Flow Events	Number of Storm Flow Events	Total Number of Events	Total Number of Samples (a)	Comment
Total As, Cd, Cu, Pb, Zn	Laboratory	16	2	6	8	128	
Dissolved As, Cd, Cu, Pb, Zn	Laboratory	16	2	6	8	128	
Total Al, Ba, Be,Co, Mn, Ni, Se, Sn, Tl	Laboratory	12	1	1	2	24	Samples for these parameters will only be collected from monitoring locations for the following land uses: commercial/industrial, residential, and forest/field/other. Samples will be analyzed during a minimum of two events: dry season base flow and first winter season storm event.
Dissolved Al, Ba, Be,Co, Mn, Ni, Se, Sn, Tl	Laboratory	12	1	1	2	24	
PCBs (209 congeners)	Laboratory	12	1	1	2	24	
Dissolved Oxygen	*In situ* with field probe	16	2	6	8	128	
pH	*In situ* with field probe	16	2	6	8	128	
Specific Conductance	*In situ* with field probe	16	2	6	8	128	
Temperature	*In situ* with field probe	16	2	6	8	128	
Flow	*In situ* with velocity meter	16	2	6	8	128	

(a) Total does not include samples collected for quality assurance purposes.

PAH = Polycyclic aromatic hydrocarbons
BNAs = Base/neutral/acid extractable compounds
PBDEs = Polybrominated diphenyl ethers
PFOAs = Perfluoroorganic acids
PFOSs = Perfluorosulfonates
TBD = To be determined
TPH = Total petroleum hydrocarbons
HEM = N-hexane extractable material
PCBs = Polychlorinated biphenyls

As = Arsenic
Cd = Cadmium
Cu = Copper
Pb = Lead
Zn = Zinc
Al = Aluminum
Ba = Barium
Be = Beryllium
Mn = Manganese
Ni = Nickel
Se = Selenium
Sn = Tin
Tl = Thallium

Table 6. Volume requirement, bottle type, bottle filling method, and sample processing requirements for monitoring parameters during base and storm flow sampling events.

Parameters	Volume Required for Analysis	Bottle Type for Collection in Field	Filling Method	Base Flow Event	Storm Event		Processing Prior to Laboratory Delivery
					Round 1	Round 2	
PAHs BNAs Pesticides Herbicides PBDEs PFOAs/PFOSs PCBs Ammonia Nitrogen Nitrate & Nitrite Nitrogen Total Nitrogen Total Organic Carbon Total Phosphorus Total Suspended Solids	11.5 L	Stainless steel 12 L	Transfer sample from stream to container with a stainless steel pitcher	Yes	Yes	Yes	Flow composite storm event samples
Gasoline	120 ml	Glass, Teflon lid, zero headspace 3 × 40 ml	Direct immersion of container in stream	Yes	Yes	No	None
Diesel Lube Oil	1 L	Amber glass, Teflon lid 1 L	Direct immersion of container in stream	Yes	Yes	No	None
Oil & Grease, HEM Diesel & Lube Oil	1 L	Glass, Teflon lid 1 L	Direct immersion of container in stream	Yes	Yes	No	None
Oil & Grease, HEM Low Detection Limit	4 L	Glass, Teflon lid 4 × 1 L	Direct immersion of container in stream	Yes (a)	Yes	No	None
Total Metals Mercury Hardness	2 L	Teflon 2 L	Direct immersion of container in stream	Yes	Yes	Yes	Flow composite storm event samples
Dissolved Metals Dissolved Organic Carbon Orthophosphate Phosphorus	2 L	Teflon 2 L	Direct immersion of container in stream	Yes	Yes	Yes	Field filter; Flow composite storm event samples

(a) Oil &Grease, HEM will be analyzed with lower detection limit during the Fall first flush event and the first Winter storm flow event. At the discretion of the project team, additional samples may also be analyzed at selected locations during additional events.

L = Liter.
ml = Milliliter.
HEM = N-Hexane-extractable material.

PAHs = Polycyclic aromatic hydrocarbons.
BNAs = Base/neutral/acid extractable compounds.
PBDEs = Polybrominated diphenyl ethers.
PFOAs = Perfluoroorganic acids.
PFOSs = Perfluorosulfonates.
PCBs = Polychlorinated biphenyls.

Table 7. Sample volumes, containers, preservation and holding times for target analytes.

Parameter	Laboratory	Method	Container	Preservation	Holding Time
PAHs	MEL	8270 SIM	1 liter amber glass, Teflon lid	Cool to ≤6°C	7 days for extraction then 40 days until analysis
BNAs	MEL	8270	1 gallon glass, Teflon lid	Cool to ≤6°C	7 days for extraction then 40 days until analysis
Pesticides	MEL	8081	1 liter amber glass, Teflon lid	Cool to ≤6°C	7 days for extraction then 40 days until analysis
Herbicides	MEL	8270	1 liter amber glass, Teflon lid	Cool to ≤6°C	7 days for extraction then 40 days until analysis
PBDEs	Pacific Rim	GC/HRMS 1668	1 liter amber glass, Teflon lid	Cool to ≤6°C	1 year from collection to analysis
PFOAs and PFOSs	Axys	MLA060	1 liter polypropylene	Cool to ≤6°C	28 days to extraction then 14 days until analysis
PCBs	Pacific Rim	GC/HRMS 1668	1 liter amber glass, Teflon lid	Cool to ≤6°C	1 year from collection to analysis
Metals	MEL	200.8 200.7	500 ml Teflon bottle	5 ml ultrapure HNO_3	6 months from collection to analysis
Mercury	MEL	245.7			28 days from collection to analysis
Gasoline	MEL	NWTPH-Gx	3 x 40 ml glass, Teflon lid, zero headspace	Cool to ≤6°C 1:1 HCl to pH <2	14 days from collection to analysis
Diesel	MEL	NWTPH-Dx	1 liter amber glass, Teflon lid	Cool to ≤6°C 1:1 HCl to pH <2	14 days from collection to analysis
Lube Oil	MEL	NWTPH-Dx			
Oil & Grease, HEM	MEL	1664, Rev. A	1 liter amber glass, Teflon lid	Cool to ≤6°C 1:1 HCl to pH <2	28 days from collection to analysis
Diesel & Lube Oil	MEL	NWTPH-Dx	Co-extracted with 1664, Rev. A aliquot)	NA	40 days from oil & grease, HEM preparation to analysis
Oil & Grease, HEM (low level)	MEL	1664, Rev. A large sample	4 x 1 liter amber glass, Teflon lid	Cool to ≤6°C 1:1 HCl to pH <2	28 days from collection to analysis
Hardness	MEL	2340B	125 ml poly	Cool to ≤6°C 1:1 H_2SO_4	6 months from collection to analysis

Table 7 (continued). Sample volumes, containers, preservation and holding times for target analytes.

Parameter	Laboratory	Method	Container	Preservation	Holding Time
Ammonia Nitrogen	MEL	4500-NH3 H	125 ml poly	Cool to ≤6°C 1:1 H_2SO_4	28 days from collection to analysis
Nitrate & Nitrite Nitrogen	MEL	4500-NO3 I			
Total Nitrogen	MEL	4500-N B			
Dissolved Organic Carbon	MEL	5310B	60 ml poly	Field filtered Cool to ≤6°C 1:1 HCl to pH<2	28 days from collection to analysis
Total Organic Carbon	MEL	5310B	125 ml poly	Cool to ≤6°C 1:1 HCl to pH<2	28 days from collection to analysis
Total Phosphorus	MEL	4500-P F			
Orthophosphate Phosphorus	MEL	4500-P G	125 ml poly	Cool to ≤6°C	48 hours
Total Suspended Solids	MEL	160.2	1 liter poly	Cool to ≤6°C	7 days (preferably 24 hours)
Dissolved Oxygen	Field Probe	YSI 556 meter	500 ml plastic or measure *in situ*	NA	Measure immediately or *in situ*
pH	Field Probe	YSI 556 meter	500 ml plastic or measure *in situ*	NA	Measure immediately or *in situ*
Specific Conductivity	Field Probe	YSI 556 meter	500 ml plastic or measure *in situ*	NA	Measure immediately or *in situ*
Temperature	Field Probe	YSI 556 meter	500 ml plastic or measure *in situ*	NA	Measure immediately or *in situ*

MEL Manchester Environmental Laboratory
ml Milliliters
°C Degrees Celsius
PAHs Polycyclic aromatic hydrocarbons
PBDEs Polybrominated diphenyl ethers
PFOAs Perfluoroorganic acids
PFOSs Perfluorosulfonates
PCBs Polychlorinated biphenyls
H_2SO_4 Sulfuric acid
HCl Hydrochloric acid
HNO_3 Nitric acid
NA Not applicable
BNAs Base/Neutral/Acid extractable compounds (semi-volatiles)
Metals Aluminum, arsenic, barium, beryllium, cadmium, calcium, cobalt, copper, lead, magnesium, manganese, nickel, selenium, thallium, tin, and zinc

Table 8. Quality control samples to be collected.

Method	Parameter	Equipment / Rinsate Blank	MS	MSD	Duplicate
8270 SIM	PAHs (use MEL blank water – 3rd)	2 per project	1/sampling event	1/sampling event	NA
8270	BNAs (use MEL blank water – 3rd)	2 per project	1/sampling event	1/sampling event	NA
8270	Herbicides (use MEL blank water – 3rd)	2 per project	1/sampling event	1/sampling event	NA
GC/HRMS 1668	PBDEs (use PacRim blank water – 2nd)	2 per project	NA	NA	1/sampling event
8081	Pesticides (use MEL blank water – 3rd)	2 per project	1/sampling event	1/sampling event	NA
MLA060	PFOAs and PFOSs (use Axys blank water – 1st)	2 per project	NA	NA	1/sampling event
GC/HRMS 1668	PCBs (use PacRim blank water – 2nd)	2 per project	NA	NA	1/sampling event
200.8	Metals	NA	1/sampling event	NA	1/sampling event
245.7	Mercury	NA	1/sampling event	NA	1/sampling event
NWTPH-Gx	Gasoline	NA	1/sampling event	1/sampling event	NA
NWTPH-Dx	Diesel & Lube Oil	NA	1/sampling event	1/sampling event	NA
1664, Rev. A	Oil & Grease, HEM	NA	1/sampling event	NA	1/sampling event
NWTPH – Dx of 1664, Rev. A residue	Oil & Grease, HEM	NA	1/sampling event	NA	1/sampling event
1664, Rev. A large sample	Oil & Grease, HEM	NA	1/sampling event	NA	1/sampling event
2340B	Hardness	NA	1/sampling event	1/sampling event	NA
4500-NH3 H	Ammonia Nitrogen	NA	1/sampling event	NA	1/sampling event
4500-NO3 I	Nitrate & Nitrite Nitrogen	NA	1/sampling event	NA	1/sampling event
4500-N B	Total Nitrogen	NA	1/sampling event	NA	1/sampling event
5310 B	Dissolved Organic Carbon	NA	1/sampling event	NA	1/sampling event
5310 B	Total Organic Carbon	NA	1/sampling event	NA	1/sampling event

Table 8 (continued). Field quality control samples for each parameter.

Method	Parameter	Equipment / Rinsate Blank	MS	MSD	Duplicate
4500-P G	Orthophosphate Phosphorus	NA	1/sampling event	NA	1/sampling event
4500-P F	Total Phosphorus	NA	1/sampling event	NA	1/sampling event
2540 D	Total Suspended Solids	NA	NA	NA	1/sampling event
YSI 556 meter	Dissolved Oxygen (field measurement)	NA	NA	NA	NA
YSI 556 meter	pH (field measurement)	NA	NA	NA	NA
YSI 556 meter	Specific Conductivity (field measurement)	NA	NA	NA	NA
YSI 556 meter	Temperature (field measurement)	NA	NA	NA	NA

NA = Not Applicable.
PAHs = Polycyclic aromatic hydrocarbons.
BNAs = Base/neutral/acid extractable compounds (semi-volatiles).
PBDEs = Polybrominated diphenyl ethers.
PFOAs = Perfluoroorganic acids.
PFOSs = Perfluorosulfonates .
PCBs = Polychlorinated biphenyls.
HEM = N-Hexane extractable material.
Metals = Aluminum, arsenic, barium, beryllium, cadmium, calcium, cobalt, copper, lead, magnesium, manganese, nickel, selenium, thallium, tin, and zinc.

Axys = Axys Analytical Services, Ltd.
1st = Rinse field collection bottle with blank water first.
MEL = Manchester Environmental Laboratory.
3rd = Rinse field collection bottle with blank water third.
PacRim = Pacific Rim Laboratories, Inc.
2nd = Rinse field collection bottle with blank water second.

Table 9. Analytical laboratory quality control samples.

Method	Parameter	Method Blank	Laboratory Control Sample (aka Ongoing Precision & Recovery Standard – OPR)	MS	MSD	Laboratory Duplicate
8270 SIM	PAHs	1/batch	1/batch	1/batch	1/batch	NA
8270	BNAs	1/batch	1/batch	1/batch	1/batch	NA
8270	Herbicides	1/batch	1/batch	1/batch	1/batch	NA
GC/HRMS 1614	PBDEs	1/batch	1/batch	**	**	NA
8081	Pesticides	1/batch	1/batch	1/batch	1/batch	NA
MLA060	PFOAs and PFOSs	1/batch	1/batch	**	**	1/batch
GC/HRMS 1668	PCBs	1/batch	1/batch	**	**	1/batch
200.8	Metals	1/batch	1/batch	1/batch	NA	1/batch
200.7	Calcium and magnesium	1/batch	1/batch	1/batch	NA	1/batch
245.7	Mercury	1/batch	1/batch	1/batch	NA	1/batch
NWTPH-Gx	Gasoline	1/batch	NA	1/batch	NA	1/batch
NWTPH-Dx	Diesel & Lube Oil	1/batch	NA	1/batch	NA	1/batch
1664, Rev. A	Oil & Grease, HEM	1/batch	NA	1/batch	NA	1/batch
NWTPH-Dx 1664, Rev. A	Diesel & Lube Oil on Oil & Grease, HEM residue	1/batch	NA	1/batch	NA	1/batch
1664, Rev. A large sample	Oil & Grease, HEM	1/batch	NA	1/batch	NA	1/batch
2340B	Hardness	1/batch	NA	NA	NA	NA
4500-NH3 H	Ammonia Nitrogen	1/batch	NA	1/batch	NA	1/batch
4500-NO3 I	Nitrate & Nitrite Nitrogen	1/batch	NA	1/batch	NA	1/batch
4500-N B	Total Nitrogen	1/batch	NA	1/batch	NA	1/batch
5310 B	Dissolved Organic Carbon	1/batch	NA	1/batch	NA	1/batch
5310 B	Total Organic Carbon	1/batch	NA	1/batch	NA	1/batch

Table 9 (continued). Analytical laboratory quality control samples.

Method	Parameter	Method Blank	Laboratory Control Sample (aka Ongoing Precision & Recovery Standard – OPR)	MS	MSD	Laborator y Duplicate
4500-P G	Orthophosphate Phosphorus	1/batch	NA	1/batch	NA	1/batch
4500-P F	Total Phosphorus	1/batch	NA	1/batch	NA	1/batch
SM2540D	Total Suspended Solids	1/batch	NA	NA	NA	1/batch
YSI 556 meter	Dissolved Oxygen	NA – measured in field	NA – field measurement	NA – measured in field	NA – measured in field	NA
YSI 556 meter	pH	NA – measured in field	NA – field measurement	NA – measured in field	NA – measured in field	NA
YSI 556 meter	Specific Conductivity	NA – measured in field	NA – field measurement	NA – measured in field	NA – measured in field	NA
YSI 556 meter	Temperature	NA – measured in field	NA – field measurement	NA – measured in field	NA – measured in field	NA

A batch is defined as all the samples collected during each sampling event.

** = These are isotopic dilution methods. No MS/MSD is required.
PAHs = Polycyclic aromatic hydrocarbons.
BNAs = Base/neutral/acid extractable compounds (semi-volatiles).
PBDEs = Polybrominated diphenyl ethers.
PFOAs = Perfluoroorganic acids.
PFOSs = Perfluorosulfonates.
PCBs = Polychlorinated biphenyls.
Metals = Aluminum, arsenic, barium, beryllium, cadmium, calcium, cobalt, copper, lead, magnesium, manganese, nickel, selenium, thallium, tin, and zinc.

Table 10. Grouping variables used to generate summary statistics with associated example subset of data.

Grouping Variables	Example Subset of Data
Chemical AND Land Use AND Flow Type	Storm flow concentrations of total zinc from agricultural land use
Chemical AND Land Use AND Flow Type AND Watershed	Base flow concentrations of dissolved copper from commercial/industrial land use in the Snohomish River Watershed
Chemical AND Flow Type	Base flow concentrations of total copper
Chemical AND Land Use	Concentrations of total lead from forest/field/other land use
Chemical AND Watershed	Concentrations of dissolved lead in the Snohomish River Watershed
Chemical	All concentrations of dissolved copper

FIGURES

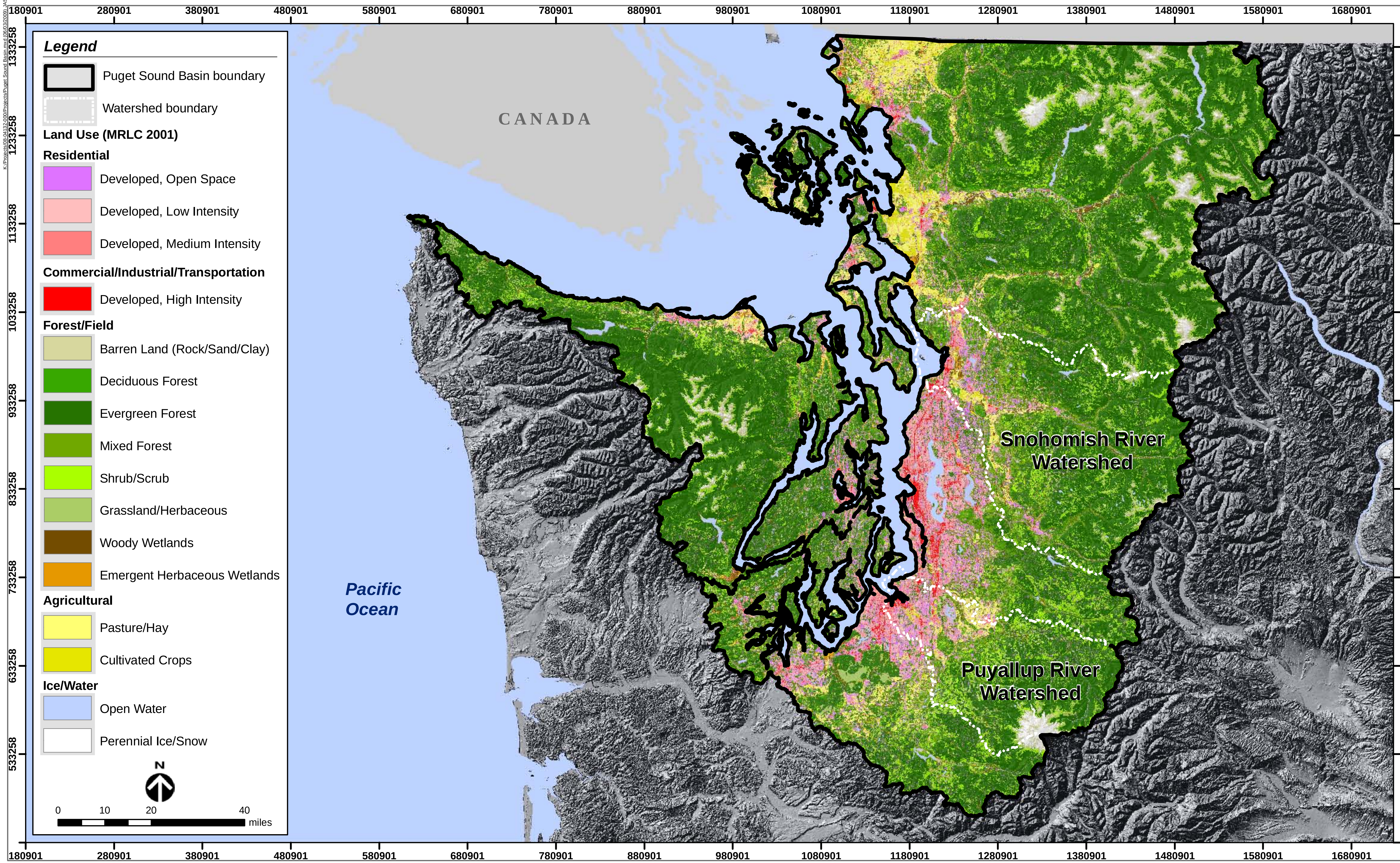


Figure 1. Regional map showing the Puget Sound Basin, Snohomish River Watershed, and Puyallup River Watershed.

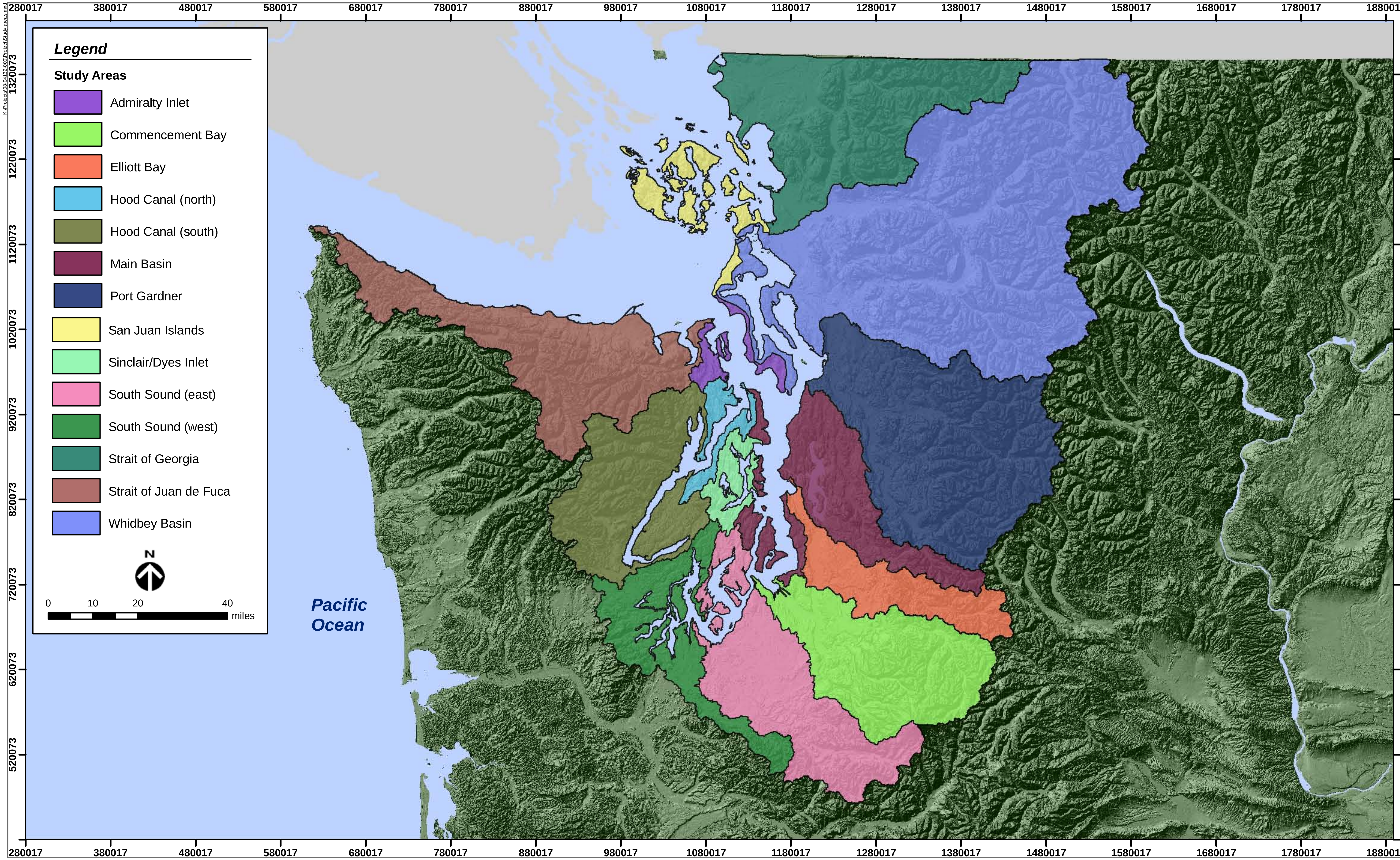


Figure 2. Fourteen study areas that provide input to the Puget Sound Box Model.

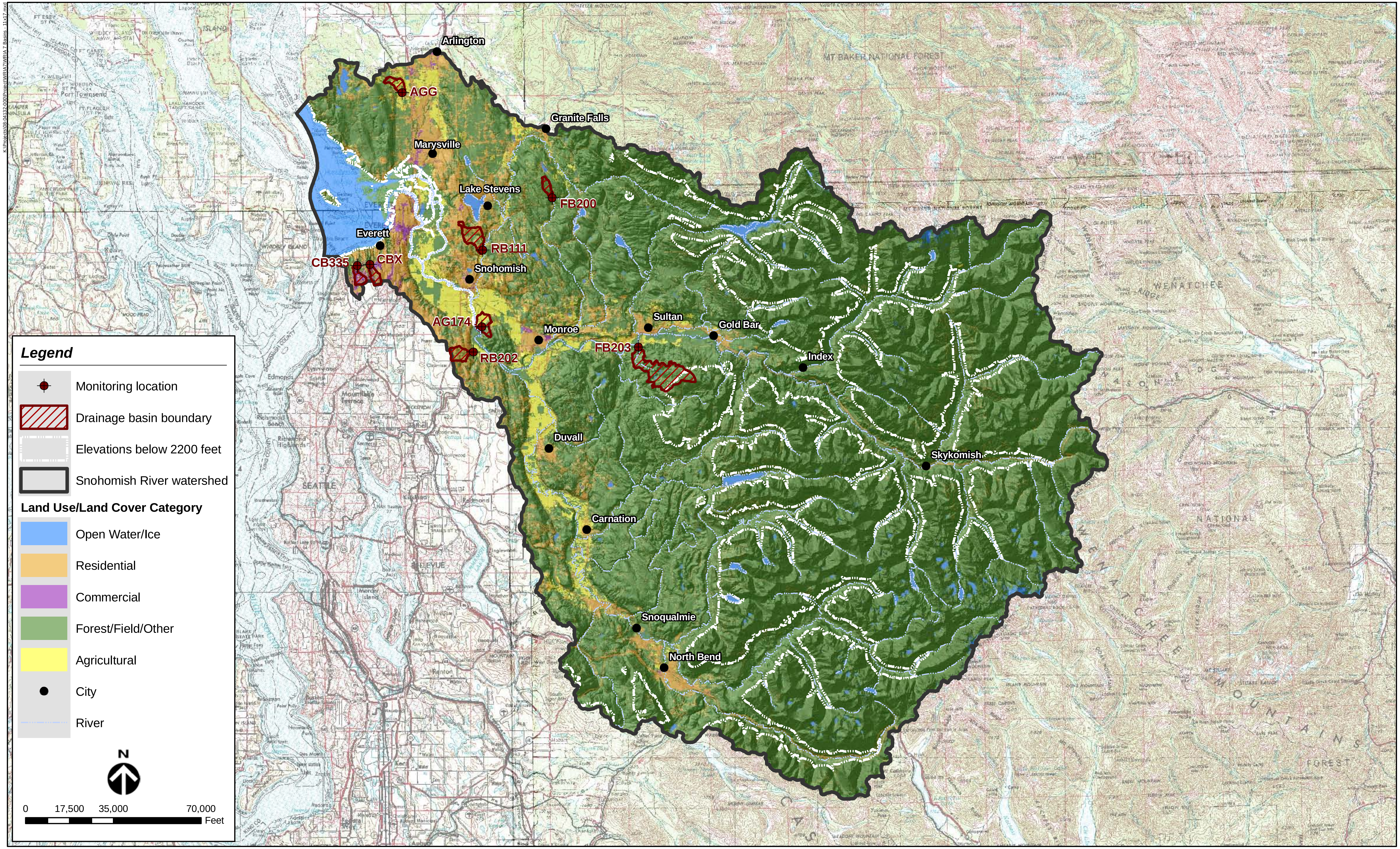


Figure 3. Individual monitoring locations and their corresponding drainage basins within the Snohomish River Watershed.

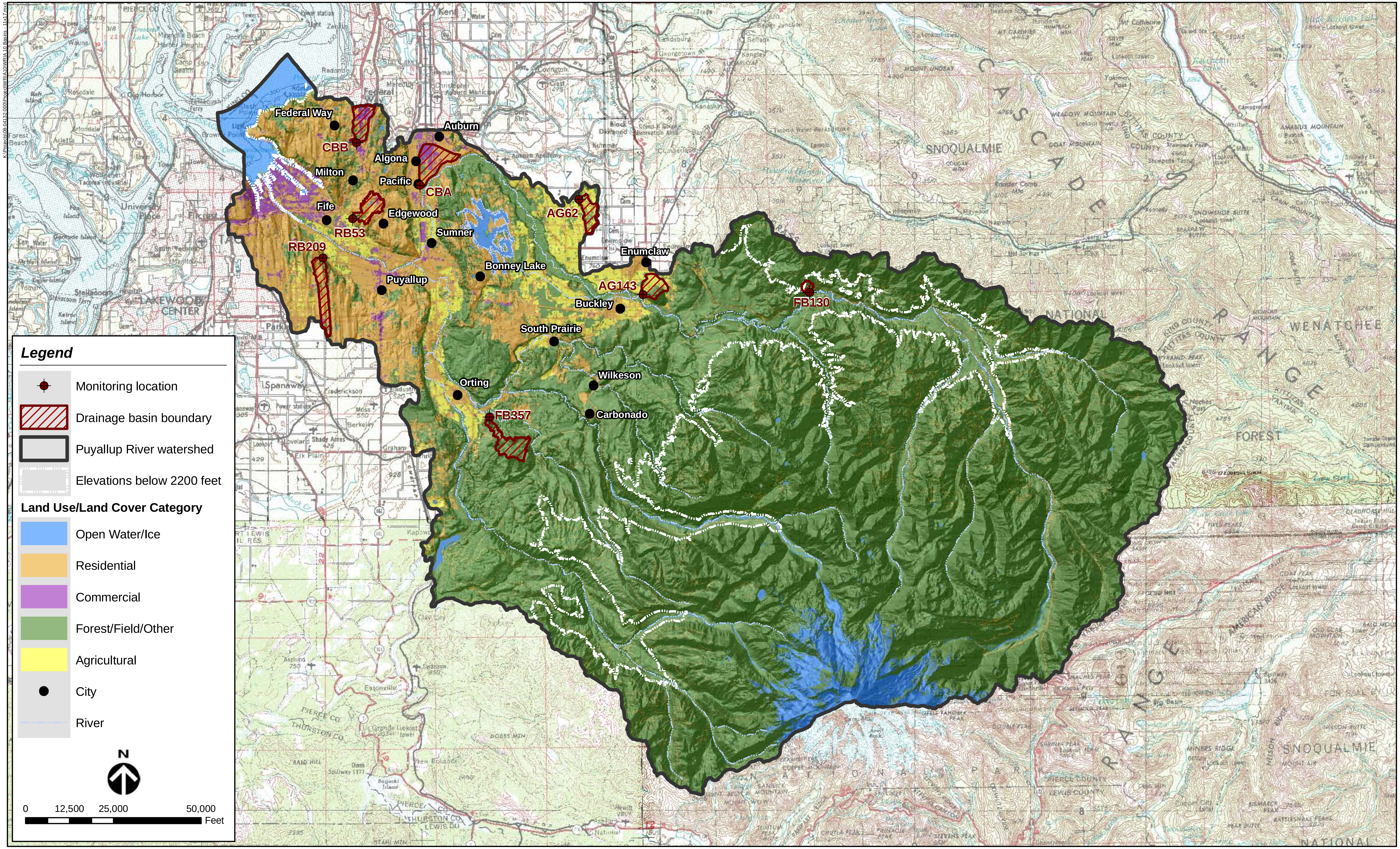
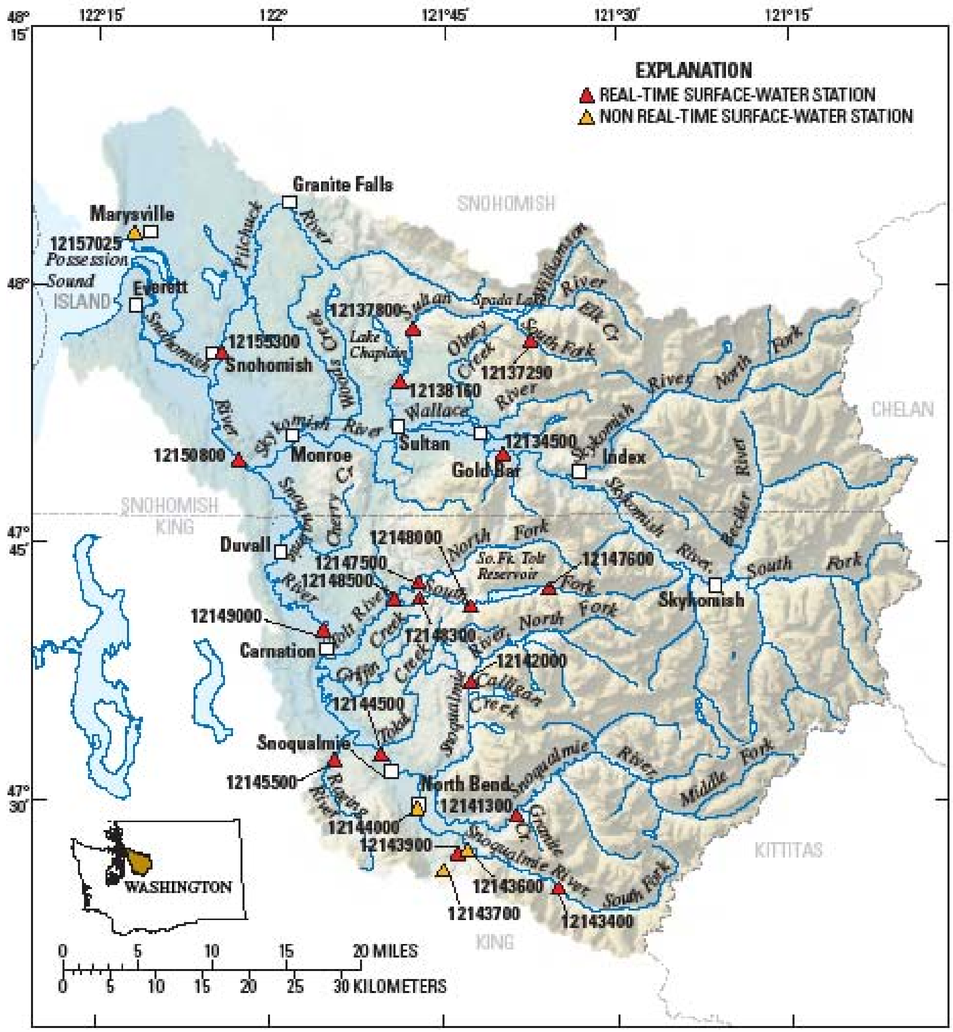


Figure 4. Individual monitoring locations and their corresponding drainage basins within the Puyallup River Watershed.

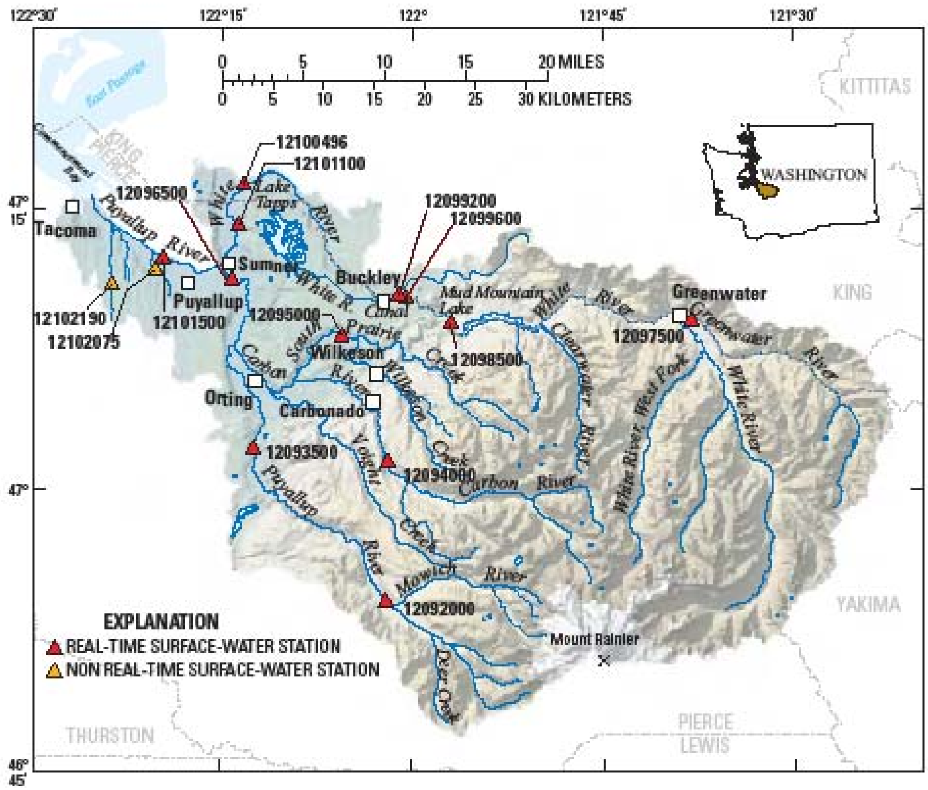
APPENDIX A

USGS Stream Gauging Network in the Snohomish River Watershed and Puyallup River Watershed



Source: USGS (2008a)

Figure A-1. USGS stream gauging network in the Snohomish River Watershed.



Source: USGS (2008b)

Figure A-2. USGS stream gauging network in the Puyallup River Watershed.

APPENDIX B

Documentation for GIS Analyses Performed During the Monitoring Location Selection Process

Documentation for GIS Analyses Performed During the Monitoring Location Selection Process

In connection with the Phase 3 study of toxic chemical loadings to Puget Sound, the project team will conduct surface runoff monitoring at 16 different locations: 8 in the Snohomish River Watershed (Water Resource Inventory Area [WRIA] 7), and 8 in the Puyallup River Watershed (WRIA 10). Each monitoring location will represent a drainage basin where one of the following land use categories is the dominant condition: commercial/industrial, residential, agricultural, or forest/field/other. Two separate drainage basins within each watershed will represent each land use type. For example, two drainage basins selected in the Puyallup watershed and two in the Snohomish watershed will represent agricultural land use, (a total of four).

To select specific monitoring locations in each watershed, the project team performed a series of GIS analyses to identify potential monitoring locations based on specific criteria for each of the following drainage basin characteristics:

- Land use
- Elevation
- Stream order

The following sections describe the data sources used in these analyses, the steps that were performed to identify potential monitoring locations, and the quality control measures that were taken to ensure that the data being generated was both correct and complete.

Data Sources and Limitations

The project team converted all GIS datasets used in the analyses described herein to the Washington State Plane South HARN 83 projection, with both the vertical and horizontal datum being in feet. Documentation on all datasets used in the analyses including the data source and native coordinate system can be found in Table B-1. These data sources are also described in the following subsections with any associated limitations that were imparted on the analyses.

Elevation Data

To facilitate site selection analyses, the project team obtained Digital Elevation Models (DEMs) with a pixel resolution of 10 meters from the United States Geological Survey (USGS) through the Washington State Geospatial Data Archive (WAGDA). This was the highest resolution topographic data available with coverage extending over the entire project area. These data were subsequently used to delineate stream networks, calculate stream order, and delineate second-order drainage basins in the Snohomish River and Puyallup River watersheds.

Table B-1. Detailed information about GIS datasets used in the monitoring site selection analyses.

Data Type	Geographic Extent	Source	Coordinate System	Online Metadata (if available)
Aerial Photos	Pierce, King, and Snohomish Counties	USDA National Agriculture Imagery Program	UTM Zone 10 NAD 83 (meters)	http://rocky2.ess.washington.edu/data/raster/naip2006/index.html
Elevation	Western Washington	USGS	UTM Zone 10 NAD 27 (meters)	http://gis.ess.washington.edu/data/raster/tenmeter/
Elevation	Puget Sound by quad	Puget Sound LiDAR Consortium	WA State Plane N NAD 83 (feet)	http://pugetsoundlidar.ess.washington.edu/lidardata/metadata/pslc2000/pslc2000_be_dem.htm
Elevation	King County	King County GIS Center	WA State Plane N NAD 83 (feet)	http://www.kingcounty.gov/operations/GIS/GISData/Metadata.aspx
Elevation	Pierce County	Pierce County GIS Team	WA State Plane S NAD 83 HARN (feet)	http://yakima.co.pierce.wa.us/geodataexpress/main.html
Hydrology	Puyallup and Snohomish River watersheds	USGS (NHD)	GCS_North_American_1983	http://nhd.usgs.gov/data.html
Hydrology	King County	King County GIS Center	WA State Plane N NAD 83 (feet)	http://www.kingcounty.gov/operations/GIS/GISData/Metadata.aspx
Hydrology	Pierce County	Pierce County GIS Team	WA State Plane S NAD 83 HARN (feet)	http://yakima.co.pierce.wa.us/geodataexpress/main.html
Hydrology	Snohomish County	Snohomish County Information Services	WA State Plane North NAD 83 (feet)	Not Available Online
Hydrology	Pierce, King, and Snohomish Counties	Washington State Department of Natural Resources	WA State Plane South HARN 83 (feet)	http://fortress.wa.gov/dnr/app1/dataweb/metadata/WA_Hydro_Data_Dic.htm
Hydrology	Washington State	Department of Ecology	WA State Plane S NAD 83 HARN (feet)	http://www.ecy.wa.gov/services/gis/data/hydro/rivers.htm
Land Use	Western Washington	Multi-Resolution Land Characteristics Consortium	USA Contiguous Albers Equal Area Conic NAD 83 (geographic)	http://www.mrlc.gov/nlcd.php
Roadway	King County	King County GIS Center	WA State Plane N NAD 83 (feet)	http://www.kingcounty.gov/operations/GIS/GISData/Metadata.aspx
Roadway	Pierce County	Pierce County GIS Team	WA State Plane S NAD 83 HARN (feet)	http://yakima.co.pierce.wa.us/geodataexpress/main.html
Roadway	Pierce, King, and Snohomish Counties	Washington State Department of Natural Resources	WA State Plane South HARN 83 (feet)	http://fortress.wa.gov/dnr/app1/dataweb/metadata/trans.htm
Roadway	Washington State	Washington State Department of Transportation	WA State Plane N NAD 83 (feet)	http://www.wsdot.wa.gov/Mapsdata/geodatacatalog/

The project team also obtained higher resolution LiDAR data with a pixel resolution of 6 feet from the Puget Sound LiDAR Consortium (PSLC). These data were used to refine drainage basin delineations for the subset of basins that were selected for monitoring. These data were available for 4 of the 16 drainage basins selected for monitoring. Contour data with an elevation interval of 20-feet or better were obtained at the county-level where available, and were also used to refine drainage basin delineations.

Since the elevation data used in this project have different levels of resolution, the drainage basin delineations vary in their accuracy. For example, a drainage basin delineated strictly from the WAGNA 10-meter DEM will inherently have more inaccuracy than a basin delineation that was refined with the high-resolution LiDAR. It should also be noted that drainage basin delineations performed for agricultural monitoring locations likely have more inaccuracy relative to those for other land use categories due to the general lack of topographic relief in these areas.

Hydrologic Data

The project team used several hydrologic datasets to verify the stream network and drainage basin delineations that were developed from the WAGNA 10-meter DEM. In particular, the project team used the National Hydrography Dataset (NHD) for this purpose. This dataset maps the surface water drainage system for the United States at a 1:24000 scale, including stream segments, water bodies, and other hydrologic features. The dataset was created by USGS in cooperation with the U.S. Environmental Protection Agency, U.S. Forest Service, and other partners.

Hydrologic data were also obtained at the county level from King, Pierce, and Snohomish counties; and at the state level from the Washington State Department of Natural Resources. Since the NHD, county, and state level hydrology datasets were much more detailed than the channel network delineated by the WAGNA 10-meter DEM, these data were helpful in determining channel accuracy, especially for agricultural monitoring locations where man-made ditches were prevalent.

Land Use Data

The project team obtained land use/land cover data from the Multi-Resolution Land Characteristics Consortium 2001 (MRLC 2001), a cooperative project that was implemented by nine federal agencies with the objective of making available Landsat 5 imagery of the conterminous United States. The National Land Cover Dataset 2001 (NLCD 2001) is a second generation raster dataset showing 21 classes of land-cover data at a resolution of 30-meter pixels. Each pixel represents a normalized land use value obtained through the combination of datasets from three time periods. Figure B-1 shows the grouped NLCD 2001 land cover in the Snohomish River and Puyallup River watersheds.

Roadway Data

The project team used GIS roadway data at the county level to evaluate monitoring location accessibility. Portions of three counties (King, Pierce, and Snohomish) are encompassed within the Snohomish River and Puyallup River watersheds. Most of these counties had publicly available GIS roadway data; where data were not available from the jurisdiction directly, data were obtained from the Washington State Department of Natural Resources. It should be noted that not all of the roadways mapped through these sources are publicly accessible, as is often the case with some forest and private roads.

Aerial Photography

The project team used color aerial photography for mapping and quality control purpose. These data were obtained at the county level (King, Pierce, and Snohomish) for the Snohomish River and Puyallup River watersheds through the U.S. Department of Agriculture National Agriculture Imagery Program (USDA NAIP). The aerial photography was flown in 2006 and has a pixel resolution of 1 meter.

Methods

This section describes the GIS methods used by the project team to delineate and classify the stream channel networks in the Snohomish River and Puyallup River watersheds, delineate second-order stream subbasins, and identify the 16 required monitoring locations for this study. An example process-flow diagram showing the analysis steps for the Snohomish River and Puyallup River watersheds is provided in Figure B-2.

Stream Network Delineation and Classification

To facilitate using an automated DEM-based approach for delineating subbasins in the Snohomish River and Puyallup River watersheds, the project team used the ArcGIS Hydrology Toolbox and the WAGNA 10-meter DEM to define a channel network in each watershed. In general, the level of channel network detail that can be extracted from an elevation dataset is limited both by the resolution of the elevation dataset itself, as well as by the landscape topography. Due to this consideration, DEM-derived channel networks often do not reflect the physical characteristics of the associated drainage basin when they are delineated at a finer resolution than the data supports. In this analysis, the project team determined that a contributing drainage area of 0.25 square kilometers produced stream networks in both watersheds that were suitably representative of on-the-ground conditions.

After the channel networks were delineated, the project team compared the resulting stream layers to publicly available high-resolution hydrology data as a quality control measure. Stream order was classified in ArcGIS using the Strahler method, which is the most commonly used algorithm for determining relative stream size. In this method, channel segments with no tributaries are assigned an order of one, and the total number of stream orders is entirely dependent on the resolution of the channel network.

Drainage Basin Delineations

After stream orders were assigned to the channel networks for both watersheds, the project team delineated drainage basins based on the classified stream segments. The project team initially performed an analysis to delineate drainage basins for all third-order stream segments; however, the average basin size delineated using these channels was too large and did not generate enough viable basins with 50 percent or more commercial, residential, agricultural, or forest land use types. Due to this consideration, the project team performed a second analysis to delineate drainage basins for all second-order streams. Because the drainage basins delineated at this scale provided substantially more options for identifying basins with the requisite land use characteristics for this study, they were used for all subsequent analyses. For reference, Table°B–2 compares the average basin size and number of viable basins meeting the land use criteria (i.e., 50 percent or more commercial, residential, agricultural, or forest land use) for both second and third order streams in the Snohomish River watershed.

Drainage basin delineation was automated by digitizing a “pour point” at the most downstream pixel of each DEM-derived stream segment. The project team then determined the total area draining to that location. Because the DEMs only take surface flow into account, pipes and manmade drainage structures (e.g., ditch networks in agricultural areas) were often not represented in the delineated drainage basins. Due to this consideration, the project team used publicly available high-resolution hydrology data to verify and correct delineated drainage basins based on these features. Where major discrepancies were identified through this process, the associated drainage basin was eliminated from all further consideration in the analyses.

Monitoring Site Selection and Subbasin Refinement

In order to ensure the land use in the drainage basins was sufficiently representative of a particular category, the project team used a stratified random sampling process to identify the individual monitoring locations. The specific goal of this process was to eliminate bias in the monitoring location selection process to the extent possible. The general steps that were used in this process are summarized below:

1. The project team screened all the drainage basins in the Snohomish River and Puyallup River watershed to identify a subset of drainage basins for which their centroid was below 2,200 feet in elevation. Drainage basins above this threshold were eliminated from further consideration. (This step was performed to ensure the drainage basins selected for monitoring would not be rendered inaccessible because of winter snow conditions.)

2. Using the most recent version of the National Land Cover Dataset (MRLC 2001), the project team screened the subset of drainage basins obtained to identify

representative drainage basins for each land use category based on the following criteria:

- Commercial/Industrial: At least 30 percent of the drainage basin must be classified as commercial/industrial land use. (Initially a minimum of 50 percent was targeted for this land use category. However, this limited the available drainage basins to only a few that largely represented only one commercial or industrial facility, which did not meet the intent of the study.)

- Residential: At least 50 percent of the drainage basin must be classified as residential land use; and no more than 10 percent may be classified as commercial/industrial land use.

- Agricultural: At least 50 percent of the drainage basin must be classified as agricultural land use.

- Forest/Field/Other: At least 90 percent of the drainage basin must be classified as forest/field/other land use.

3. Using the subset of drainage basins that met these criteria, the project team randomly selected five drainage basins for each land use category within each of the two watersheds. The project team then performed field reconnaissance on these randomly selected drainage basins to evaluate their suitability for actual monitoring relative to the following criteria:

    - Traffic and water safety
    - Ease of access
    - Property access restrictions
    - Representativeness for the targeted land use
    - Suitability for gauging (channel morphology, diversions, dams, *etc.*)

4. Drainage basins that were not suitable for monitoring based on observations from the field reconnaissance were eliminated from further consideration. If fewer than two drainage basins for any given land use were identified as being suitable for monitoring through this process, the project team randomly selected five additional drainage basins for that land use. The project team then performed field reconnaissance on these additional drainage basins as described in Step 5. This process continued until at least two drainage basins for each land use were identified as being suitable for monitoring in each of the two watersheds.

This method was used to identify 12 of the 16 monitoring locations and associated drainage basins in the Puyallup and Snohomish River watersheds. However, after all the potential drainage basins were evaluated through the process described above, suitable monitoring locations could not be found for the following land use and watershed combinations:

- One monitoring location for agricultural land use in the Snohomish River watershed
- Two monitoring locations for commercial/industrial land use in the Puyallup River watershed
- One monitoring location for commercial/industrial land use in the Snohomish River watershed

Therefore, the project team performed a more detailed GIS analysis to identify drainage basins within each watershed with the requisite land use that had not been identified through the stratified random sampling process described above. This involved manually identifying concentrated areas of commercial and agricultural land use and searching for potential streams to monitor that were not identified using the LiDAR or the DEM. After these basin boundaries had been delineated, the project team then performed field reconnaissance on these drainage basins to evaluate their suitability for actual monitoring relative to the criteria defined in Step 3 above. Once suitable drainage basins were found through this process, they were identified using a letter designation to differentiate them from drainage basins selected using the random stratified approach (see Table 4 in QAPP main text).

After 16 subbasins meeting the selection criteria had been identified in the two watersheds, the project team performed and verified the subbasin boundaries using higher-resolution topographic data, including LiDAR and county-level contour data where available. These data were used to confirm the accuracy of the delineated boundaries and to identify any possible topographic variations that might not be identifiable at the 10-meter DEM scale. In general, the precision of the basin boundaries is dependent on the resolution of the data used to refine them; therefore, all basin boundaries are approximate.

Table B-2. Comparison of second and third order drainage basins meeting the land use selection criteria in the Puyallup and Snohomish River watersheds.

Watershed Name	WRIA Number	Stream Order	Average Basin Size (hectares)	Total Number of Basins Meeting Land Use Selection Criteria[a]			
				Agricultural	Residential	Commercial	Forest/Field/Other
Puyallup River Watershed	10	2nd	250.4	10	51	4	39
Snohomish River Watershed	7	2nd	253.6	18	59	5	251
Snohomish River Watershed	7	3rd	926.2	2	13	0	183

[a] Indicates the total number of drainage basins with at least 50 percent of the total land area represented by the indicated land use.

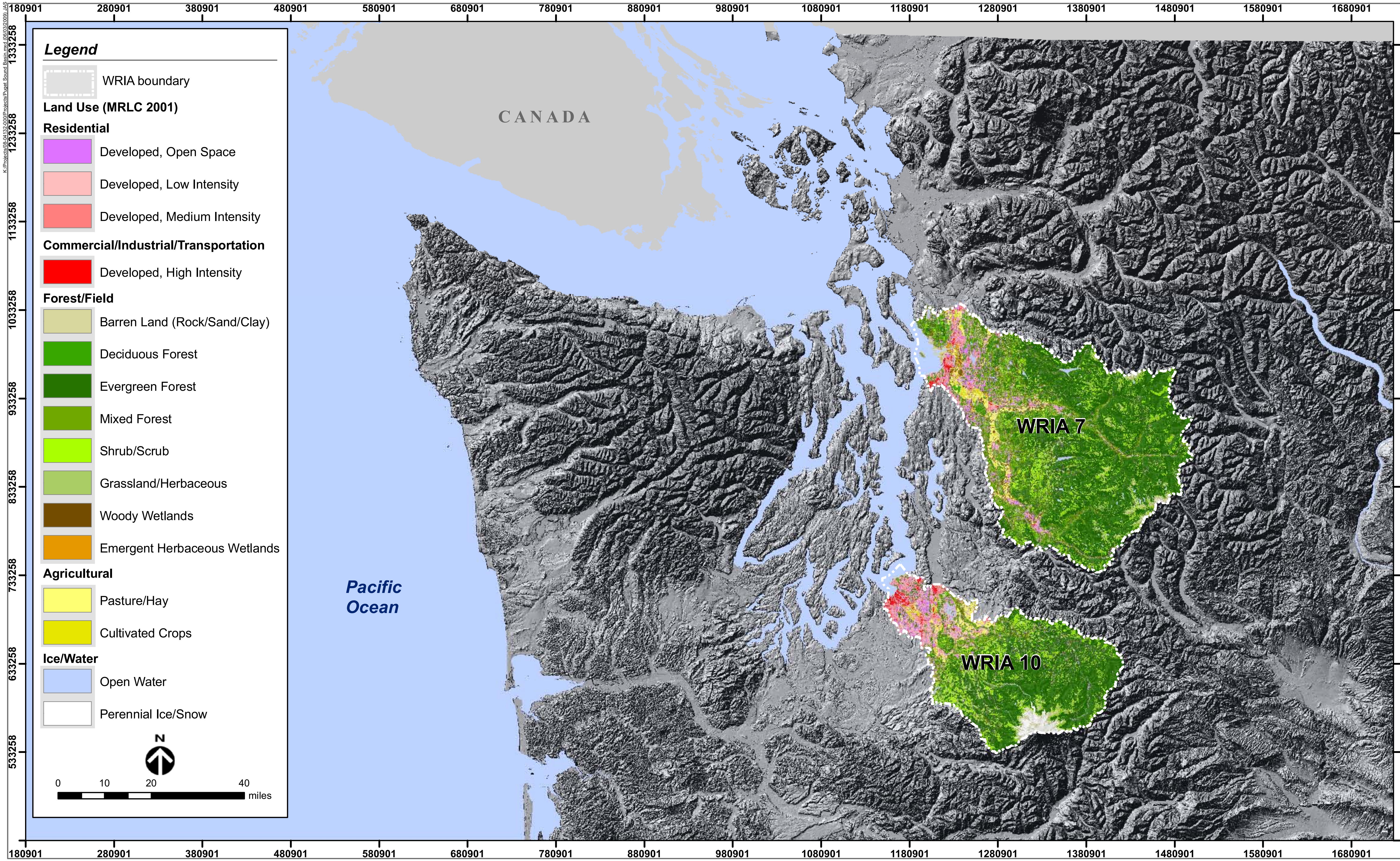


Figure B-1. Land use shown by the National Land Cover Dataset 2001 (NLCD 2001) in the Puyallup and Snohomish River watersheds.

Step One: Stream Network Delineation and Classification

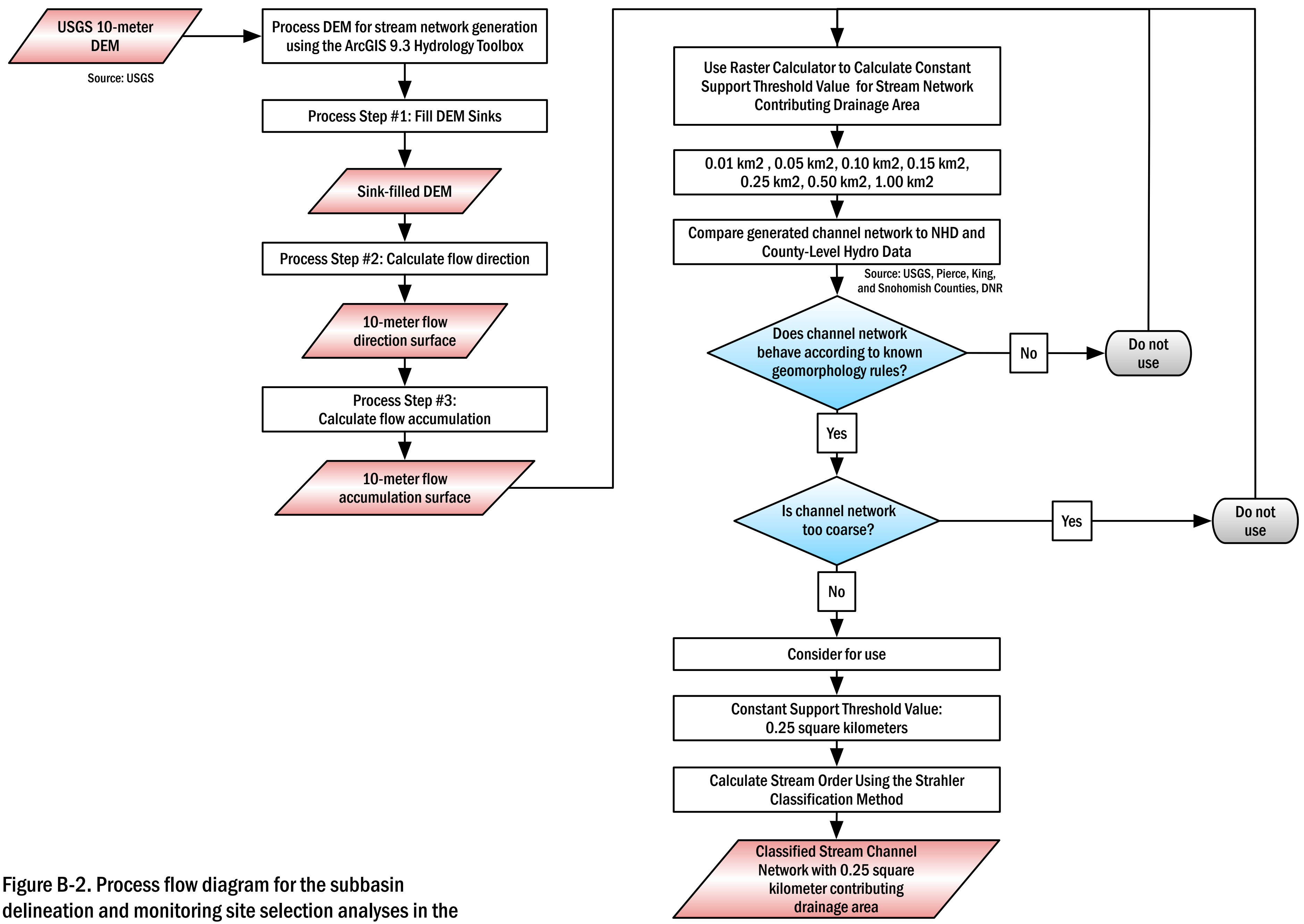


Figure B-2. Process flow diagram for the subbasin delineation and monitoring site selection analyses in the Puyallup river watershed. (Sheet 1 of 3)

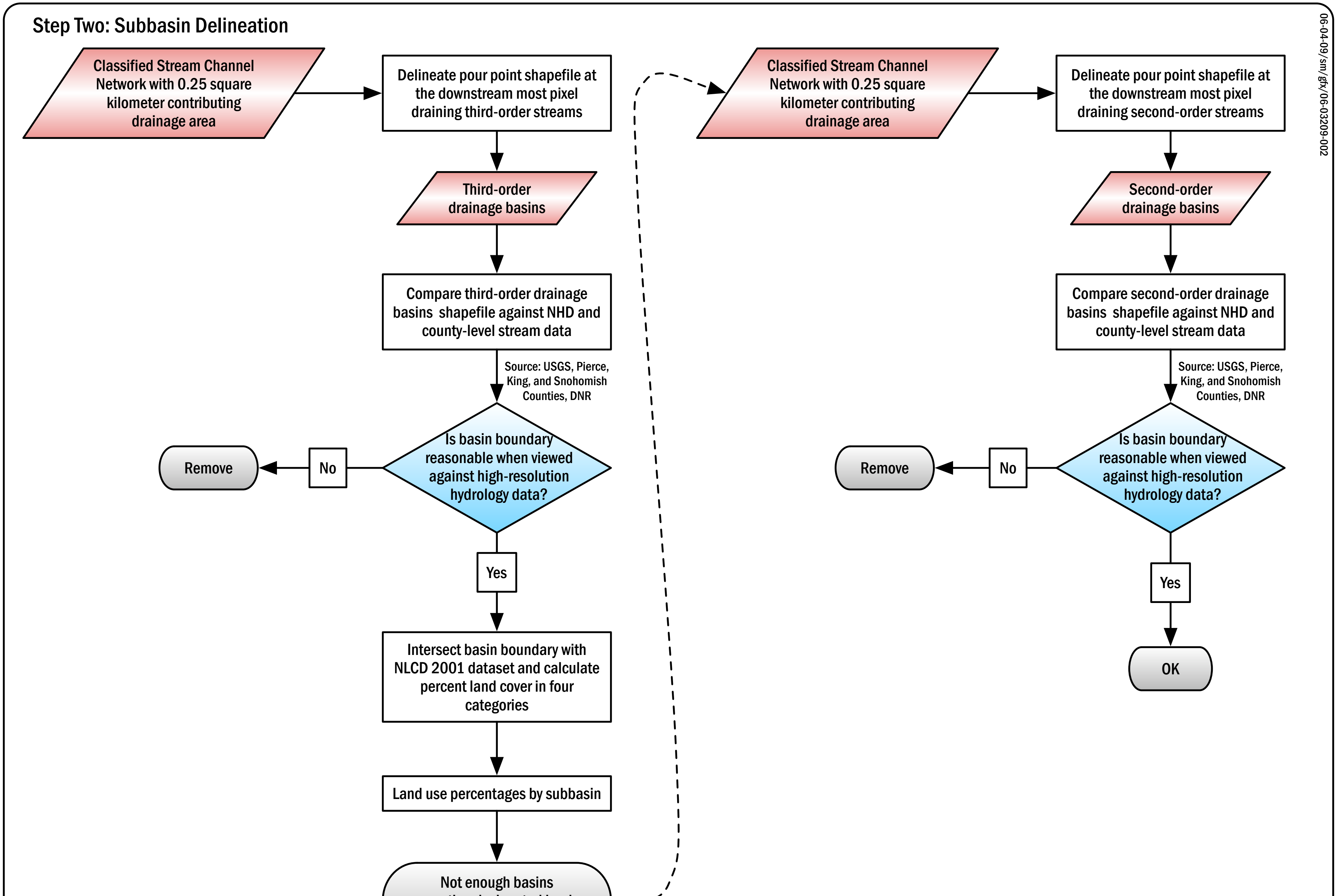


Figure B-2. Process flow diagram for the subbasin delineation and monitoring site selection analyses in the Puyallup river watershed. (Sheet 2 of 3)

Step Three: Monitoring Site Selection and Subbasin Refinement

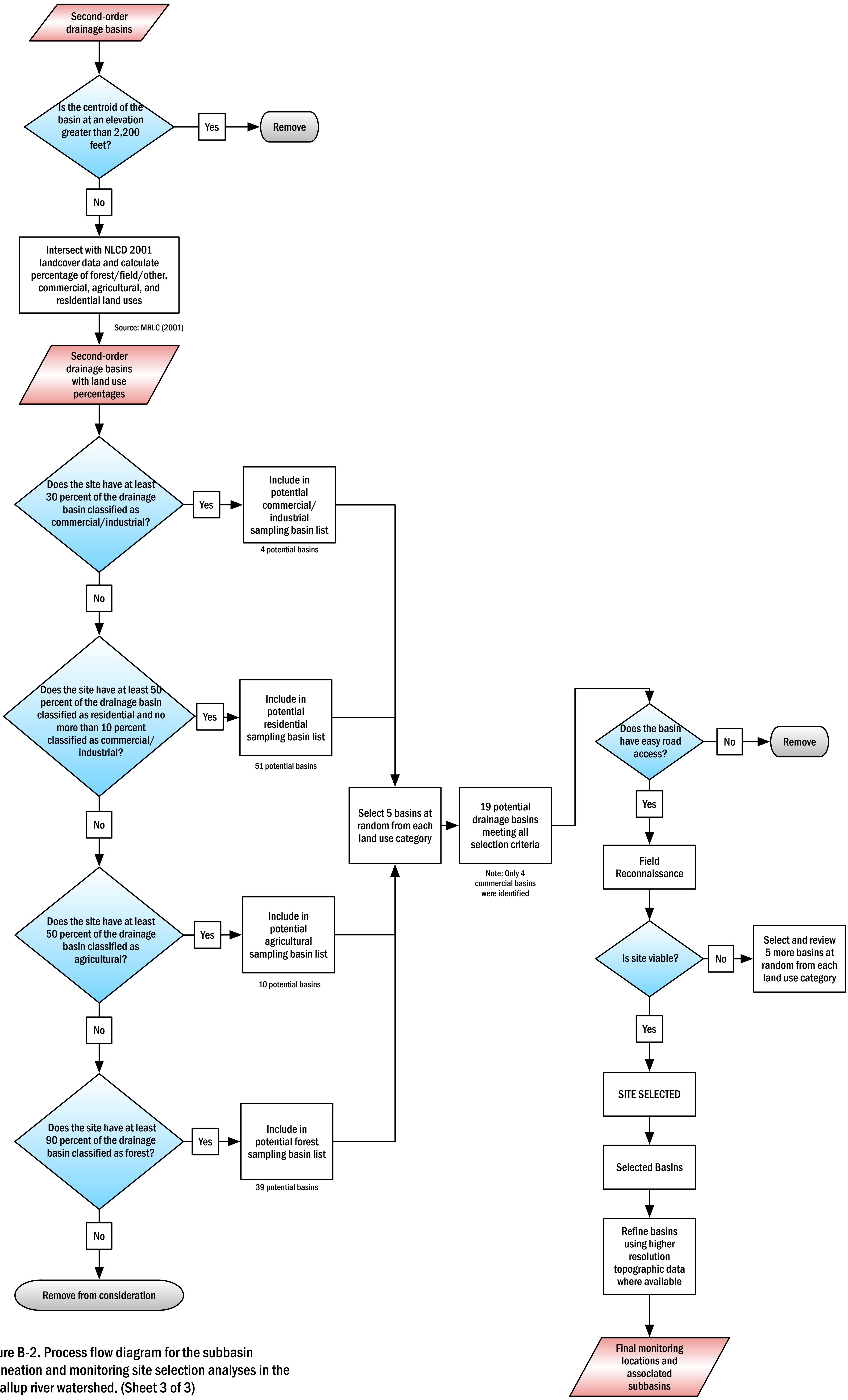


Figure B-2. Process flow diagram for the subbasin delineation and monitoring site selection analyses in the Puyallup river watershed. (Sheet 3 of 3)

06-04-09/sm/gfx/06-03209-002

APPENDIX C

Summary of Monitoring Locations Evaluated Through the Site Reconnaissance Process

Table C1. Summary of observations made during field reconnaissance to identify monitoring locations

WRIA	Basin	Go/No-Go	Comments
7	**Agricultural Basin 174**	**Go**	The stream emerges from beneath Shorts School Road in a 2 foot wide by 1 foot deep channel, constrained in a man made ditch. It is unclear how the stream is conveyed through the field upstream, as the property could not be accessed, and it was obscured by brush. The stream emerges from a 2 foot diameter culvert beneath the road and flows in the ditch for 500 feet through farm fields, before entering a final culvert through a dike along the river bank. This dike may cause the stream to backwater, but likely not as far upstream as the proposed station. There may be access issues as the location appears to be on private property, but is accessible from the right of way. How the upstream area drains is unclear, and may be an additional issue. The basin also drains significant forest area. Discharge can be measured at the exit of the culvert beneath Shorts School Road and a pressure transducer can be installed nearby downstream.
7	**Agricultural Basin G**	**Go**	The 3 foot wide stream flows in a constrained roadside ditch along the east side of 23rd Ave NE. The stream is conveyed beneath a few different driveways along the route where it is accessible. Discharge can be measured at the mouth of one of the culverts that convey the stream beneath driveways, and a pressure transducer can be installed in the immediate vicinity. Access may need to be coordinated with property owners for safer parking.
7	**Agricultural Basin 151**	No-Go	Location could not be accessed for reconnaissance due to private property restrictions.
7	**Agricultural Basin 197**	No-Go	Location could not be accessed for reconnaissance due to private property restrictions.
7	**Agricultural Basin 550**	No-Go	There is no stream in the area as mapped. All water has been diverted to agricultural ditches, which are impounded. Access is through an area clearly marked private property.
7	**Agricultural Basin 614**	No-Go	Location inappropriate for monitoring due to backwater conditions.
7	**Agricultural Basin D**	No-Go	Location inappropriate for monitoring due to backwater conditions.
7	**Agricultural Basin C**	No-Go	Location inappropriate for monitoring due to backwater conditions.
7	**Agricultural Basin B**	No-Go	Location inappropriate for monitoring due to backwater conditions and access restrictions.
7	**Agricultural Basin A**	No-Go	Location inappropriate for monitoring due to backwater conditions.
7	**Agricultural Basin E**	No-Go	Location inappropriate for monitoring due to backwater conditions.
7	**Commercial Basin 335**	**Go**	The stream, also known as Powder Mill Creek, originates from stormwater ponds that drain the Boeing business park. The stream emerges from a culvert beneath Seaway Blvd. in a deep ravine where it flows in a constrained 10 foot wide channel through a forested area, and then proceeds to flow through another culvert 200 feet downstream. Either culvert would make good monitoring locations. Discharge can be measured from the culvert and a pressure transducer can be placed in a nearby pool. There is an access gate with Everett Public Works information in the business park lot. Some jurisdiction is already monitoring flow here.
7	**Commercial Basin X**	**Go**	The stream, also known as Merrill and Ring Creek, follows a 10 foot wide confined channel along the west side of Hardeson Road. It passes through a series of box culverts beneath driveways (such as at a Federal-Express facility). It eventually enters an energy dissipation structure covered in a steel grate, and is inaccessible below that point. The driveway bridge to Federal-Express would make a good monitoring station. Discharge could be measured at the mouth of the bridge box culvert, and a pressure transducer could be placed nearby in the stream. Flow appears to be monitored nearby in the energy dissipation structure downstream. Access may require coordination with Federal Express.
7	**Commercial Basin 380**	No-Go	The stream flows alongside the railroad tracks (but separated by an access road) in a manmade constrained ditch about 3 feet wide and 1 foot deep. It is diverted into a large pond, where it then flows into a drop structure, and is conveyed by a culvert to a deep, inaccessible ravine. Discharge could be monitored in the ditch flowing along the railroad tracks. The location drains similar land uses in the adjacent Commercial Basin 335, and has been rejected primarily due to its close proximity.
7	**Forest Basin 200**	**Go**	The stream emerges from beneath North Carpenter Road at the mouth of a 10 foot wide box culvert. It then flows in a man made channel along the roadside for a quarter of a mile. Flow can be measured at the culvert mouth, and a pressure transducer can be installed in a nearby pool alongside a cabled-in piece of Large Woody Debris. The stream can be accessed by walking down a gentle bank from the road to the culvert. The stream is in a pasture here which is likely private property.
7	**Forest Basin 203**	**Go**	Upstream of the Ben Howard Road crossing, the stream flows as a cascade in a steep v-notch. It crosses beneath the road in a 10 foot half pipe culvert. Downstream of the road, the stream is slightly more gradual in gradient, but also seems to have the potential to braid. Discharge can be measured at the culvert mouth either in the water, or from above in high water. A pressure transducer can be mounted within the culvert or immediately downstream. The stream can be accessed by walking down a road cut. This appears to be public property. The basin above is all forest.
7	**Forest Basin 146**	No-Go	While it would be possible to measure discharge and sample here, the basin has too much development upstream to well represent forest runoff.
7	**Forest Basin 158**	No-Go	Location could not be accessed for reconnaissance due to private property restrictions.
7	**Forest Basin 161**	No-Go	Location could not be accessed for reconnaissance due to private property restrictions.
7	**Forest Basin 67**	No-Go	Location could not be accessed for reconnaissance due to private property restrictions.
7	**Forest Basin 699**	No-Go	Location could not be accessed for reconnaissance due to private property restrictions.
7	**Forest Basin 721**	No-Go	Location could not be accessed for reconnaissance due to private property restrictions.
7	**Forest Basin 844**	No-Go	The stream flows from an agricultural area upstream of SR-203, in a ditch. The stream then crosses under the road and emerges from a 36 inch concrete culvert. It then flows through a forested area in a fairly constrained channel. Discharge can be measured at the culvert mouth and a pressure transducer can be installed nearby. The monitoring location appears to be publicly accessible from the road. The stream was only a few inches deep in the concrete culvert, and may go dry during summer.

Table C1. Summary of observations made during field reconnaissance to identify monitoring locations

7	**Forest Basin 89**	No-Go	Location could not be accessed for reconnaissance due to private property restrictions.
7	**Residential Basin 111**	**Go**	The stream flows out of a pasture upstream, and passes beneath Old Machias Rd. in a 3 foot diameter corrugated pipe culvert. It then enters a fairly constrained 3 foot wide channel full of LWD enhancement projects. It then passes into another culvert beneath South Machias Rd., and emerges into a similar channel. Both would make good monitoring stations. Discharge can be measured at the culvert exit, and a pressure transducer can be installed nearby in a pool protected by LWD. These areas appear to be publically accessible.
7	**Residential Basin 202**	**Go**	The stream winds down along the steep Riverside Road in a two foot wide roadside ditch. It then crosses beneath Connelly Road in a set of two stacked culverts, and emerges into a fairly constrained 10 foot wide stream. The best spots for monitoring may be along Riverside Rd., where driveway culverts may offer the most uniform flow for discharge measurement, but could also be made in the stream channel downstream of the double culverts beneath Connelly Road. The Riverside Rd. spots would require accessing a culvert beneath a private driveway. It us unclear who owns the downstream property, but it appears to be publicly accessible.
7	**Residential Basin 167**	No-Go	The stream flows from a natural channel in a forested area upstream, into a ditch which conveys it through a farm staging area. The banks of this ditch are actively eroding into the channel. An outfall from an upstream stormwater pipe joins the ditch about 40 feet before it conveys the stream beneath a barn. A culvert conveys it beneath the road onto private property. The stream could be monitored upstream of the staging area in the forest, although it may require passing through private property.
7	**Residential Basin 81**	No-Go	The stream, Munsen Creek, flows in a 3 foot wide natural channel through a suburban ravine. It then flows through a 36 inch corrugated pipe culvert beneath 58th Drive NE and emerges into a high gradient channel in thick brush. Discharge can be measured at the culvert mouth and a pressure transducer can be installed nearby. A more low gradient monitoring location is available upstream of the road.
7	**Residential Basin 93**	No-Go	The stream flows through a steep ravine on private property and then flows through a small box culvert beneath Sunnyside Rd. It emerges in a 2 foot wide man-made ditch which conveys it onto private property. Discharge could be measured at the culvert exit, and a pressure transducer can be place in the ditch nearby. The location appears to be on private property and its small size may indicate that it may go dry in summer.
10	**Agricultural Basin 62**	**Go**	The stream originates in a pasture east of 212 Ave SE, and flows through a 2 foot diameter culvert west of 212th St. Upstream it is swale-like and brushy. Downstream of the culvert it is constrained in a two foot wide agricultural ditch. Discharge can be measured at the culvert exit, and a pressure transducer can be installed downstream in the vicinity. The stream is accessed by walking down the road shoulder. The stream is adjacent to pasture on both sides, and may be private property.
10	**Agricultural Basin 143**	**Go**	The stream flows through a man made ditch in farmers field. It crosses beneath SE 472nd St. in a 2 foot culvert where it is accessible. It also passes under Mud Mt. Rd, but is in an inaccessible ravine. The 472nd St. monitoring location is accessed by parking in a small turnout, and directly accessing the culvert from the road shoulder. There is fenced pasture on both sides, so this is likely to be private property. The flow is also small, and there is a danger of it going dry in the summer. Discharge can be measured at the culvert mouth, and a pressure transducer can be installed in the vicinity downstream.
10	**Agricultural Basin 159**	No-Go	The stream could not be located in the vicinity of the area marked on the field map.
10	**Agricultural Basin 102**	No-Go	The stream was located in a deep ravine that was inaccessible.
10	**Agricultural Basin 72**	No-Go	This stream has poor access and is backwatered by a small earthen dam to create a livestock watering hole.
10	**Agricultural Basin 89**	No-Go	The stream emerges from a pasture where it meanders in a four foot wide braded channel in an 8 foot deep ravine. It enters a roadside ditch along SE 188 street, where it is constrained and conveyed a few hundred feet along the road in the ditch through a couple of driveway culverts which look adequate for discharge monitoring and sampling. The flow observed was low and will likely go dry during the summer, making it a marginal sampling location.
10	**Agricultural Basin 90**	No-Go	This area is an inappropriate monitoring location because the culvert outfall is perched 5 feet in the air at the bottom of a steep and inaccessible ravine on the side of the highway.
10	**Agricultural Basin A**	No-Go	This Location would potentially work as a monitoring Location, but the flow is small in May during light rain, and may go dry in the summer.
10	**Commercial Basin A**	**Go**	The stream is slough-like. It is about 25 feet wide, and It flows along train tracks in a constrained channel. It thenfollows a bend to the west and crosses beneath Butte Ave in a series of 4, 2-foot diameter culverts. Discharge can be measured by measuring in the four culverts, which can be reached from the bridge. A pressure transducer can be installed nearby in the stream. The monitoring location is publically accessible.
10	**Commercial Basin B**	**Go**	This stream is known as Hylebos Creek. The stream at this point runs in a constrained man-made roadside ditch after emerging from an industrial area. It enters a culvert on S. 344th St., and is piped for a few blocks until it emerges between two business parks near 348th St. The stream could be monitored upstream in the ditch, a hundred feet upstream of the culvert inlet, where there should be no backwater effects. Discharge could be measured in this area as well, and a pressure transducer could be installed anywhere in the immediate vicinity. The location is publically accessible.
10	**Commercial Basin C**	No-Go	This station would be inappropriate because it appears to be stagnant.
10	**Commercial Basin 10**	No-Go	This stream will already be monitored at proposed Basin B monitoring station. This location could be monitored and thus is a backup.
10	**Forest Basin 130**	**Go**	The stream flows down the forested hillside above SR-410. It crosses beneath the highway in a 2 foot diameter concrete culvert, and discharges to a channel which quickly transitions from a 10 foot glide section into a steep cascading channel. Discharge can be measured at the culvert mouth, and a pressure transducer can be installed in the immediate vicinity. This may be on private timber land, but is accessible from the right of way.

Table C1. Summary of observations made during field reconnaissance to identify monitoring locations

10	**Forest Basin 372**	**Go**	This stream, known as Coppler Creek, flows from a forested mountainside upstream, through a 10 foot diameter culvert beneath 190 Ave E, and begins to braid a short distance downstream. Discharge can be measured at the mouth of the culvert and a pressure transducer can be installed in the near vicinity. This may be on private property, but I met the neighbor and he was enthusiastic about the project happening here.
10	**Forest Basin 163**	No-Go	Location could not be accessed for reconnaissance due to private property restrictions.
10	**Forest Basin 175**	No-Go	Location could not be accessed for reconnaissance due to private property restrictions.
10	**Forest Basin 282**	No-Go	Location could potentially be monitored, but access is on private property and the area may be snowed in during the winter.
10	**Forest Basin 357**	No-Go	Location could potentially be monitored, but its large size of contributing basin may make high flow measurements impractical.
10	**Forest Basin 170**	No-Go	Location could not be accessed for reconnaissance due to private property restrictions.
10	**Forest Basin 406**	No-Go	This location could potentially be monitored; however, low flows may make it unsuitable for summer base flow sampling.
10	**Forest Basin 464**	No-Go	Location could not be accessed for reconnaissance due to private property restrictions.
10	**Forest Basin 262**	No-Go	This location was removed from consideration because no stream could be located in the area indicated on the map.
10	**Residential Basin 209**	**Go**	The stream flows along the east side of Canyon Drive, then crosses beneath Pioneer way in a 4 foot wide box culvert. Upstream it's a braided channel and wetlands. Downstream is quite brushy, and the channel is not very constrained 50 feet downstream of the culvert. Discharge can be measured at the culvert mouth and a pressure transducer can be installed there as well. This appears to be public access. Most of the basin drains residential areas, but one caveat is a concrete plant observed upstream in the basin.
10	**Residential Basin 53**	**Go**	The stream flows beneath Freeman Road in a 2 foot diameter culvert into a man made ditch, which conveys it through a field. The stream conveys flow from Surprise Lake to Hylebos Creek. Discharge can be measured at the culvert mouth, and a pressure transducer can be installed in the immediate vicinity. The location is accessed by parking in a roadside turnout and walking down a gentle bank to the culvert. The culvert is on private property with a for sale sign in place. Land use above the station is dominated by residential areas.
10	**Residential Basin 1**	No-Go	Inappropriate monitoring location due upstream influence of a large wetland.
10	**Residential Basin 226**	No-Go	Location inaccessible due to traffic safety concerns.
10	**Residential Basin 5**	No-Go	Location inappropriate for monitoring because the upstream area is impounded in a man made lake.

WRIA 7: Snohomish River Watershed
WRIA 10: Puyallup River Watershed

APPENDIX D

Standardized Forms Documenting Observations from Field Reconnaissance Performed During the Monitoring Location Selection Process

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/8/2009
Weather conditions:	Partly cloudy. No rain.

Monitoring station location	
Watershed Name	WRIA 10
Site I.D.	AG 62
Nearest Intersection	0.2 miles north of SE 400th Street on 212th Ave SE
Access	Park on road shoulder and walk down gentle bank to culvert and ditch. This is across from a house and adjacent to a pasture. No fence to cross, but may be private?

Safety	
Traffic Safety	Narrow shoulder. Proceed with caution.
Water Safety	No special issues.

Physical description of monitoring station site	
Stream Overview	The stream originates in a pasture east of 212 Ave SE, and flow through a culvert west of 212th. Upstream it is swalelike and brushy. Downstream of the culvert it is constrained in an agricultural ditch.
Width (ft)	2
Depth (ft)	1
Bankfull Depth (ft)	3-4
Bankfull Width (ft)	3
Slope (%)/Hydraulic condition	1%
Substrate	armored.
Channel stability	Constrained ditch.
Suitability for staff gage and stilling well	No protected areas, and no serious pools, but it looks possible to install a pd in the glide areas of the ditch.
Suitability for manual discharge measurement	Discharge can be measured from culvert, or downstream in the ditch.
Suitability for sampling	Good. But does it flow all summer?
Existing gauging or sampling station?	None observed.

Photo log	Photo #
640	Culvert for manual discharge measurements and sampling.
644	Possible gauging station,
651	Upstream from road.
638	Parking
movie 647	Site overview

Conclusion	This site would make a good monitoring station.

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/8/2009
Weather conditions:	
Monitoring station location	
Watershed Name	WRIA 7
Site I.D.	AG 72
Nearest Intersection	188th Ave SE and SE 409th St
Access	Park on shoulder, walk to stream. Barbed wire prevents access to culvert. The stream is on a pasture that appears to be private
Safety	
Traffic Safety	No good parking parked on shoulder.
Water Safety	No issues.
Physical description of monitoring station	
Stream Overview	The stream flows from a ditch in a pasture. It crosses beneath 188th St. in a culvert and is immediately pooled by a small earthen dam used to contain water to encourage cows to water. It flows over a
Width (ft)	2
Depth (ft)	1
Bankfull Depth (ft)	2
Bankfull Width (ft)	4
Slope (%)/Hydraulic condition	1%
Substrate	soil
Channel stability	constrained
Suitability for staff gage and stilling well	Backwatered due to cow drinking pond dam.
Suitability for manual discharge measurement	O.K. at culvert mouth.
Suitability for sampling	O.K. at culvert mouth.
Existing gauging or sampling station?	None.
Photo log	Photo #
Movie 660	Overview of downstream site.
	.
Conclusions	This stream has poor access and is backwatered by a small earthen dam to create a livestock watering hole.

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/14/2009
Weather conditions:	Light rain

Monitoring station location	
Watershed Name	WRIA 10
Site I.D.	AB 90
Nearest Intersection	SR-410
Access	Park on road shoulder. Did not attempt to access culvert outlet in
Safety	
Traffic Safety	Dangerous shoulder parking.
Water Safety	Stream drops from culvert outfall perched 5 feet in the air and transitions into steep cascade.
Physical description of monitoring station site	
Stream Overview	Upstream of SR-410 the stream is backwatered in an agricultrual field. The stream flows beneath the highway and drops from a culvert
Width (ft)	10
Depth (ft)	
Bankfull Depth (ft)	
Bankfull Width (ft)	
Slope (%)/Hydraulic condition	
Substrate	
Channel stability	
Suitability for staff gage and stilling well	
Suitability for manual discharge measurement	
Suitability for sampling	
Existing gauging or sampling station?	
Photo log	Photo #
Movie 105	Site overview

Conclusions	This area is an inappropriate monitoring location because the the culvert outfall is perched 5 feet in the air at the bottom of a steep and

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/14/2009
Weather conditions:	Light rain

Monitoring station location	
Watershed Name	WRIA 10
Site I.D.	AB 90
Nearest Intersection	SR-410
Access	Park on road shoulder. Did not attempt to access culvert outlet in
Safety	
Traffic Safety	Dangerous shoulder parking.
Water Safety	Stream drops from culvert outfall perched 5 feet in the air and transitions into steep cascade.
Physical description of monitoring station site	
Stream Overview	Upstream of SR-410 the stream is backwatered in an agricultrual field. The stream flows beneath the highway and drops from a culvert
Width (ft)	10
Depth (ft)	
Bankfull Depth (ft)	
Bankfull Width (ft)	
Slope (%)/Hydraulic condition	
Substrate	
Channel stability	
Suitability for staff gage and stilling well	
Suitability for manual discharge measurement	
Suitability for sampling	
Existing gauging or sampling station?	
Photo log	Photo #
Movie 105	Site overview

Conclusions	This area is an inappropriate monitoring location because the the culvert outfall is perched 5 feet in the air at the bottom of a steep and

CHEMLOADPH3 Monitoring Station Reconnaissance Form

The purpose of this form is to record observations made during reconnaissance of potential discharge and water quality monitoring sites for

Field Crew:	Dan Bennett
Date/Time:	5/8/2009
Weather conditions:	Light rain
Monitoring station location	
Watershed Name	WRIA 10
Site I.D.	Agricultural Basin 102
Nearest Intersection	SE 456th Way and SE 448th St.
Access	The stream was located in a deep ravine that was inaccessible.
Safety	
Traffic Safety	
Water Safety	
Physical description of monitoring station site	
Stream Overview	The stream was located in a deep ravine that was inaccessible.
Width (ft)	
Depth (ft)	
Bankfull Depth (ft)	
Bankfull Width (ft)	
Slope (%)/Hydraulic condition	
Substrate	
Channel stability	
Suitability for staff gage and stilling well	
Suitability for manual discharge measurement	
Suitability for sampling	
Existing gauging or sampling station?	
Photo log	Photo #
Conclusions	The stream was located in a deep ravine that was inaccessible.

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/5/2009
Weather conditions:	Light rain for more than 24 hours
Monitoring station location	
Watershed Name	WRIA 7
Site I.D.	AG 135
Nearest Intersection	Home Acres Road/ Skipply Road
Access	Park at small bridge access. This appears to be an acces to private
Safety	
Traffic Safety	Busy road. Parking is sort of on shoulder.
Water Safety	Deep water, too deep to get in. Would need to be measured from bridg
Physical description of monitoring station site	
Stream Overview	The stream is a wide low velocity slough.
Width (ft)	25
Depth (ft)	3
Bankfull Depth (ft)	8
Bankfull Width (ft)	40?
Slope (%)/Hydraulic condition	1%
Substrate	muck
Channel stability	Constrained
Suitability for staff gage and stilling well	We could put a staff gage under the bridge. We could measure flow from the bridge in high water, otherwise it would require waders. It still may not be ideal due to under bridge geometry. But, the area is
Suitability for manual discharge measurement	Could be done from bridge'
Suitability for sampling	Good
Existing gauging or sampling station?	No
Photo log	Photo #
207	Slough from bridge.
Movie "Bridge"	Potential monitoring site.
Conclusions	This site wouldn't make a good monitoring station due to slough-like backwater conditions. Access also appears to be on a private access road. Furthermore, the slough is wide and deep, and flow

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/14/2009
Weather conditions:	Light rain
Monitoring station location	
Watershed Name	WRIA 10
Site I.D.	AG 143
Nearest Intersection	SE 472nd ST. and 260th Ave SE
Access	Stream inaccessible at Mud Mt. Road, but crosses SE 472nd street in
Safety	
Traffic Safety	Narrow parking on shoulder
Water Safety	No issues
Physical description of monitoring station site	
Stream Overview	The stream runs through ditch in farmers field, crosses under SE 472nd St. in a culvert. Passes under Mud Mt. Rd. in an inaccessible
Width (ft)	2
Depth (ft)	1
Bankfull Depth (ft)	3
Bankfull Width (ft)	4
Slope (%)/Hydraulic condition	1%
Substrate	muck
Channel stability	Constrained in ditch.
Suitability for staff gage and stilling well	Adequate
Suitability for manual discharge measurement	Good
Suitability for sampling	Good
Existing gauging or sampling station?	None observed
Photo log	Photo #
Movie 43, 44	Crossing at 472nd Street.
43	ditch upstream of 472nd
44	Culvert inlet above 472nd
Conclusions	This site could work at the spot upstream at 472nd St.

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/5/2009
Weather conditions:	Light rain

Monitoring station location	
Watershed Name	WRIA7
Site I.D.	AG 151
Nearest Intersection	92nd St. SE and 88th St. SE
Access	I could not gain access to this site. The stream is at the end of a
Safety	
Traffic Safety	
Water Safety	
Physical description of monitoring station site	
Width (ft)	
Depth (ft)	
Bankfull Depth (ft)	
Bankfull Width (ft)	
Slope (%)/Hydraulic condition	
Substrate	
Channel stability	
Suitability for staff gage and stilling well	
Suitability for manual discharge measurement	
Suitability for sampling	
Existing gauging or sampling station?	
Photo log	Photo #
	.
Conclusions	This site was not explored as an option because we could not gain access through the private property for reconnaissance.

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/8/2009
Weather conditions:	Light rain

Monitoring station location	
Watershed Name	WRIA 10
Site I.D.	Agricultural Basin 159
Nearest Intersection	212 Ave SE and SE 400th St.
Access	The stream could not be located in the vicinity of the area marked on
Safety	
Traffic Safety	
Water Safety	
Physical description of monitoring station site	
Stream Overview	The stream could not be located in the vicinity of the area marked on
Width (ft)	
Depth (ft)	
Bankfull Depth (ft)	
Bankfull Width (ft)	
Slope (%)/Hydraulic condition	
Substrate	
Channel stability	
Suitability for staff gage and stilling well	
Suitability for manual discharge measurement	
Suitability for sampling	
Existing gauging or sampling station?	
Photo log	Photo #

Conclusions	The stream could not be located in the vicinity of the area marked on the field map.

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/5/2009
Weather conditions:	Light rain for more than 24 hours

Monitoring station location	
Watershed Name	WRIA 7
Site I.D.	Agricultural Basin 174
Nearest Intersection	Shorts School Road/ 132nd St SE
Access	Park on road shoulder. Walk down gentle bank into agricultural dicth. This ditch is in a farmers field. W may need permission to access, although there were not any No Trespass signs and no fence.
Safety	
Traffic Safety	Narrow shoulder parking.
Water Safety	No issues.
Physical description of monitoring station site	
Stream overview	The stream emerges from beneath Shorts School Rd. It is unclear how it is conveyed through the field upstream. It comes out in a 2 ft culvert beneath the road into a man made agricultural ditch, which conveys it through 500 feet of farm fields, before entering a final
Width (ft)	2
Depth (ft)	1
Bankfull Depth (ft)	3
Bankfull Width (ft)	5
Slope (%)/Hydraulic condition	1%
Substrate	Muck
Channel stability	Constrained.
Suitability for staff gage and stilling well	No protected areas, but no large debris observed. I think it emerges from a pipe upstream. Not hidden very well. Will be observable
Suitability for manual discharge measurement	Good.
Suitability for sampling	Good.
Existing gauging or sampling station?	None Observed.
Photo log	Photo #
425-6	Culvert in ditch downstream of Shorts School Road.
427	Downstream channel
Movie "culvert downstream of road access"	Overview of monitoring site.

Conclusions	This site would make a good candidate for monitoring. Potential issues include priveate property access, and potential backwater

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/5/2009
Weather conditions:	Light rain

Monitoring station location	
Watershed Name	WRIA 7
Site I.D.	AG 197
Nearest Intersection	
Access	I could not gain access to this site. The stream is at the end of a
Safety	
Traffic Safety	
Water Safety	
Physical description of monitoring station site	
Width (ft)	
Depth (ft)	
Bankfull Depth (ft)	
Bankfull Width (ft)	
Slope (%)/Hydraulic condition	
Substrate	
Channel stability	
Suitability for staff gage and stilling well	
Suitability for manual discharge measurement	
Suitability for sampling	
Existing gauging or sampling station?	
Photo log	Photo #

.

Conclusions	This site was not explored as an option because we could not gain access through the private property for reconnaissance.

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/13/2009
Weather conditions:	Light rain all day

Monitoring station location	
Watershed Name	WRIA 7
Site I.D.	AG 550
Nearest Intersection	Crescent Lake Rd. Snoqualmie King County Highway.
Access	There is no stream in the area as mapped. All water has been diverted to agricultrual ditches, which are impounded. Access is through
Safety	
Traffic Safety	
Water Safety	
Physical description of monitoring station site	
Stream Overview	
Width (ft)	
Depth (ft)	
Bankfull Depth (ft)	
Bankfull Width (ft)	
Slope (%)/Hydraulic condition	
Substrate	
Channel stability	
Suitability for staff gage and stilling well	
Suitability for manual discharge measurement	
Suitability for sampling	
Existing gauging or sampling station?	
Photo log	Photo #
	.
Conclusions	There is no stream in the area as mapped. All water has been diverted to agricultrual ditches, which are impounded. Access is through

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/13/2009
Weather conditions:	Light rain all day

Monitoring station location	
Watershed Name	WRIA 7
Site I.D.	AG 614
Nearest Intersection	West Snoqualmie River Rd.
Access	The stream is a backwatered slough on the banks of the Snoqualmie River, accessible only through private property.
Safety	
Traffic Safety	No issues
Water Safety	The culvert outlet is under water in Snoqualmie River.
Physical description of monitoring station site	
Stream Overview	The stream is a backwatered slough, 20 feet wide, and controlled by
Width (ft)	20
Depth (ft)	2
Bankfull Depth (ft)	4
Bankfull Width (ft)	40
Slope (%)/Hydraulic condition	1%
Substrate	Muck
Channel stability	Confined in slough.
Suitability for staff gage and stilling well	Backwatered upstream, and culvert downstream discharges beneath
Suitability for manual discharge measurement	Poor.
Suitability for sampling	O.K.
Existing gauging or sampling station?	None
Photo log	Photo
Movie 871	Site overview
	.

Conclusions	This site would make an inappropriate monitoring location due to backwater conditions.

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/19/2009
Weather conditions:	Light rain

Monitoring station location	
Watershed Name	WRIA 7
Site I.D.	AG A
Nearest Intersection	100 Ave SE. and dead end of 111th Ave.
Access	The stream is a backwatered slough on the banks of the Snohomish River accessed by parking at the end of 111th Ave and hiking 0.25
Safety	
Traffic Safety	No issues
Water Safety	The stream is completely backwatered, as it is impounded by a dike.
Physical description of monitoring station site	
Stream Overview	The stream is a backwatered slough, impounded by a dike.
Width (ft)	10
Depth (ft)	5
Bankfull Depth (ft)	10
Bankfull Width (ft)	40
Slope (%)/Hydraulic condition	1%
Substrate	Muck
Channel stability	Confined in slough.
Suitability for staff gage and stilling well	Backwatered upstream.
Suitability for manual discharge measurement	Poor.
Suitability for sampling	O.K.
Existing gauging or sampling station?	None
Photo log	Photo
Movie 216	Site overview
	.

Conclusions	This site would make an inappropriate monitoring location due to backwater conditions.

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/14/2009
Weather conditions:	Light rain
Monitoring station location	
Watershed Name	WRIA 10
Site I.D.	Agricultural Basin A
Nearest Intersection	SE 473rd St.
Access	Park on residential street, stream is in ditch beside street.
Safety	
Traffic Safety	No issues.
Water Safety	No issues.
Physical description of monitoring station site	
Stream Overview	The stream comes out of a field and runs along the roadside in a small ditch. It comes throug a few different culvert where it could be
Width (ft)	2
Depth (ft)	0.5
Bankfull Depth (ft)	1.5
Bankfull Width (ft)	3
Slope (%)/Hydraulic condition	1%
Substrate	sandy
Channel stability	roadside ditch
Suitability for staff gage and stilling well	O.k.
Suitability for manual discharge measurement	good
Suitability for sampling	May run dry in summer.
Existing gauging or sampling station?	None
Photo log	Photo #
Movies 48	upstream site
Movie 52	better site, downstream.
52	downstream culvert site
Conclusions	This site would potentially work as a monitoring site, but the flow is small now, and may go dry in the summer.

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/19/2009
Weather conditions:	Light rain

Monitoring station location	
Watershed Name	WRIA 7
Site I.D.	AG B
Nearest Intersection	190 St. SE. and Tualco Loop Road.
Access	The stream is on private property, and is a backwatered slough.
Safety	
Traffic Safety	No issues
Water Safety	The stream is completely backwatered.
Physical description of monitoring station site	
Stream Overview	The stream is a backwatered slough.
Width (ft)	10
Depth (ft)	2
Bankfull Depth (ft)	5
Bankfull Width (ft)	40
Slope (%)/Hydraulic condition	1%
Substrate	Muck
Channel stability	Confined in slough.
Suitability for staff gage and stilling well	Poor.
Suitability for manual discharge measurement	Poor.
Suitability for sampling	O.K.
Existing gauging or sampling station?	None
Photo log	Photo
Movie 179	Site overview

Conclusions	This site would make an inappropriate monitoring location due to backwater conditions and inaccessiblility.

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/19/2009
Weather conditions:	Light rain

Monitoring station location	
Watershed Name	WRIA 7
Site I.D.	AG C
Nearest Intersection	West Snoqualmie River Rd. and NE 165th Street.
Access	The stream is a backwatered slough on the banks of the Snoqualmie River. The downstream appears to be below the water line, and the
Safety	
Traffic Safety	No issues
Water Safety	The culvert outlet is under water in Snoqualmie River, and controlled by a tide gate.
Physical description of monitoring station site	
Stream Overview	The stream is a backwatered slough, 20 feet wide, and controlled by
Width (ft)	20
Depth (ft)	2
Bankfull Depth (ft)	4
Bankfull Width (ft)	40
Slope (%)/Hydraulic condition	1%
Substrate	Muck
Channel stability	Confined in slough.
Suitability for staff gage and stilling well	Backwatered upstream, and culvert downstream discharges beneath
Suitability for manual discharge measurement	Poor.
Suitability for sampling	O.K.
Existing gauging or sampling station?	None
Photo log	Photo
Movie 871	Site overview
	.

Conclusions	This site would make an inappropriate monitoring location due to backwater conditions.

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/19/2009
Weather conditions:	Light rain all day

Monitoring station location	
Watershed Name	WRIA 7
Site I.D.	AG D
Nearest Intersection	West Snoqualmie River Rd. and NE 165th Street.
Access	The stream is a backwatered slough on the banks of the Snoqualmie River. The downstream appears to be below the water line, and the
Safety	
Traffic Safety	No issues
Water Safety	The culvert outlet is under water in Snoqualmie River, and controlled by a tide gate.
Physical description of monitoring station site	
Stream Overview	The stream is a backwatered slough, 20 feet wide, and controlled by
Width (ft)	20
Depth (ft)	2
Bankfull Depth (ft)	4
Bankfull Width (ft)	40
Slope (%)/Hydraulic condition	1%
Substrate	Muck
Channel stability	Confined in slough.
Suitability for staff gage and stilling well	Backwatered upstream, and culvert downstream discharges beneath
Suitability for manual discharge measurement	Poor.
Suitability for sampling	O.K.
Existing gauging or sampling station?	None
Photo log	Photo
Movie 871	Site overview
	.

Conclusions	This site would make an inappropriate monitoring location due to backwater conditions.

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/19/2009
Weather conditions:	Light rain all day

Monitoring station location	
Watershed Name	WRIA 7
Site I.D.	AG E
Nearest Intersection	I-5 Southbound.
Access	The stream is a backwatered slough. The only access is by parking on the shoulder of I-5 and climbing down a steep bank.
Safety	
Traffic Safety	No issues
Water Safety	The culvert outlet is under water in Snoqualmie River, and controlled
Physical description of monitoring station site	
Stream Overview	The stream is a backwatered slough, 20 feet wide with gentle marshy
Width (ft)	20
Depth (ft)	3
Bankfull Depth (ft)	5
Bankfull Width (ft)	40
Slope (%)/Hydraulic condition	1%
Substrate	Muck
Channel stability	Confined in slough.
Suitability for staff gage and stilling well	Poor, no flow observed, backwatered.
Suitability for manual discharge measurement	Poor.
Suitability for sampling	O.K.
Existing gauging or sampling station?	None
Photo log	Photo
Movie 217	Site overview
	.

Conclusions	This site would make an inappropriate monitoring location due to

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/21/2009
Weather conditions:	Light rain all day

Monitoring station location	
Watershed Name	WRIA 7
Site I.D.	AG G
Nearest Intersection	23rd Ave NE and 45 Road
Access	Park in driveway turnout and walk to culvert for roadside ditch.
Safety	
Traffic Safety	Shoulder parking and work area.
Water Safety	No issues
Physical description of monitoring station site	
Stream Overview	The three foot wide stream flows in a constrained roadside ditch along the east side of 23rd Ave NE. The stream is conveyed beneath
Width (ft)	3
Depth (ft)	2
Bankfull Depth (ft)	5
Bankfull Width (ft)	4
Slope (%)/Hydraulic condition	1%
Substrate	muck
Channel stability	Constrained in a ditch.
Suitability for staff gage and stilling well	Good, but maybe hard to hide from vandals.
Suitability for manual discharge measurement	Good.
Suitability for sampling	Good.
Existing gauging or sampling station?	None observed.
Photo log	Photo
Movies 382 and 383.	Site overview downstream of where we will likely monitor.
380, 383	Stream in ditch

Conclusions	This site would make a feasible monitoring station. Access may require coordination with property owners.

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/14/2009
Weather conditions:	Light rain

Monitoring station location	
Watershed Name	WRIA 10
Site I.D.	Commercial Basin 10
Nearest Intersection	9th Ave and S. 348th St.
Access	Park in "Park and Ride" lot. Walk down bank to stream, or cross north over 348th to alternative access. Is access to the area 100 feet
Safety	
Traffic Safety	No issues.
Water Safety	No issues.
Physical description of monitoring station site	
Stream Overview	Hylebos Creek flows in a field in a greenspace between two business parks. The stream is in a brushy channel and eventually enters twin 24" culverts with trash gates. The stream emerges from the culverts
Width (ft)	3
Depth (ft)	0.5
Bankfull Depth (ft)	1.5
Bankfull Width (ft)	6-20
Slope (%)/Hydraulic condition	1%
Substrate	Small cobbles.
Channel stability	Moderately constrained upstream, braided downstream of 348th.
Suitability for staff gage and stilling well	It would work upstream, but not downstream.
Suitability for manual discharge measurement	Good 100 feet upstream of 348th.
Suitability for sampling	Good.
Existing gauging or sampling station?	None observed.
Photo log	Photo #
Movie 138	Potential monitoring site 100 feet upstream of 348th.
138	Potential monitoring site 100 feet upstream of 348th.

Conclusions	This site could be monitored 100 feet upstream of 348th St.

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/13/2009
Weather conditions:	Light rain all day

Monitoring station location	
Watershed Name	WRIA 7
Site I.D.	Commercial Basin 335. A.K.A. Powder Mill Gulch?
Nearest Intersection	Seaway Blvd, east of 36th Ave West
Access	Park in parking area at business park with Exotic Tools Welding. Walk 200 feet down public works access road to stream and culverts.
Safety	
Traffic Safety	No issues.
Water Safety	No issues.
Physical description of monitoring station site	
Stream Overview	The stream appears to originate from stormwater ponds that drain Boeing business park. The stream is in a deep ravine, and emerges from a culvert beneth Seaway Blvd. into a constrained 10 foot wide
Width (ft)	10 foot stream,
Depth (ft)	0.5-1
Bankfull Depth (ft)	2-3
Bankfull Width (ft)	12
Slope (%)/Hydraulic condition	2%
Substrate	Large to medium cobbles
Channel stability	Constrained
Suitability for staff gage and stilling well	Good, there is already a gauge in place from another agency.
Suitability for manual discharge measurement	Good.
Suitability for sampling	Good.
Existing gauging or sampling station?	Yes, pressure transducer and staff gauge observed.
Photo log	Photo #
Movie 922 and 923	Downstream area overview
Movie 939	Upstream site, just below Seaway Blvd.
915	Downstream site culvert
937	Upstream site culvert

Conclusions	This would make a good monitoring station, as long as we can gain

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/13/2009
Weather conditions:	Light rain all day

Monitoring station location	
Watershed Name	WRIA 7
Site I.D.	Commerical Basin 380
Nearest Intersection	5th Street
Access	Park on railroad access road. Walk past gate aout 200 feet to stream. This is adjacent to the railroad, although the access gate may be for
Safety	
Traffic Safety	The site is adjacent to train tracks, so we might need to discuss railroad safety with owners.
Water Safety	No issues.
Physical description of monitoring station site	
Stream Overview	The stream flows in a manmade constrained ditch. It is diverted into a large pond, where it then overflows into a drop structure, and is
Width (ft)	3
Depth (ft)	0.5
Bankfull Depth (ft)	1
Bankfull Width (ft)	5
Slope (%)/Hydraulic condition	1%
Substrate	Sandy, and peat
Channel stability	Constrained in ditch, but may leap to floodplane.
Suitability for staff gage and stilling well	Good
Suitability for manual discharge measurement	Good
Suitability for sampling	Good
Existing gauging or sampling station?	None
Photo log	Photo #
Movie 952	Channel upstream of road, before diversion t pond.
953, 960-1	Potential monitoring site in ditch
962	Pond and drop structure.

Conclusions	This site can be monitored. We may have access issues with

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/14/2009
Weather conditions:	Light rain

Monitoring station location	
Watershed Name	WRIA 10
Site I.D.	Commercial Basin A
Nearest Intersection	Butte Ave SE and 6th Ave SE
Access	Park on Butte Rd. Walk down bank to culverts
Safety	
Traffic Safety	No issues.
Water Safety	Water is fairly deep and wide.
Physical description of monitoring station site	
Stream Overview	The stream is slough-like. It is very wide, and It flows along train tracks in constrained channel. It then crosses under Butte Ave in a
Width (ft)	20
Depth (ft)	1
Bankfull Depth (ft)	4
Bankfull Width (ft)	25
Slope (%)/Hydraulic condition	1%
Substrate	Mud
Channel stability	Constrained
Suitability for staff gage and stilling well	Seems a bit stagnant, but would probably work.
Suitability for manual discharge measurement	It would need to be done from the bridge, measuring each pipe flow.
Suitability for sampling	Good
Existing gauging or sampling station?	None
Photo log	Photo #
Movie 97	Bridge under Butte Ave.
93	Main channel
97	Culvert

Conclusions	This site may work. Manual discharge measurements from bridge

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/14/2009
Weather conditions:	Light rain

Monitoring station location	
Watershed Name	WRIA 10
Site I.D.	Commercial Basin B
Nearest Intersection	South 344th Street, 9th Ave
Access	Park on quite side street. Walk down gentle bank to stream in ditch
Safety	
Traffic Safety	No issues.
Water Safety	No issues.
Physical description of monitoring station site	
Stream Overview	Hylebos Creek. The creek at this poin runs in a roadside ditch after emerging from an industrial area. It enters a culvert on S. 344th St., and is piped for a few blocks until it emerges between two business
Width (ft)	3
Depth (ft)	1
Bankfull Depth (ft)	3
Bankfull Width (ft)	3
Slope (%)/Hydraulic condition	2%
Substrate	Small cobbles.
Channel stability	Constrained in a ditch.
Suitability for staff gage and stilling well	Good
Suitability for manual discharge measurement	Good
Suitability for sampling	Good
Existing gauging or sampling station?	None observed.
Photo log	Photo #
140	Ditch upstream of 344th St.
141	Culvert inlet.

Conclusions	This site would make a feasible sampling station.

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/14/2009
Weather conditions:	Light rain

Monitoring station location	
Watershed Name	WRIA 10
Site I.D.	Commercial Basin C
Nearest Intersection	29th Ave SE
Access	Park on residential street. Walk down gentle banks to stream.
Safety	
Traffic Safety	No issues
Water Safety	No issues
Physical description of monitoring station site	
Stream Overview	Stream runs very slowly. It runs beneath road in large box culvert, and then flows in constrained ditch. Lots of orange periphyton.
Width (ft)	10
Depth (ft)	1
Bankfull Depth (ft)	3
Bankfull Width (ft)	15
Slope (%)/Hydraulic condition	1%
Substrate	large cobbles
Channel stability	Constrained.
Suitability for staff gage and stilling well	Good.
Suitability for manual discharge measurement	May have very little velocity.
Suitability for sampling	Good.
Existing gauging or sampling station?	None
Photo log	Photo #
Movies 79,83,89	site overviews
82-3	culvert
87-8	downstream channel

Conclusions	This station may be too stagnant for flow monitoring.

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/19/2009
Weather conditions:	Light rain all day

Monitoring station location	
Watershed Name	WRIA 7
Site I.D.	Commercial Basin X. AKA Merrill and Ring Creek.
Nearest Intersection	Hardeson Road and Industry st.
Access	Park in Fed-Ex parking lot. Access stream by walking down bank
Safety	
Traffic Safety	No issues.
Water Safety	No issues.
Physical description of monitoring station site	
Stream Overview	The stream follows a confined channel along the west side of Hardeson Road. It passes through a series of box culverts beneath driveways (such as to Fed-Ex). It eventually enters an energy
Width (ft)	10
Depth (ft)	1
Bankfull Depth (ft)	2-3
Bankfull Width (ft)	12
Slope (%)/Hydraulic condition	2%
Substrate	Large to medium cobbles
Channel stability	Constrained
Suitability for staff gage and stilling well	Good.
Suitability for manual discharge measurement	Good.
Suitability for sampling	Good.
Existing gauging or sampling station?	None observed.
Photo log	Photo #
Movie 238	Overview of site at Fed-Ex driveway.

Conclusions	This would make a good monitoring station.

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/13/2009
Weather conditions:	Light rain all day

Monitoring station location	
Watershed Name	WRIA 7
Site I.D.	FB 67
Nearest Intersection	
Access	This site was not explored as an option because we could not gain access through private property for reconnaissance.
Safety	
Traffic Safety	
Water Safety	
Physical description of monitoring station site	
Stream Overview	
Width (ft)	
Depth (ft)	
Bankfull Depth (ft)	
Bankfull Width (ft)	
Slope (%)/Hydraulic condition	
Substrate	
Channel stability	
Suitability for staff gage and stilling well	
Suitability for manual discharge measurement	
Suitability for sampling	
Existing gauging or sampling station?	
Photo log	Photo #
	.
Conclusions	This site was not explored as an option because we could not gain access through private property for reconnaissance.

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/13/2009
Weather conditions:	Light rain all day
Monitoring station location	
Watershed Name	WRIA 7
Site I.D.	FB 89
Nearest Intersection	
Access	This site was not explored as an option because we could not gain access through private property for reconnaissance.
Safety	
Traffic Safety	
Water Safety	
Physical description of monitoring station site	
Stream Overview	
Width (ft)	
Depth (ft)	
Bankfull Depth (ft)	
Bankfull Width (ft)	
Slope (%)/Hydraulic condition	
Substrate	
Channel stability	
Suitability for staff gage and stilling well	
Suitability for manual discharge measurement	
Suitability for sampling	
Existing gauging or sampling station?	
Photo log	Photo #
	.
Conclusions	This site was not explored as an option because we could not gain access through private property for reconnaissance.

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/14/2009
Weather conditions:	Light rain
Monitoring station location	
Watershed Name	WRIA 10
Site I.D.	Forest Basin 130
Nearest Intersection	WA-410
Access	Park at logging landing. Walk down gentle bank to stream and
Safety	
Traffic Safety	No issues
Water Safety	No issues
Physical description of monitoring station site	
Stream Overview	Stream flows down hillside above SR-410, it crosses beneath road in 2 foot concrete culvert, and discharges to steep cascading channel.
Width (ft)	3
Depth (ft)	1.5
Bankfull Depth (ft)	3
Bankfull Width (ft)	4
Slope (%)/Hydraulic condition	3%
Substrate	large cobbles.
Channel stability	Good at culvert, deteriorates downstream
Suitability for staff gage and stilling well	Best spot is right near culvert mouth.
Suitability for manual discharge measurement	Good at culvert, deteriorates downstream
Suitability for sampling	Good.
Existing gauging or sampling station?	None
Photo log	Photo #
Movie 996	Overview
996	Culvert
Conclusions	This site would make a good candidate for a monitoring station.

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/5/2009
Weather conditions:	Light rain for more than 24 hours

Monitoring station location	
Watershed Name	WRIA 7
Site I.D.	FB 146 (French Creek)
Nearest Intersection	Upstream site at 171st Ave SE/ 96th St SE, downstream site at
Access	Upstream site, walk into stream from road. Private pasture on both sides. Gentle bank to stream on both sides. Downstream side needs
Safety	
Traffic Safety	Shoulder parking only, but a quite residentialy street.
Water Safety	No issues.
Physical description of monitoring station site	
Stream overview	The stream originates in a swale upstream of 96th Street SE. About 200 feet up the swale is a culvert where discharge could be measured. The stream flows about 200 feet in a gently banked channel with potential for braiding. It then passes through a 24" culvert beneath
Width (ft)	8
Depth (ft)	0.5
Bankfull Depth (ft)	2.5
Bankfull Width (ft)	20
Slope (%)/Hydraulic condition	1%
Substrate	medium cobble
Channel stability	2.5 feet to flood plane, but fairly defined channel with no braids
Suitability for staff gage and stilling well	Good site for channel measurement 50 feet upstream of 96th. As I went further upstream, the channel had very shallow banks. Even better site 200 feet upstream at mouth of culvert, with pool and protected area for Pressure transducer. Could also monitor at 3 ft culvert downstream of 96th could not full penetrate the blackberry at
Suitability for manual discharge measurement	Good at culvert upstream. Likely possible downstream of 96th.
Suitability for sampling	Good
Existing gauging or sampling station?	No

Photo log	Photo
323	Parking area
345	upstream culvert potential site
330	inlet to culvert beneath 96th
336	looking downstream at 96th street culvert. Shows potential downstream site.
359	channel downstream of 96th
Movie 331	Potential site 200 feet upstream of 96th.
Movie 350	Downstream of 96th

Conclusion	This is a good basin. We could monitor at two locations. The basin may have too much development upstream to represent forest runoff

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/5/2009
Weather conditions:	Light rain

Monitoring station location	
Watershed Name	WRIA 10
Site I.D.	FB 158
Nearest Intersection	NA
Access	I could not gain access to this site. The stream is beyond the gates of
Safety	
Traffic Safety	
Water Safety	
Physical description of monitoring station site	
Width (ft)	
Depth (ft)	
Bankfull Depth (ft)	
Bankfull Width (ft)	
Slope (%)/Hydraulic condition	
Substrate	
Channel stability	
Suitability for staff gage and stilling well	
Suitability for manual discharge measurement	
Suitability for sampling	
Existing gauging or sampling station?	
Photo log	Photo #
	.
Conclusions	This site is not an option unless we gain access through the private property.

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/13/2009
Weather conditions:	Light rain all day

Monitoring station location	
Watershed Name	WRIA 7
Site I.D.	FB 161
Nearest Intersection	
Access	This site was not explored as an option because we could not gain access through private property for reconnaissance.
Safety	
Traffic Safety	
Water Safety	
Physical description of monitoring station site	
Stream Overview	
Width (ft)	
Depth (ft)	
Bankfull Depth (ft)	
Bankfull Width (ft)	
Slope (%)/Hydraulic condition	
Substrate	
Channel stability	
Suitability for staff gage and stilling well	
Suitability for manual discharge measurement	
Suitability for sampling	
Existing gauging or sampling station?	
Photo log	Photo #
	.
Conclusions	This site was not explored as an option because we could not gain access through private property for reconnaissance.

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/14/2009
Weather conditions:	Light rain
Monitoring station location	
Watershed Name	WRIA 10
Site I.D.	FB 163
Nearest Intersection	
Access	Location could not be accessed for reconnaissance due to private
Safety	
Traffic Safety	
Water Safety	
Physical description of monitoring station site	
Stream Overview	
Width (ft)	
Depth (ft)	
Bankfull Depth (ft)	
Bankfull Width (ft)	
Slope (%)/Hydraulic condition	
Substrate	
Channel stability	
Suitability for staff gage and stilling well	
Suitability for manual discharge measurement	
Suitability for sampling	
Existing gauging or sampling station?	
Photo log	Photo #
	.
Conclusions	Location could not be accessed for reconnaissance due to private property restrictions.

CHEMLOADPH3 Monitoring Station Reconnaissance Form

The purpose of this form is to record observations made during reconnaissance of potential discharge and water quality monitoring sites for

Field Crew:	Alex Svendsen
Date/Time:	5/8/2009
Weather conditions:	Sunny

Monitoring station location	
Watershed Name	WRIA 10
Site I.D.	FB 170
Nearest Intersection	
Access	Location could not be accessed for reconnaissance due to private
Safety	
Traffic Safety	
Water Safety	
Physical description of monitoring station site	
Stream Overview	
Width (ft)	
Depth (ft)	
Bankfull Depth (ft)	
Bankfull Width (ft)	
Slope (%)/Hydraulic condition	
Substrate	
Channel stability	
Suitability for staff gage and stilling well	
Suitability for manual discharge measurement	
Suitability for sampling	
Existing gauging or sampling station?	
Photo log	Photo #
	.
Conclusions	Location could not be accessed for reconnaissance due to private

CHEMLOADPH3 Monitoring Station Reconnaissance Form

The purpose of this form is to record observations made during reconnaissance of potential discharge and water quality monitoring sites for

Field Crew:	Dan Bennett
Date/Time:	5/14/2009
Weather conditions:	Light rain
Monitoring station location	
Watershed Name	WRIA 10
Site I.D.	FB 175
Nearest Intersection	
Access	No access. Private Rd.
Safety	
Traffic Safety	
Water Safety	
Physical description of monitoring station site	
Stream Overview	
Width (ft)	
Depth (ft)	
Bankfull Depth (ft)	
Bankfull Width (ft)	
Slope (%)/Hydraulic condition	
Substrate	
Channel stability	
Suitability for staff gage and stilling well	
Suitability for manual discharge measurement	
Suitability for sampling	
Existing gauging or sampling station?	
Photo log	Photo #
	.
Conclusions	Location could not be accessed for reconnaissance due to private property restrictions.

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/13/2009
Weather conditions:	Light rain all day

Monitoring station location	
Watershed Name	WRIA 7
Site I.D.	FB 200
Nearest Intersection	North Carpenter Road, 1.6 miles from Robe Menzel Road
Access	Park in turnout, walk down roadbank to stream to culvet.
Safety	
Traffic Safety	Roadside parking.
Water Safety	Larger than most streams, proceed with caution in high water.
Physical description of monitoring station site	
Stream Overview	The stream flows beneath carpenter road in a 10 foot wide box culvert. It then flows into a manmade channel along the roadside for
Width (ft)	10
Depth (ft)	0.5
Bankfull Depth (ft)	2
Bankfull Width (ft)	15
Slope (%)/Hydraulic condition	2%
Substrate	large to medium cobbles
Channel stability	Constrained in culvert and ditch.
Suitability for staff gage and stilling well	Good
Suitability for manual discharge measurement	Good
Suitability for sampling	Good
Existing gauging or sampling station?	None
Photo log	Photo #
movies 904 and 907	Site overview.
900	Culvert
907	Pressure transducer site

Conclusions	This site would make a good candidate for monitoring.

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/5/2009
Weather conditions:	Light rain for more than 24 hours

Monitoring station location	
Watershed Name	WRIA 7
Site I.D.	Forest Basin 203
Nearest Intersection	Ben Howard Rd. and Mann Rd.
Access	Park in turnout and walk down gentle bank from the road.
Safety	
Traffic Safety	Park at road turnout.
Water Safety	This creek could become really wide during a flood.
Physical description of monitoring station site	
Stream Overview	The stream uptream of the road is in a steep v-notch. It is a cascade. It crosses the road in a 10 foot half pipe culvert. Downstream of the road it is slightly more gradual gradient, but also seems to have the
Width (ft)	10 foot culvert.
Depth (ft)	1 foot
Bankfull Depth (ft)	3 feet
Bankfull Width (ft)	? Big flood plane, could be 100 feet. Probably 25.
Slope (%)/Hydraulic condition	riffles to cascade
Substrate	Lare jagged cobbles.
Channel stability	Fairly stable main channel, but wouldn't take much to start braiding.
Suitability for staff gage and stilling well	Inside the culvert would be good. It seems to have a natural bottom.
Suitability for manual discharge measurement	At the culvert mouth would be best, but it could be done down in the channel. Could be done from road on top in high water.
Suitability for sampling	Excellent.
Existing gauging or sampling station?	None Observed.
Photo	Photo #
276	Culvert mouth
278	Looking down channel
Movie	Culvert mouth video

Conclusions	This site is an excellent candidate for monitoring.

CHEMLOADPH3 Monitoring Station Reconnaissance Form

The purpose of this form is to record observations made during reconnaissance of potential discharge and water quality monitoring sites for

Field Crew:	Alex Svendsen
Date/Time:	5/8/2009
Weather conditions:	Sunny

Monitoring station location	
Watershed Name	WRIA 10
Site I.D.	FB 262
Nearest Intersection	
Access	The stream could not be located in the vicinity of the area marked on
Safety	
Traffic Safety	
Water Safety	
Physical description of monitoring station site	
Stream Overview	
Width (ft)	
Depth (ft)	
Bankfull Depth (ft)	
Bankfull Width (ft)	
Slope (%)/Hydraulic condition	
Substrate	
Channel stability	
Suitability for staff gage and stilling well	
Suitability for manual discharge measurement	
Suitability for sampling	
Existing gauging or sampling station?	
Photo log	Photo #
	.
Conclusions	The stream could not be located in the vicinity of the area marked on the field map.

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/14/2009
Weather conditions:	Light rain

Monitoring station location	
Watershed Name	WRIA 10
Site I.D.	Forest Basin 282
Nearest Intersection	End of road at Mountainside Drive East.
Access	Park at end of small Hancock Forest access road. Walk 50 feet to
Safety	
Traffic Safety	None.
Water Safety	This is a large stream, and might be dangerous in high water.
Physical description of monitoring station site	
Stream Overview	Stream comes down from steep forest area. In a steep v-notch it enters a large culvert beneath road. Downstream it braids out into a
Width (ft)	10 (6ft culvert)
Depth (ft)	0.5-1
Bankfull Depth (ft)	3
Bankfull Width (ft)	20
Slope (%)/Hydraulic condition	3%
Substrate	Large cobbles, boulders
Channel stability	Constrained here, and in culvert, but braided below.
Suitability for staff gage and stilling well	O.K.
Suitability for manual discharge measurement	Good.
Suitability for sampling	Good.
Existing gauging or sampling station?	None.
Photo log	Photo #
Movie 979	Upstream site overview.
979	Monitoring site

Conclusions	This site could potentially be monitored, but access is on private property and the area may be snowed in during the winter.

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Alex Svendsen
Date/Time:	5/8/2009
Weather conditions:	Sunny

Monitoring station location	
Watershed Name	WRIA 10
Site I.D.	FB 357
Nearest Intersection	
Access	Location could potentially be monitored; plenty of flow so stream conditions are likely perenial. The stream flows through the Dalles
Safety	
Traffic Safety	No issues; plenty of parking.
Water Safety	The monitoring station would be located below a bridge, so flow measurements could be taken from above during high flows.
Physical description of monitoring station site	
Stream Overview	Unnamed creek. This creek flows down a hillside, enters a series of 2 box culverts in the Dalles Campground area.
Width (ft)	8
Depth (ft)	0.8
Bankfull Depth (ft)	12
Bankfull Width (ft)	40
Slope (%)/Hydraulic condition	Approximately 5-10% / moderately velocities would be encountered
Substrate	Cobble and large boulders 1 - 5 feet in diameter.
Channel stability	Channel appears to be relatively stable due to large substrate and
Suitability for staff gage and stilling well	Good suitability for gage/stilling well at the downstream end of either
Suitability for manual discharge measurement	Good suitability at the downstream end of the box culverts.
Suitability for sampling	Good.
Existing gauging or sampling station?	No.
Photo log	Photo #

.

Conclusions	Location could potentially be monitored, but its large size of contributing basin may make high flow measurements impractical.

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/14/2009
Weather conditions:	Light rain

Monitoring station location	
Watershed Name	WRIA 10
Site I.D.	Forest Basin 372, A.K.A. Coplar Creek.
Nearest Intersection	190 Ave East, 196th Ave
Access	Park in turnout, walk down bank to culvert
Safety	
Traffic Safety	No issues.
Water Safety	This stream looks powerful. Neighbor says he can't imagine standing in it at full flow. Discharge may need to be taken from side.
Physical description of monitoring station site	
Stream Overview	Coplar Creek. Stream comes down from mountainside, runs through 10 ft culvert, begins to braid and floodout downstream.
Width (ft)	20
Depth (ft)	1
Bankfull Depth (ft)	3
Bankfull Width (ft)	30
Slope (%)/Hydraulic condition	3%
Substrate	Large cobbles and boulders.
Channel stability	Good at culvert, but weak downstream.
Suitability for staff gage and stilling well	No good protection.
Suitability for manual discharge measurement	Good at culvert, but may be difficult in high water.
Suitability for sampling	Good.
Existing gauging or sampling station?	None.
Photo log	Photo #
Movie 55, 60	overview
55	culvert

Conclusions	This location would make a good monitoring station.

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Alex Svendsen
Date/Time:	5/8/2009
Weather conditions:	Sunny
Monitoring station location	
Watershed Name	WRIA 10
Site I.D.	FB 406
Nearest Intersection	
Access	Location could potentially be monitored, but flows appear low currently, indicating that perennial flow may not occur. In addition, snow is likely present at this site during the winter and evidence of
Safety	
Traffic Safety	No issues.
Water Safety	The monitoring station would be located on a very steep slope, so monitoring at this location would be potentially difficult during high
Physical description of monitoring station site	
Stream Overview	Unnamed creek. This creek flows down a steep hillside, enters a culvert approximately 36 inches in diameter for app. 25 feet, before
Width (ft)	3
Depth (ft)	0.2
Bankfull Depth (ft)	10
Bankfull Width (ft)	20
Slope (%)/Hydraulic condition	Approximately 20% / very high velocities due to steep slopes on each
Substrate	Cobble and small boulders.
Channel stability	Low to moderate stability, due to steep slope.
Suitability for staff gage and stilling well	Good suitability for gage/stilling well at the downstream end of the
Suitability for manual discharge measurement	Good suitability at the downstream end of the culvert.
Suitability for sampling	Good, but flows during the summer and fall are likely periodic.
Existing gauging or sampling station?	No.
Photo log	Photo #

.

Conclusions	This location could potentially be monitored; however, low flows may make it unsuitable for summer base flow

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Alex Svendsen
Date/Time:	5/8/2009
Weather conditions:	Sunny
Monitoring station location	
Watershed Name	WRIA 10
Site I.D.	FB 464
Nearest Intersection	
Access	The stream could not be accessed for reconnaissance due to poor road conditions; portions of the road had been washed away and
Safety	
Traffic Safety	
Water Safety	
Physical description of monitoring station site	
Stream Overview	
Width (ft)	
Depth (ft)	
Bankfull Depth (ft)	
Bankfull Width (ft)	
Slope (%)/Hydraulic condition	
Substrate	
Channel stability	
Suitability for staff gage and stilling well	
Suitability for manual discharge measurement	
Suitability for sampling	
Existing gauging or sampling station?	
Photo log	Photo #
	.
Conclusions	The stream could not be accessed for reconnaissance due to poor road conditions; portions of the road had been washed away and

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/13/2009
Weather conditions:	Light rain all day
Monitoring station location	
Watershed Name	WRIA 7
Site I.D.	Forest Basin 699
Nearest Intersection	
Access	This site was not explored as an option because we could not gain access through the private property for reconnaissance.
Safety	
Traffic Safety	
Water Safety	
Physical description of monitoring station site	
Stream Overview	
Width (ft)	
Depth (ft)	
Bankfull Depth (ft)	
Bankfull Width (ft)	
Slope (%)/Hydraulic condition	
Substrate	
Channel stability	
Suitability for staff gage and stilling well	
Suitability for manual discharge measurement	
Suitability for sampling	
Existing gauging or sampling station?	
Photo log	Photo #
	.
Conclusions	This site was not explored as an option because we could not gain access through the private property for reconnaissance.

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/13/2009
Weather conditions:	Light rain all day
Monitoring station location	
Watershed Name	WRIA 7
Site I.D.	Forest Basin 721
Nearest Intersection	
Access	This site is behind a locked gate.
Safety	
Traffic Safety	
Water Safety	
Physical description of monitoring station site	
Width (ft)	
Depth (ft)	
Bankfull Depth (ft)	
Bankfull Width (ft)	
Slope (%)/Hydraulic condition	
Substrate	
Channel stability	
Suitability for staff gage and stilling well	
Suitability for manual discharge measurement	
Suitability for sampling	
Existing gauging or sampling station?	
Photo log	Photo #
	.
Conclusions	This site was not explored as an option because we could not gain access through the private property for reconnaissance.

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/13/2009
Weather conditions:	Light rain all day

Monitoring station location	
Watershed Name	WRIA 7
Site I.D.	Forest Basin 844
Nearest Intersection	WA-203, 0.9 miles from NE Tolt Hill Rd.
Access	Walk down steep bank from road shoulder.
Safety	
Traffic Safety	Parking is either on a narrow shoulder, or we can cross the street from safer parking.
Water Safety	No issues.
Physical description of monitoring station site	
Stream Overview	Stream flows from agricultural area upstream of WA-203, in a swale/ditch. It crosses under the road and emerges in a 36 inch concrete culvert. It then flows through a forested area in a fairly
Width (ft)	36" culvert, 6-8 ft wide
Depth (ft)	0.5
Bankfull Depth (ft)	2
Bankfull Width (ft)	10
Slope (%)/Hydraulic condition	2%
Substrate	Mediem cobbles
Channel stability	Fairly constrained.
Suitability for staff gage and stilling well	Good.
Suitability for manual discharge measurement	Good at culvert.
Suitability for sampling	Good
Existing gauging or sampling station?	None
Photo log	Description
Movie 846	Overview of site on WA-203
843	Culvert outlet

Conclusions	This is a good candidate site for sampling.

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/6/2009
Weather conditions:	Light rain

Monitoring station location	
Watershed Name	WRIA 7
Site I.D.	Residential Basin 81, A.K.A. Munsen Creek
Nearest Intersection	58th Drive NE and 70th Street NE
Access	Park on road shoulder. Walk down steep brushy banks to creek.
Safety	
Traffic Safety	No issues, except shoulder parking.
Water Safety	No special issues.
Physical description of monitoring station site	
Stream overview	The stream flows in a natural 3 foot wide channel through an suburban ravine. It flows through a 36 inch corrugated pipe culvert beneath 58th Drive NE and then emerges into a high gradient channel
Width (ft)	3
Depth (ft)	1
Bankfull Depth (ft)	3
Bankfull Width (ft)	5
Slope (%)/Hydraulic condition	3%
Substrate	Gravel.
Channel stability	Fairly well constrained.
Suitability for staff gage and stilling well	Good
Suitability for manual discharge measurement	Good
Suitability for sampling	Excellent
Existing gauging or sampling station?	None observed.
Photo log	Photo #
movie 348	Downstream overview.

Conclusions	This would make an good site for monitoring, but may be a bit too sma

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/6/2009
Weather conditions:	Light rain
Monitoring station location	
Watershed Name	WRIA 7
Site I.D.	Residential Basin 93, A.K.A. King Creek
Nearest Intersection	Sunnyside Rd. and Soper Hill Rd.
Access	At lower site, park on road shoulder, walk gentle bank to stream. At upstream site, walk down steep brushy banks to creek.
Safety	
Traffic Safety	No issues, except shoulder parking.
Water Safety	No special issues.
Physical description of monitoring station site	
Stream overview	The stream flows through a steep ravine on private property and then flows through a small box culvert beneath Sunnyside Rd. It emerges in a 2 foot wide man-made ditch which conveys it onto private
Width (ft)	3
Depth (ft)	1
Bankfull Depth (ft)	3
Bankfull Width (ft)	3
Slope (%)/Hydraulic condition	1%
Substrate	Gravel.
Channel stability	Fairly well constrained.
Suitability for staff gage and stilling well	Good
Suitability for manual discharge measurement	Good
Suitability for sampling	Excellent
Existing gauging or sampling station?	None observed.
Photo log	Photo #
movie 303	Downstream overview.
Conclusions	This would make an good site for monitoring, but may be a bit too sm

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/6/2009
Weather conditions:	Light rain

Monitoring station location	
Watershed Name	WRIA 7
Site I.D.	Residential Basin 111
Nearest Intersection	Old Machias Rd/ S. Machias Rd.
Access	Park on road shoulder. Walk down gentle banks to creek.
Safety	
Traffic Safety	No issues, except shoulder parking.
Water Safety	No special issues.
Physical description of monitoring station site	
Stream overview	The stream comes out of a pasture, and passes benetah Old Machias Rd in a 3 ft. corrugate pipe culvert. It then enters a fairly constrained channel full of LWD enhancement projects. It then passes into another culvert beneath S Machias Rd, and emerges into a similar
Width (ft)	3
Depth (ft)	1
Bankfull Depth (ft)	3
Bankfull Width (ft)	5
Slope (%)/Hydraulic condition	2%, glide
Substrate	muck, gravel.
Channel stability	Constrained.
Suitability for staff gage and stilling well	Excellent
Suitability for manual discharge measurement	Excellent
Suitability for sampling	Excellent
Existing gauging or sampling station?	None observed.
Photo log	Photo #
movie	ecotox 261
channel	252
culvert	258

Conclusions	This would make an excellent site for monitoring.

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/5/2009
Weather conditions:	Light rain for more than 24 hours.

Monitoring station location	
Watershed Name	WRIA 7
Site I.D.	RB 167
Nearest Intersection	Lowell Larrimer Road / 131st St SE
Access	I'm not sure if this is private property. It appears to be part of someones farm, although, there is a sewer district facility down there. I drove down to the pump station, and directly accesses banks of
Safety	
Traffic Safety	No issues
Water Safety	No issues
Physical description of monitoring station site	
Stream Overview	The stream flows from a natural channel in forested area upstream into a ditch which conveys it through a vehicle/farm staging area. The banks of this ditch are actively eroding. An outfall from some upstream stormwater pipe joins the ditch about 40 feet before it
Width (ft)	2
Depth (ft)	1
Bankfull Depth (ft)	2
Bankfull Width (ft)	5
Slope (%)/Hydraulic condition	1%
Substrate	Gravelly.
Channel stability	By the barn, it’s a gravel staging area with banks actively eroding. Up above in the forest may be a better place with a natural channel in
Suitability for staff gage and stilling well	Immediately upstream of birdcage structure? Or downstream to
Suitability for manual discharge measurement	Good
Suitability for sampling	Good upstream, issues of staging area erosion near mouth.
Existing gauging or sampling station?	No
Photo log	Photo #
455	Channel in forest
461	Channel in parking area, eroding banks
462	sewer district lift station.
Movie "Upstream in the woods"	Shows possible undisturbed area upstream of parking area.
Movie "Mouth near birdcage"	Overview of possible downstream monitoring area.

Conclusions	This area could be monitored if access issues could be resolved.

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/5/2009
Weather conditions:	Light rain for more than 24 hours

Monitoring station location	
Watershed Name	WRIA 7
Site I.D.	Residential Basin 202
Nearest Intersection	Elliot road/ Cathcart River road
Access	Park in turnout, walk down gentle banks to creek.
Safety	
Traffic Safety	No issues.
Water Safety	No issues.
Physical description of monitoring station site	
Stream Overview	The stream winds down along a steep road (Riverside Rd), in a roadside ditch. It crosses beneath another road in a set of stacked culverts, and emerges into a fairly constrained stream. The best spots for monitoring may be along Riverside Rd, where driveway culverts
Width (ft)	10 (2 feet in ditch aling riverside rd)
Depth (ft)	0.5 (1)
Bankfull Depth (ft)	3
Bankfull Width (ft)	20
Slope (%)/Hydraulic condition	2%
Substrate	small cobble
Channel stability	Constrained
Suitability for staff gage and stilling well	Good sites amongst trees. Good sites 100 feet down. Only issue is flood plane seems only about 2 feet above bank, with lots of signs of past flooding. Upstream of road seems more constrained, perhaps easier to measure. Best place may be in ditch on Elliot road 9i.e. the
Suitability for manual discharge measurement	Good
Suitability for sampling	Good
Existing gauging or sampling station?	None observed.
Photo log	Photo #
447	culverts along road where we could do manual discharge.
movie 445	upstream monitoring sites along riverside road.
movie 433	downstream channel.
431	downstream channel.
Conclusions	This site would make a good candidate for monitoring.

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/8/2009
Weather conditions:	Partly cloudy. No rain.

Monitoring station location	
Watershed Name	WRIA 10
Site I.D.	RES 1
Nearest Intersection	on SW Dash Point Rd, about 200 feet southwest of 21st Way SW
Access	Park on road shoulder, walk down gentle slope to culvert an stream.
Safety	
Traffic Safety	Not a great parking area.
Water Safety	No special issues.
Physical description of monitoring station site	
Stream Overview	The stream is fed from a wetland adjancent to Lakota High School, It is piped beneath a playfield about 300 yards, and surfaces at the culvert north of Dash point road. The stream comes out of a 2 foot
Width (ft)	2
Depth (ft)	0.5
Bankfull Depth (ft)	2
Bankfull Width (ft)	4
Slope (%)/Hydraulic condition	2%
Substrate	mud and gravel.
Channel stability	gentle banks to flood plane downstream of site. Channel defined in muck near culvert, but channelized for at least 50 ft.
Suitability for staff gage and stilling well	Looks good just downstream of culvert and possible for 30 feet.
Suitability for manual discharge measurement	Looks good at culvert.
Suitability for sampling	Good, may go dry in summer.
Existing gauging or sampling station?	None observed.
Photo log	Photo #
819-820	culvert sampling site
821	parking
movie 814	site overview

Conclusions	This area is an inappropriate monitoring location because the upstream area is a large wetland.

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/8/2009
Weather conditions:	Partly cloudy. No rain.

Monitoring station location	
Watershed Name	WRIA 10
Site I.D.	RES 5
Nearest Intersection	1st Place SW and SW 332nd St.
Access	Park in apartment complex, follow trail to stream
Safety	
Traffic Safety	No issues.
Water Safety	No issues.
Physical description of monitoring station site	
Stream Overview	Stream emerges from 24 inch culvert in forested channel. Upstream, the stream is channeled through a 2-3 acre man-made lake with
Width (ft)	3
Depth (ft)	1
Bankfull Depth (ft)	3
Bankfull Width (ft)	5
Slope (%)/Hydraulic condition	2%
Substrate	small cobble
Channel stability	Constrained
Suitability for staff gage and stilling well	Good
Suitability for manual discharge measurement	Good
Suitability for sampling	Good
Existing gauging or sampling station?	None.
Photo log	Photo #
Movie 796	Overview of downstream area near culvert.
Movie 800	Downstream culvert and upstream lake issue.

Conclusions	Location inaccessible due to traffic safety concerns.

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/8/2009, 5/12/09
Weather conditions:	Partly cloudy. No rain.

Monitoring station location	
Watershed Name	WRIA 10
Site I.D.	RES 53: Tributary 0009 to Hylebos Creek from Surprise Lake.
Nearest Intersection	20th St. E., 0.2 miles east of 70th Ave E.. Second Trip, Freeman
Access	Park on road shoulder. Walk down gentle slope to culvert in field.
Safety	
Traffic Safety	Shoulder parking on a busy road.
Water Safety	No serious issues, but bank is hard to see in deep grass. Could trim wi
Physical description of monitoring station site	
Stream Overview	The stream appears to be an agricultural ditch. It flows south across 20th Ave, and emerges from a 24 inch culvert. The channel is constrained, the banks are tall grass. The water is free flowing. On a second trip, I explored upstream at Freeman Rd. The stream emerges
Width (ft)	2
Depth (ft)	1
Bankfull Depth (ft)	3
Bankfull Width (ft)	4
Slope (%)/Hydraulic condition	1%
Substrate	hard clay and muck.
Channel stability	constrained in ditch.
Suitability for staff gage and stilling well	No protections, but even bottom and laminar flow. No big debris.
Suitability for manual discharge measurement	Good at culvert, or downstream in ditch.
Suitability for sampling	Good, but the basin is only marginally residential.
Existing gauging or sampling station?	None observed.d
Photo log	Photo #
774-778	Culvert and ditch
Movie 776	Site overview.
Movie 832	Culvert at Freeman Rd.

Conclusions	The site can be sampled. The question remains if it is representative enough of residential uses. Upstream at Freeman Rd. would be best.

CHEMLOADPH3 Monitoring Station Reconnaissance Form

The purpose of this form is to record observations made during reconnaissance of potential discharge and water quality monitoring sites for

Field Crew:	Dan Bennett
Date/Time:	5/8/2009
Weather conditions:	Partly cloudy. No rain.

Monitoring station location	
Watershed Name	WRIA 10
Site I.D.	RES 209
Nearest Intersection	Canyon Road E /Pioneer Way E.
Access	Park on road shoulder and walk down gentle bank to stream. Appears
Safety	
Traffic Safety	Busy multiway intersecton
Water Safety	No special issues.
Physical description of monitoring station site	
Stream Overview	The stream flows along side the east side of Canyon Drive, then crosses under Pioneer way in a box culvert, about 4 feet wide. Upstream it's a braided channel and wetlands. Downstream is quite
Width (ft)	4 feet at culvert, 6-8 feet downstream.
Depth (ft)	0.5
Bankfull Depth (ft)	2
Bankfull Width (ft)	10
Slope (%)/Hydraulic condition	2%
Substrate	Cobbles
Channel stability	Constrained in culvert, but becomes very gentle banks with wide obvious wetland type floodplains downstream.
Suitability for staff gage and stilling well	We could put a staff gage in front of culvet, or attach it to a tree 20 feet downstream that appears to be in a deeper spot.
Suitability for manual discharge measurement	Good at culvert discharge.
Suitability for sampling	Good at culvert discharge. There is a concrete company immediately
Existing gauging or sampling station?	Observed upstream of road 100 feet.Staff gage.
Photo log	Photo #
762, 763	box culvert sampling station.
Movie 764	box culvert sampling station.

Conclusion	This site is a good candidate for monitoring.

CHEMLOADPH3 Monitoring Station Reconnaissance Form

Field Crew:	Dan Bennett
Date/Time:	5/8/2009
Weather conditions:	Partly cloudy. No rain.

Monitoring station location	
Watershed Name	WRIA 10
Site I.D.	RES 226
Nearest Intersection	
Access	Location innaccessible due to traffic safety concerns.
Safety	
Traffic Safety	No parking nearby, would need to cross freeway to access site.
Water Safety	No issues.
Physical description of monitoring station site	
Width (ft)	3
Depth (ft)	1
Bankfull Depth (ft)	3
Bankfull Width (ft)	5
Slope (%)/Hydraulic condition	1%
Substrate	muck
Channel stability	Constrained in agricultural ditch.
Suitability for staff gage and stilling well	o.k. dowstream of dammed area, but backwatered at culvert outlet.
Suitability for manual discharge measurement	o.k.,
Suitability for sampling	o.k.
Existing gauging or sampling station?	None.
Photo log	Photo #
Movie 747	Overview of downstream area near culvert.
747	Downstream culvert.

Conclusions	Location inaccessible due to traffic safety concerns.

APPENDIX E

Detailed Maps of Monitoring Locations and Their Associated Drainage Basins

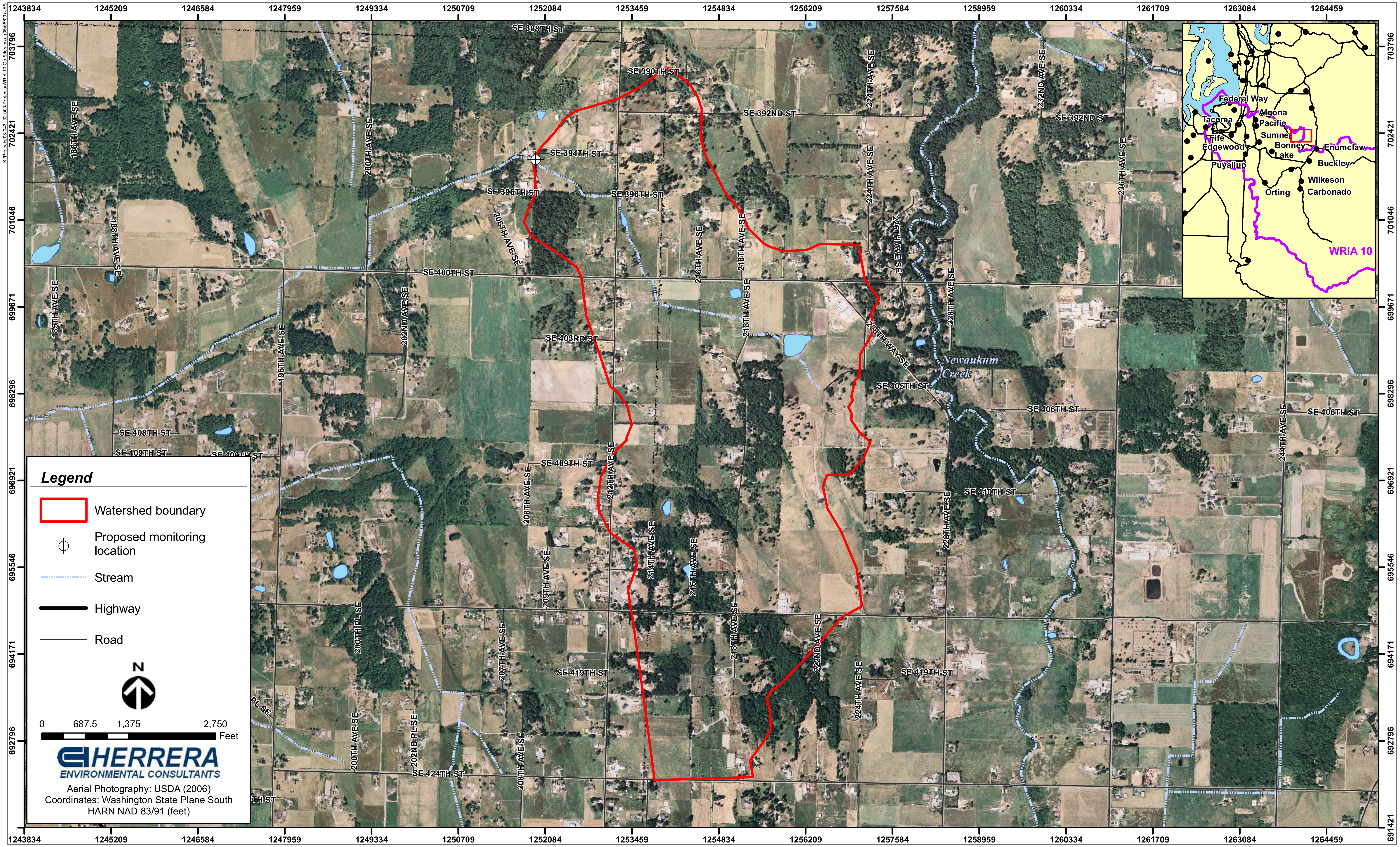


Figure E-1. Monitoring location AG62 in the Puyallup River Watershed for characterizing toxic chemicals in runoff from the agricultural land use category.

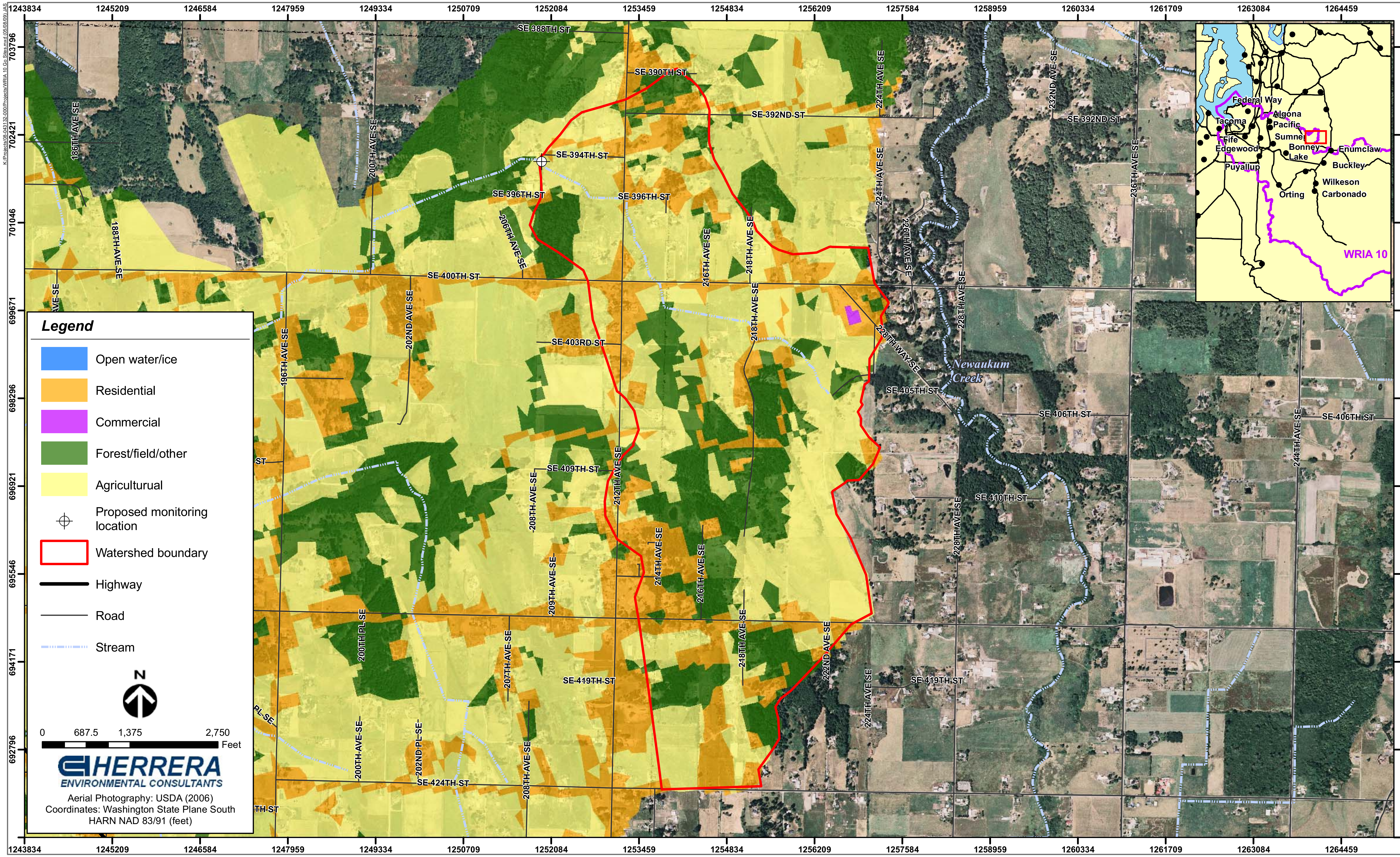


Figure E-2. Monitoring location AG62 in the Puyallup River Watershed for characterizing toxic chemicals in runoff from the agricultural land use category.

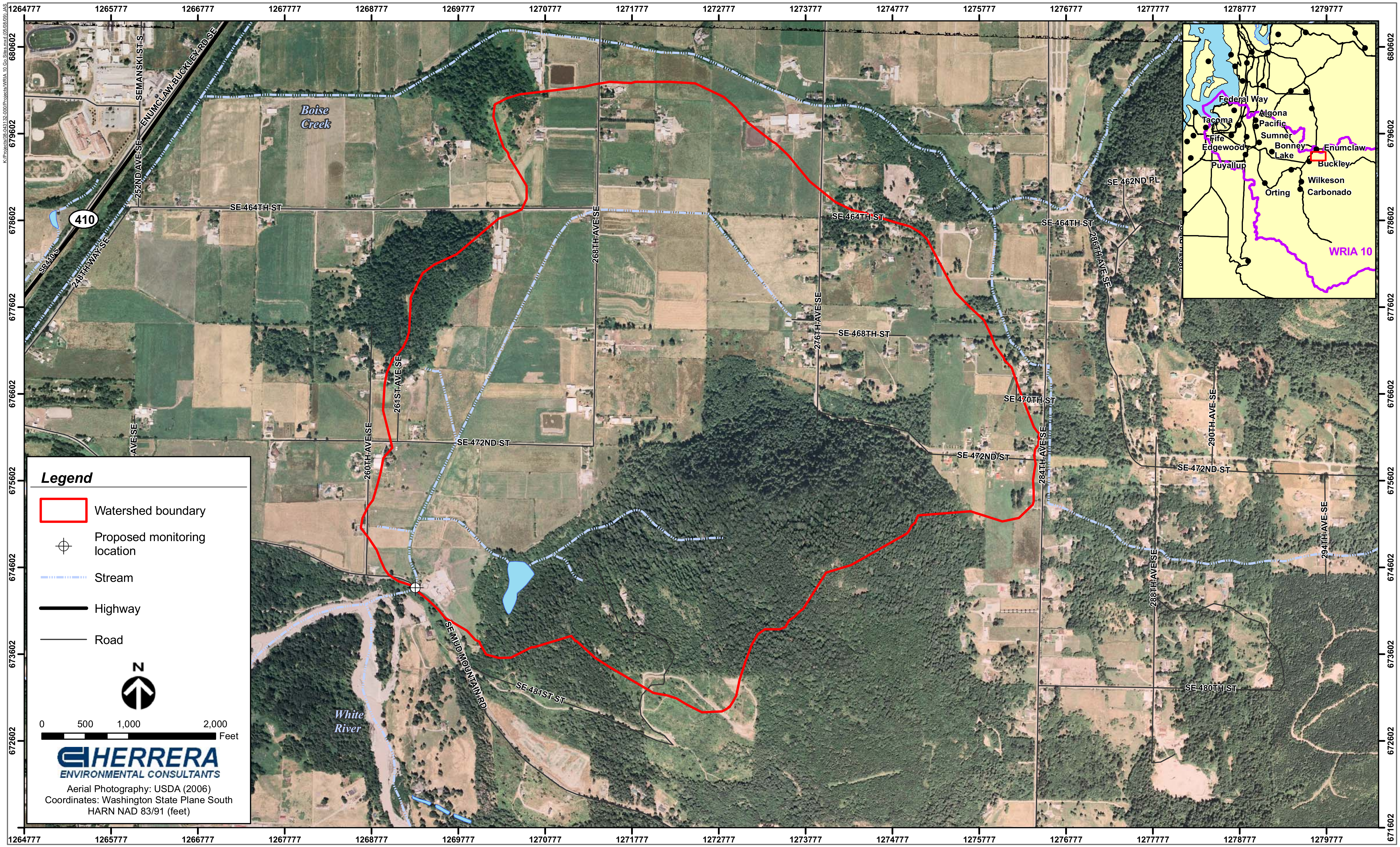


Figure E-3. Monitoring location AG143 in the Puyallup River Watershed for characterizing toxic chemicals in runoff from the agricultural land use category.

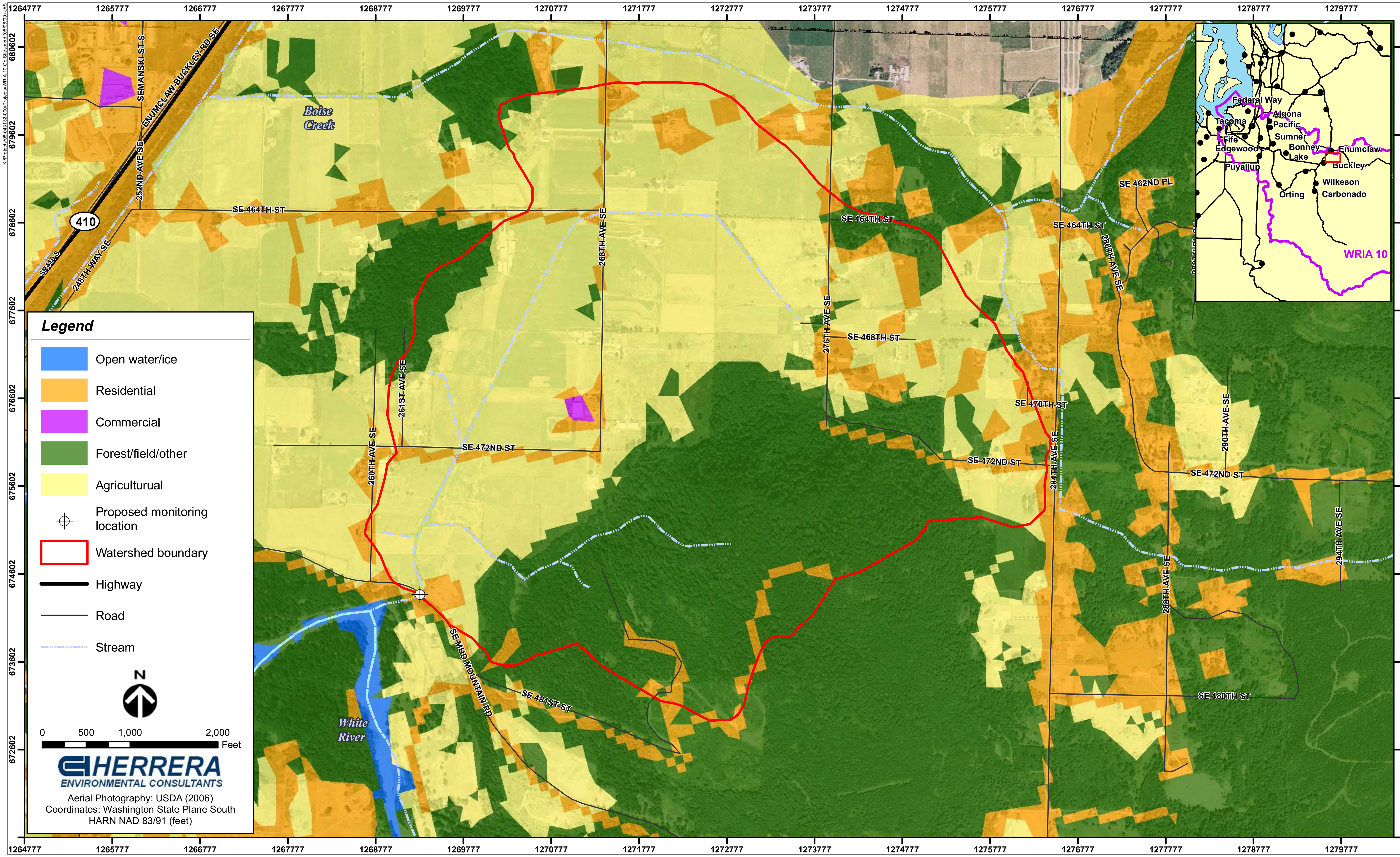


Figure E-4. Monitoring location AG143 in the Puyallup River Watershed for characterizing toxic chemicals in runoff from the agricultural land use category.

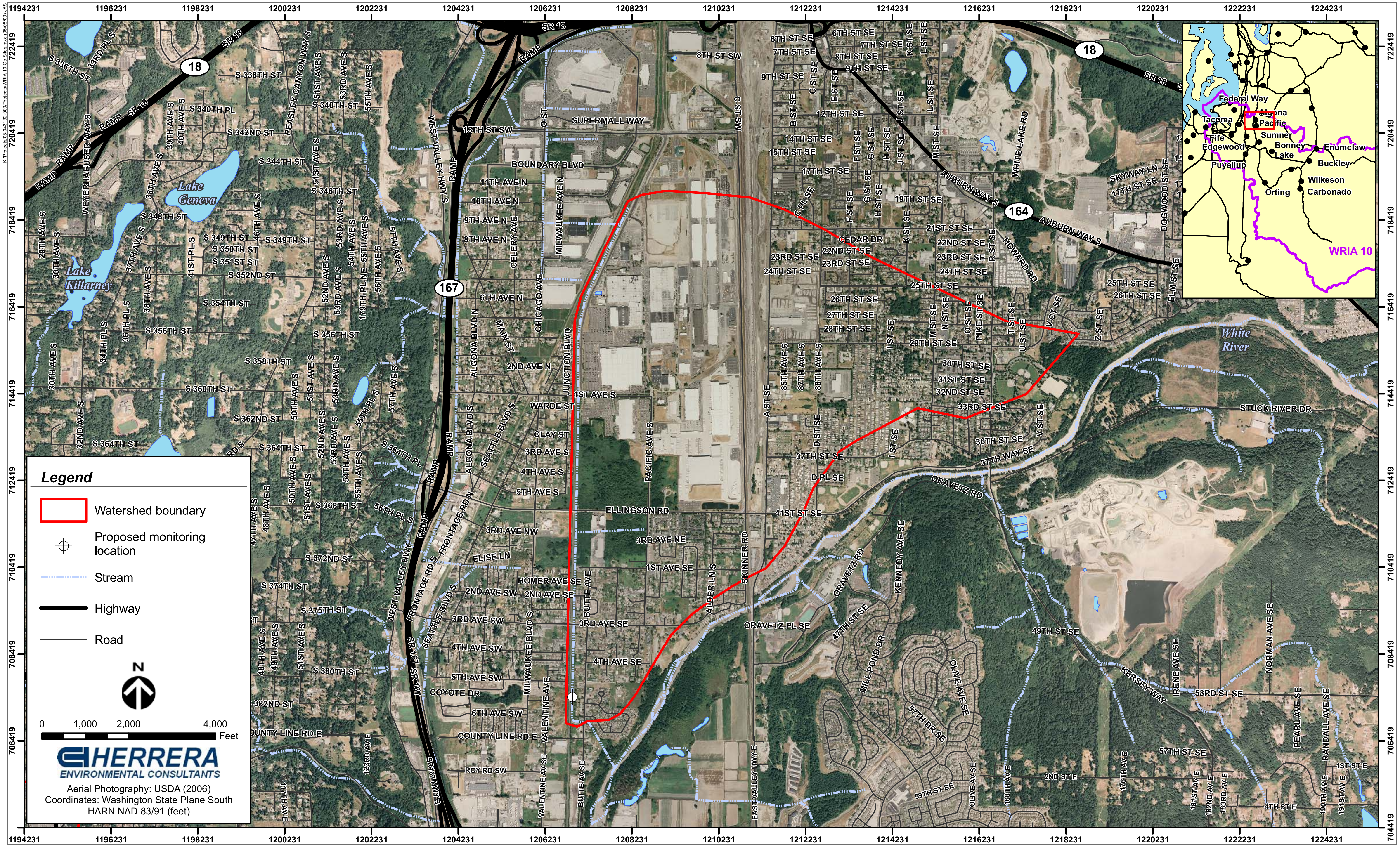


Figure E-5. Monitoring location CBA in the Puyallup River Watershed for characterizing toxic chemicals in runoff from the commercial land use category.

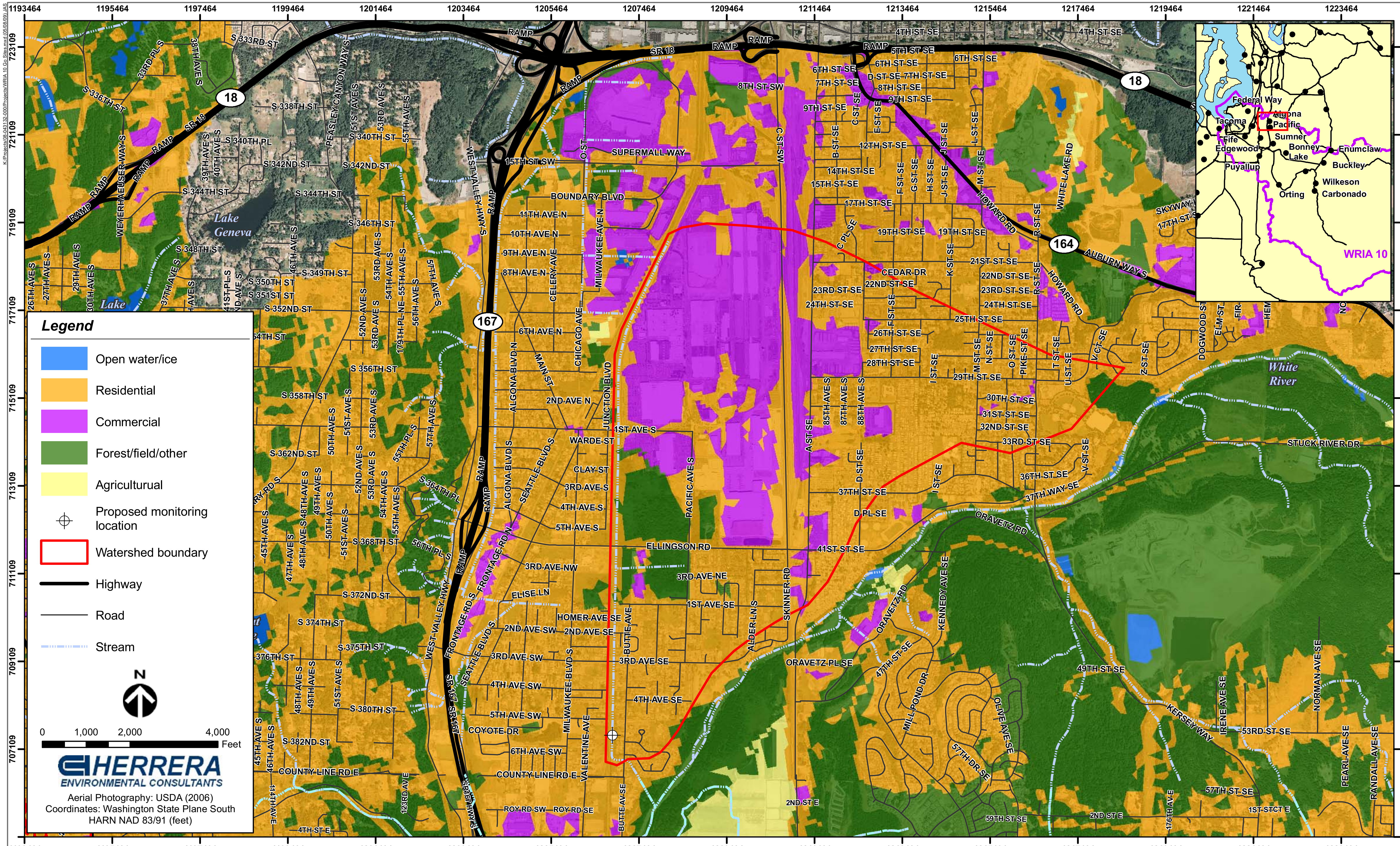


Figure E-6. Monitoring location CBA in the Puyallup River Watershed for characterizing toxic chemicals in runoff from the commercial land use category.

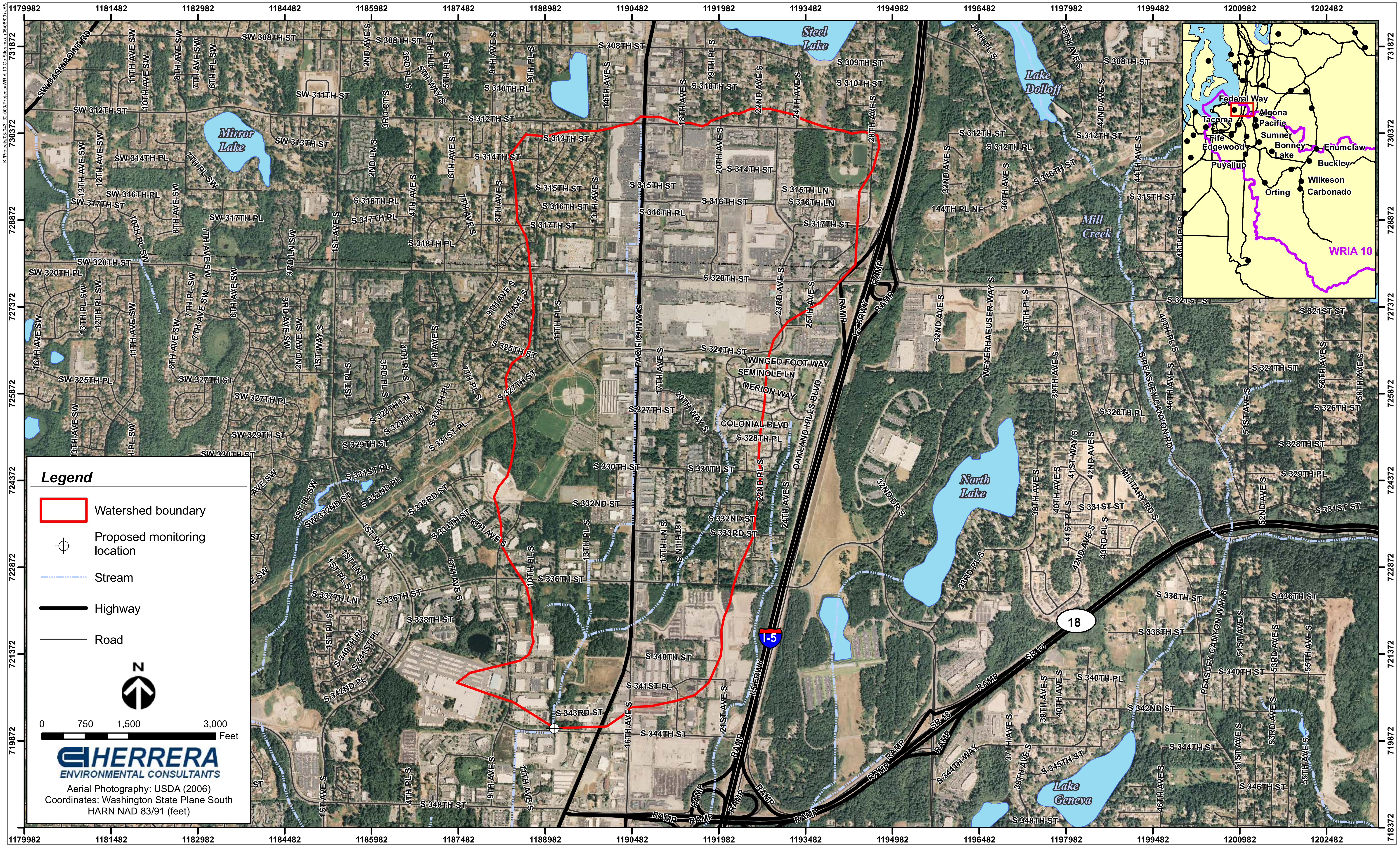


Figure E-7. Monitoring location CBB in the Puyallup River Watershed for characterizing toxic chemicals in runoff from the commercial land use category.

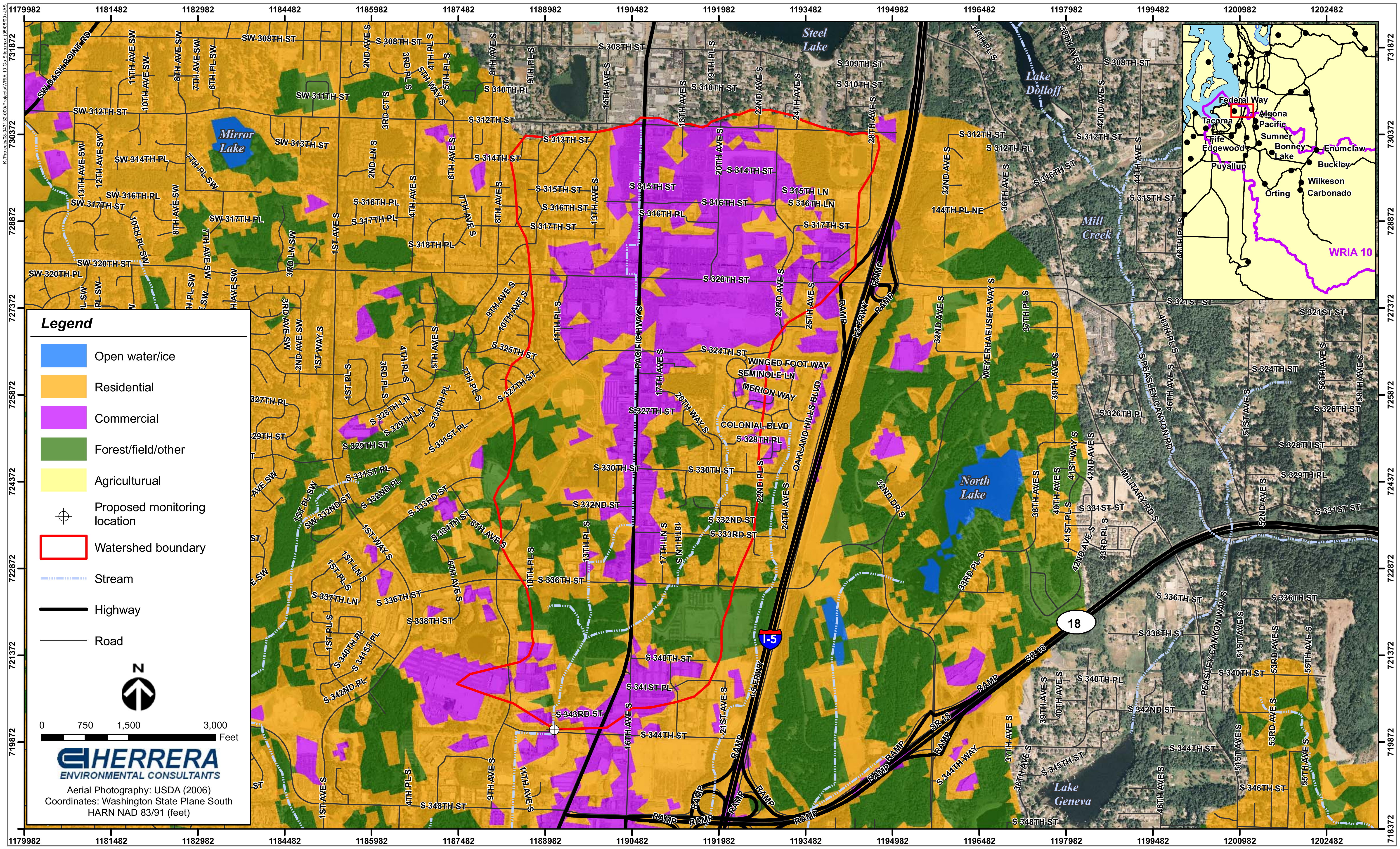


Figure E-8. Monitoring location CBB in the Puyallup River Watershed for characterizing toxic chemicals in runoff from the commercial land use category.

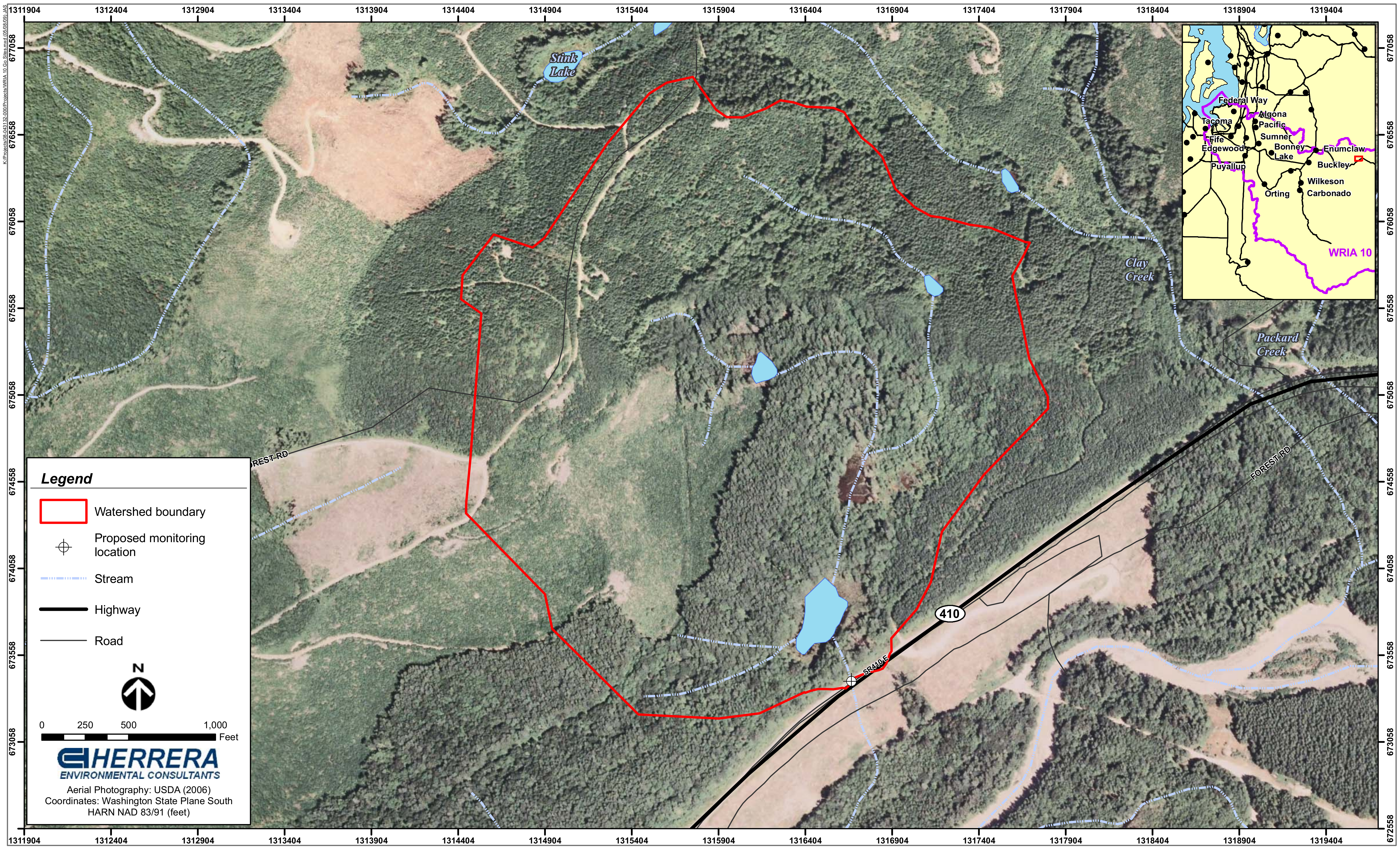


Figure E-9. Monitoring location FB130 in the Puyallup River Watershed for characterizing toxic chemicals in runoff from the forest/field/other land use category.

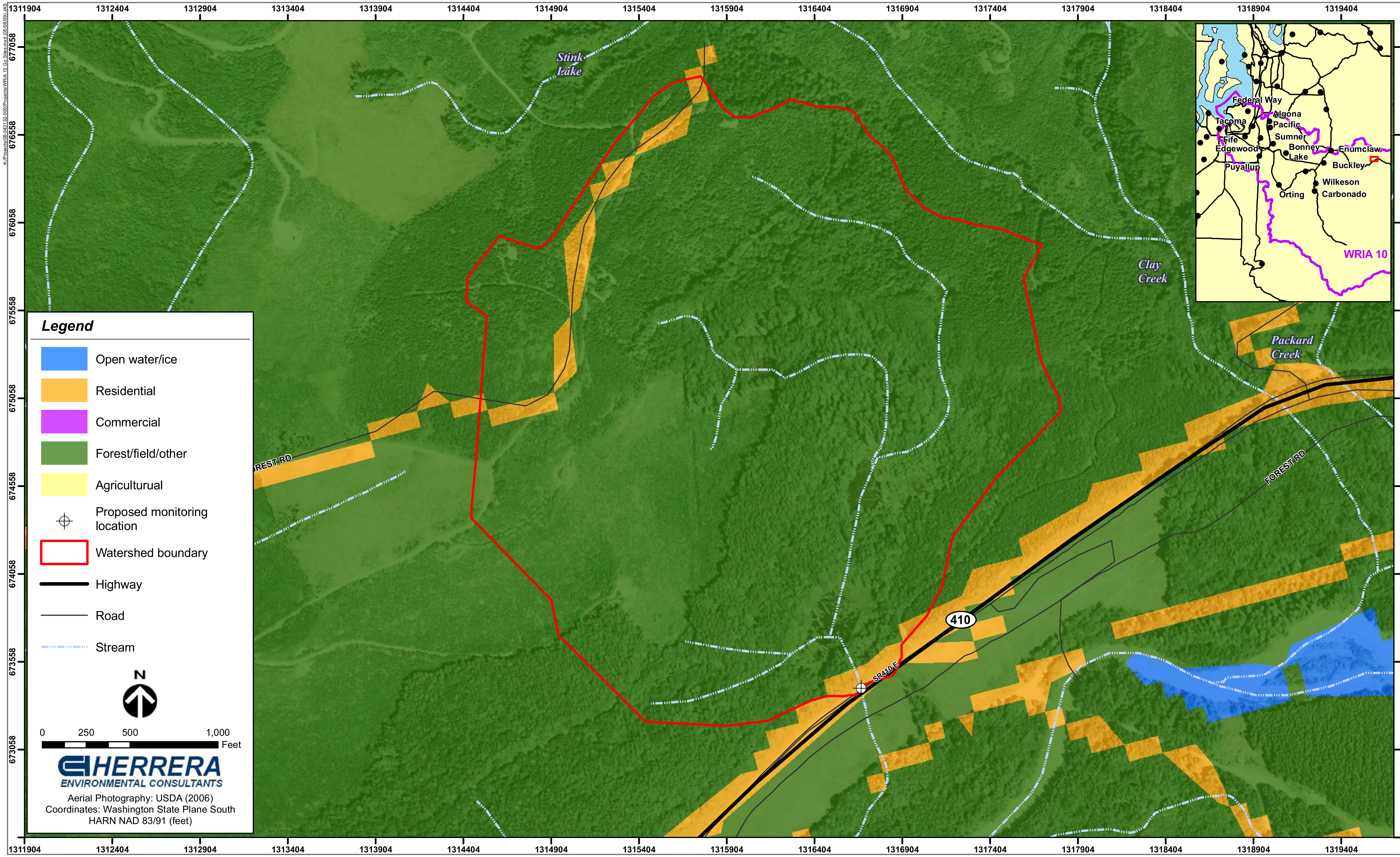


Figure E-10. Monitoring location FB130 in the Puyallup River Watershed for characterizing toxic chemicals in runoff from the forest/field/other land use category.

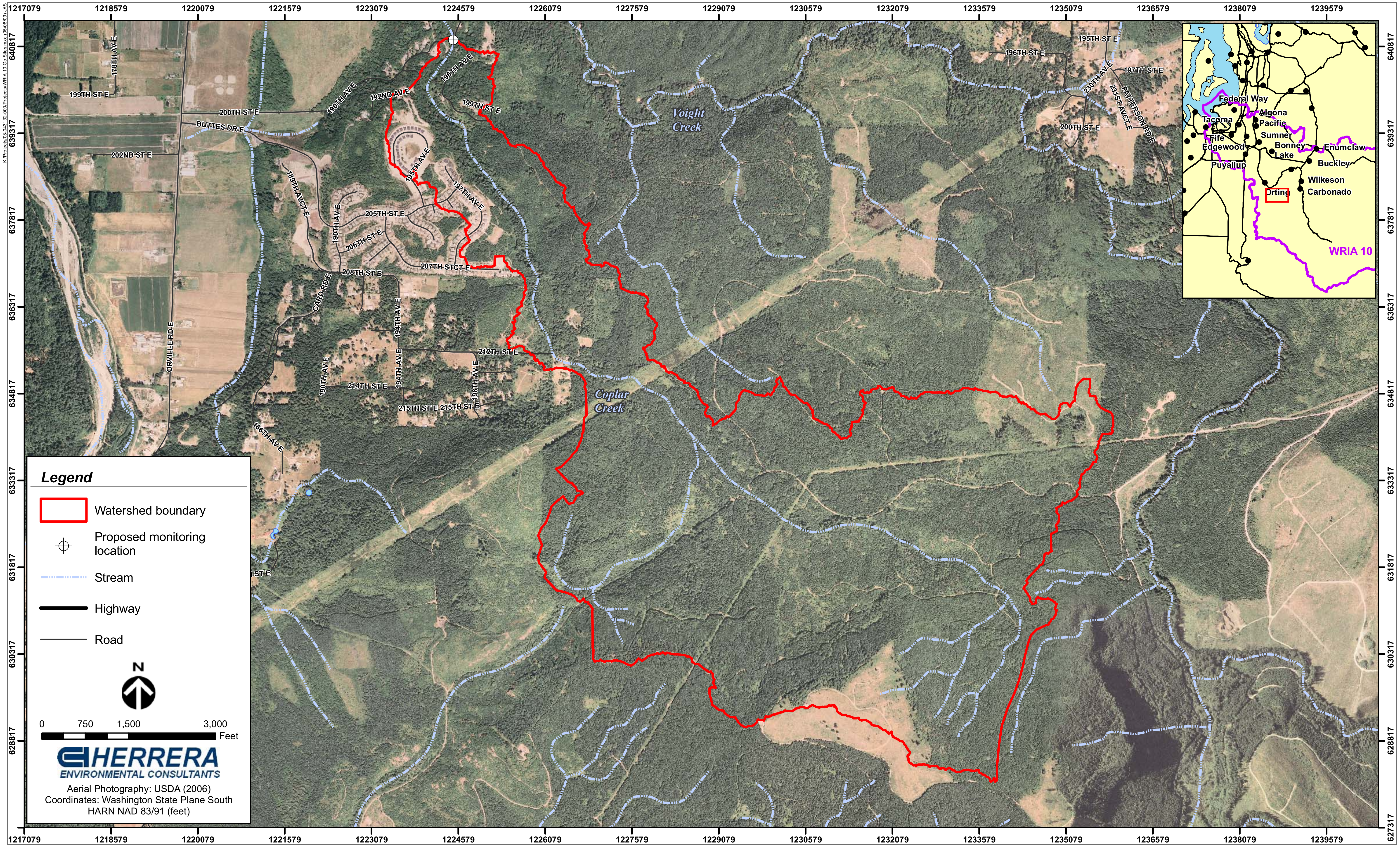


Figure E-11. Monitoring location FB372 in the Puyallup River Watershed for characterizing toxic chemicals in runoff from the forest/field/other land use category.

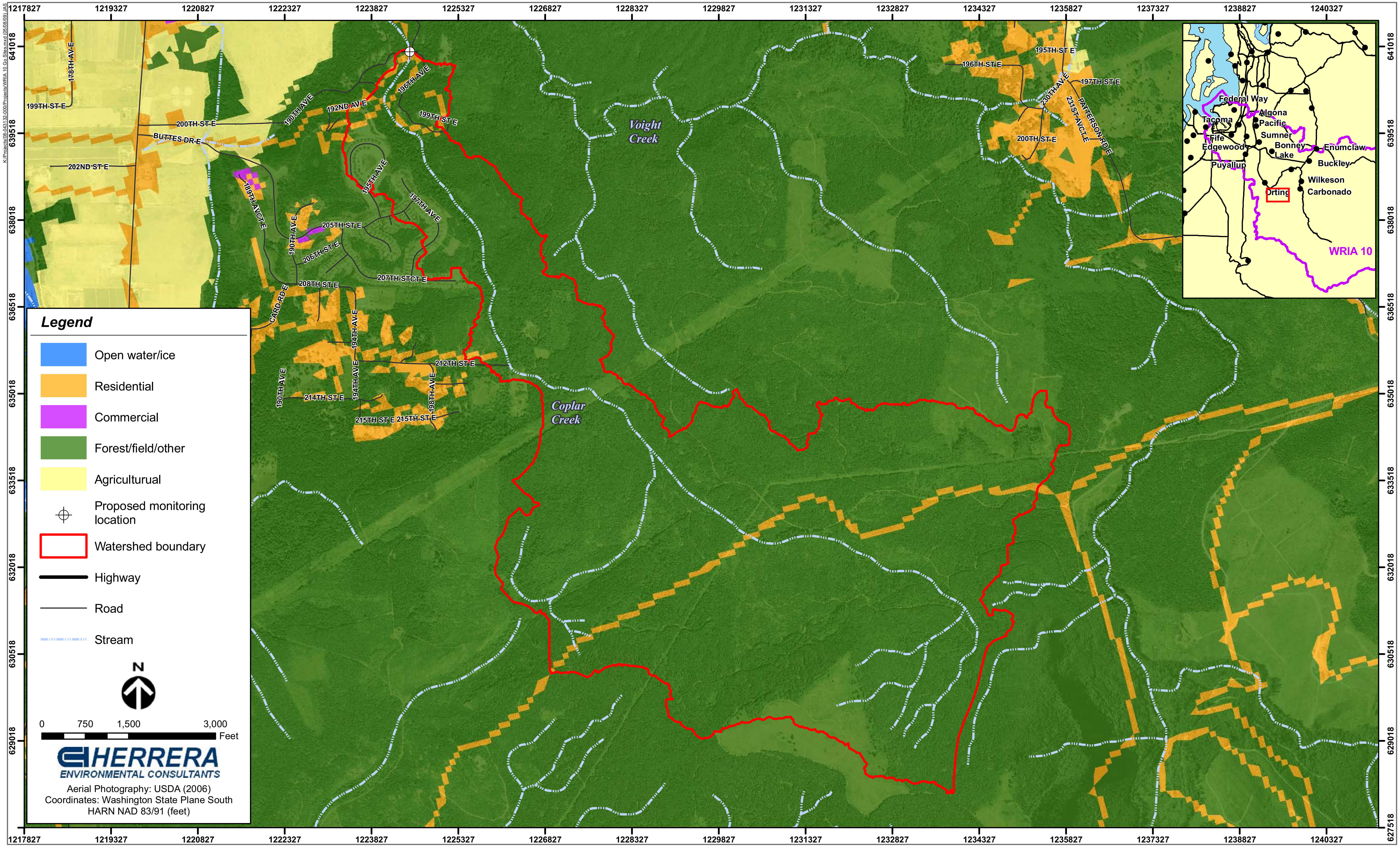


Figure E-12. Monitoring location FB372 in the Puyallup River Watershed for characterizing toxic chemicals in runoff from the forest/field/other land use category.

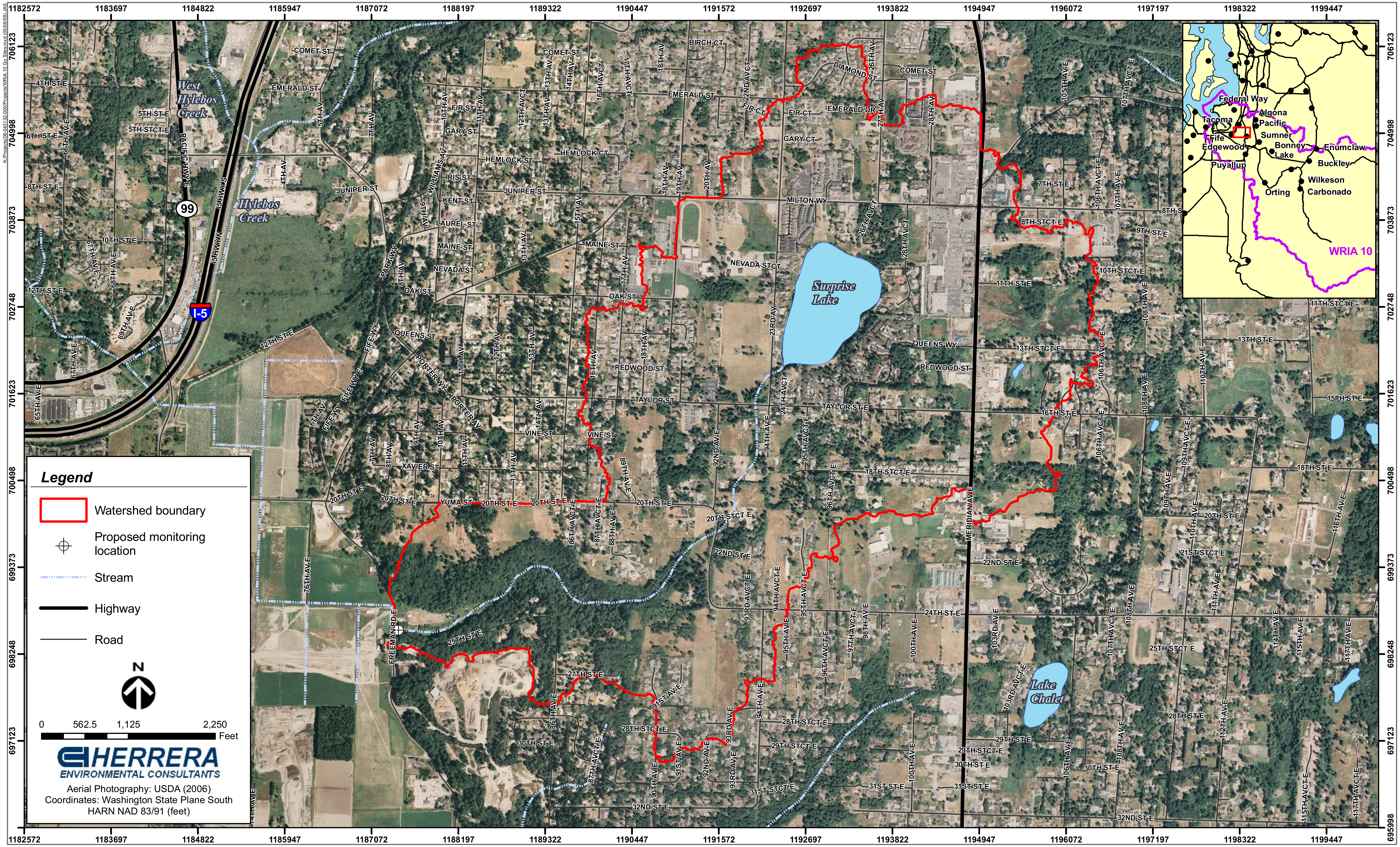


Figure E-13. Monitoring location RB53 in the Puyallup River Watershed for characterizing toxic chemicals in runoff from the residential land use category.

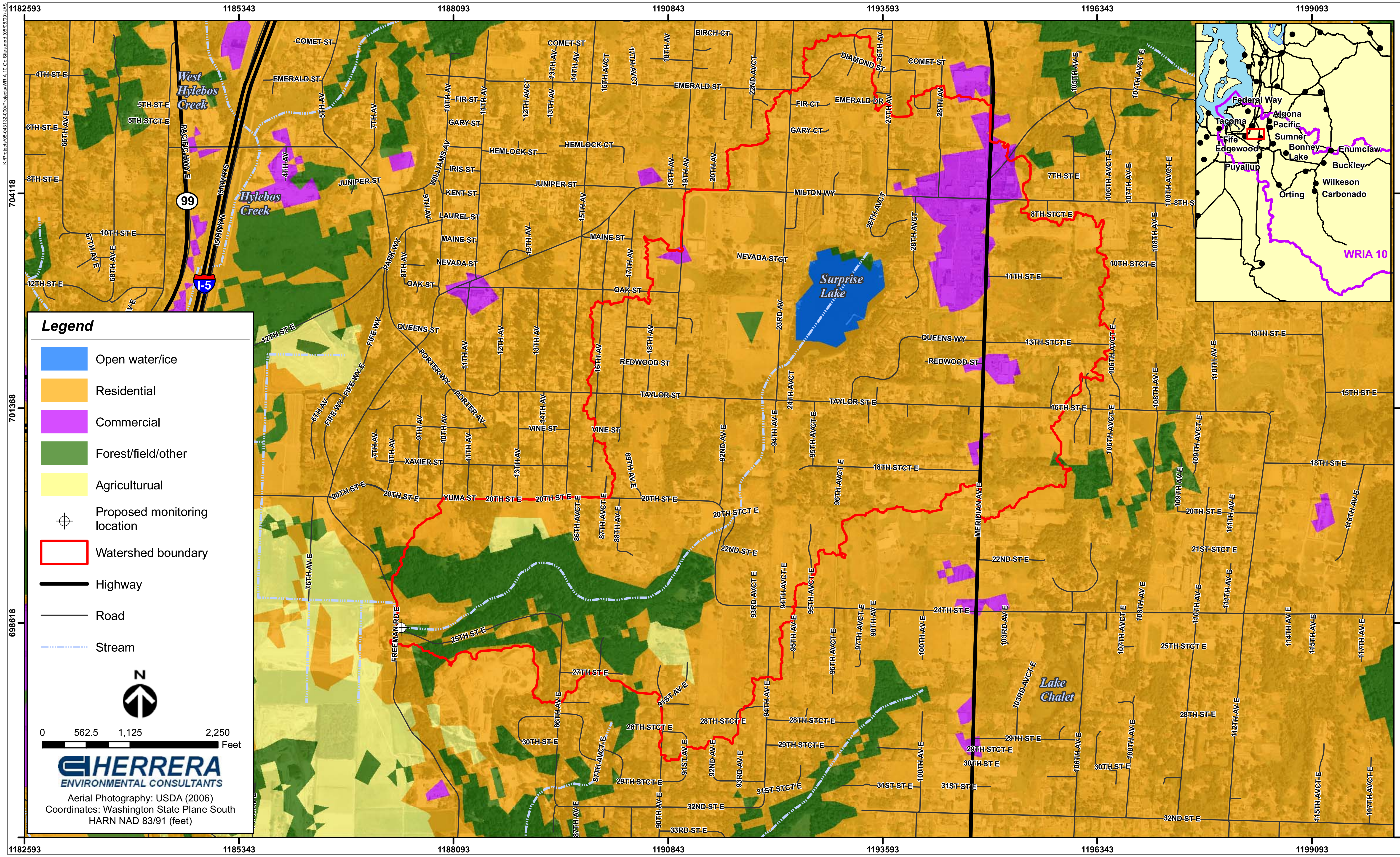


Figure E-14. Monitoring location RB53 in the Puyallup River Watershed for characterizing toxic chemicals in runoff from the residential land use category.

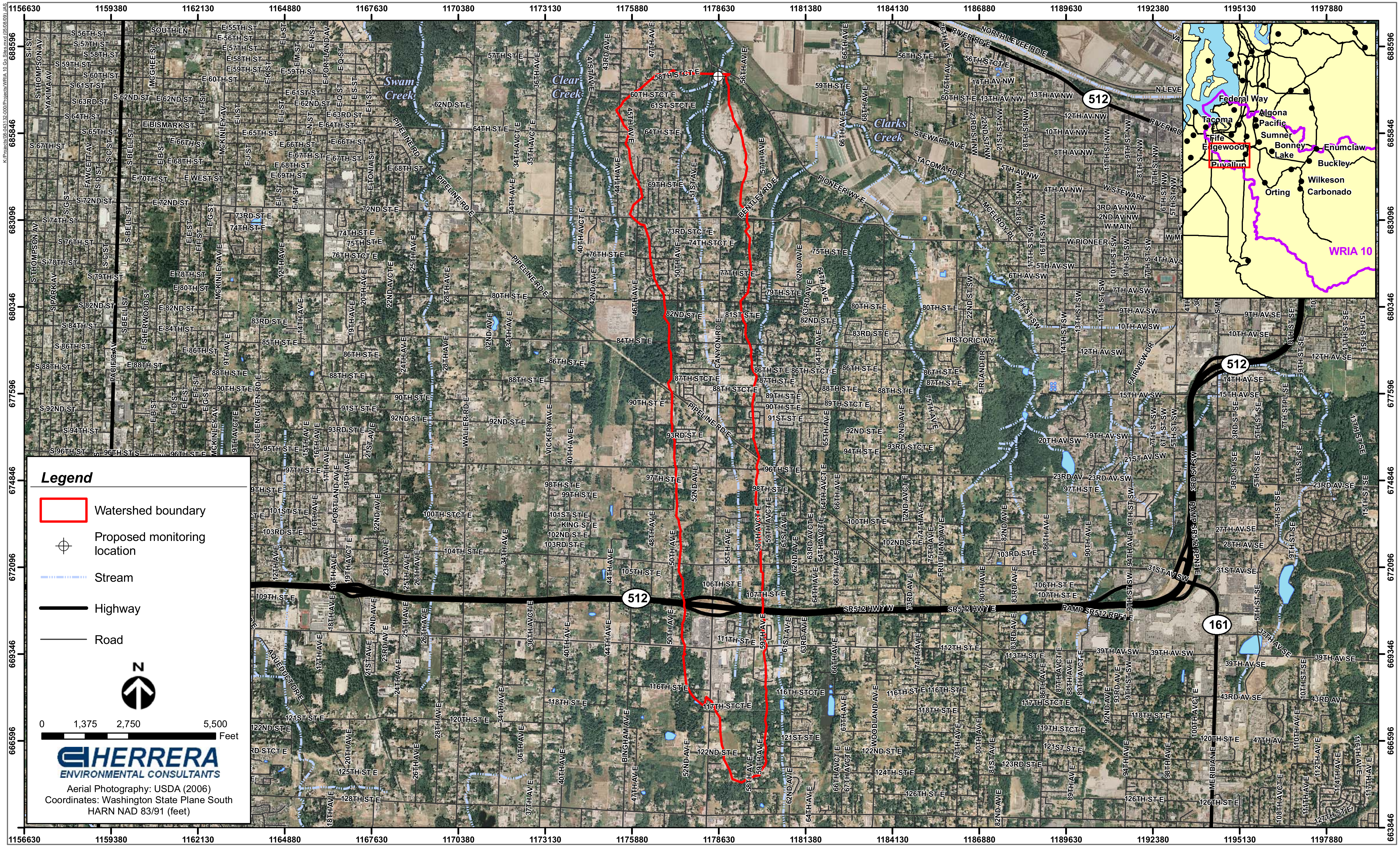


Figure E-15. Monitoring location RB209 in the Puyallup River Watershed for characterizing toxic chemicals in runoff from the residential land use category.

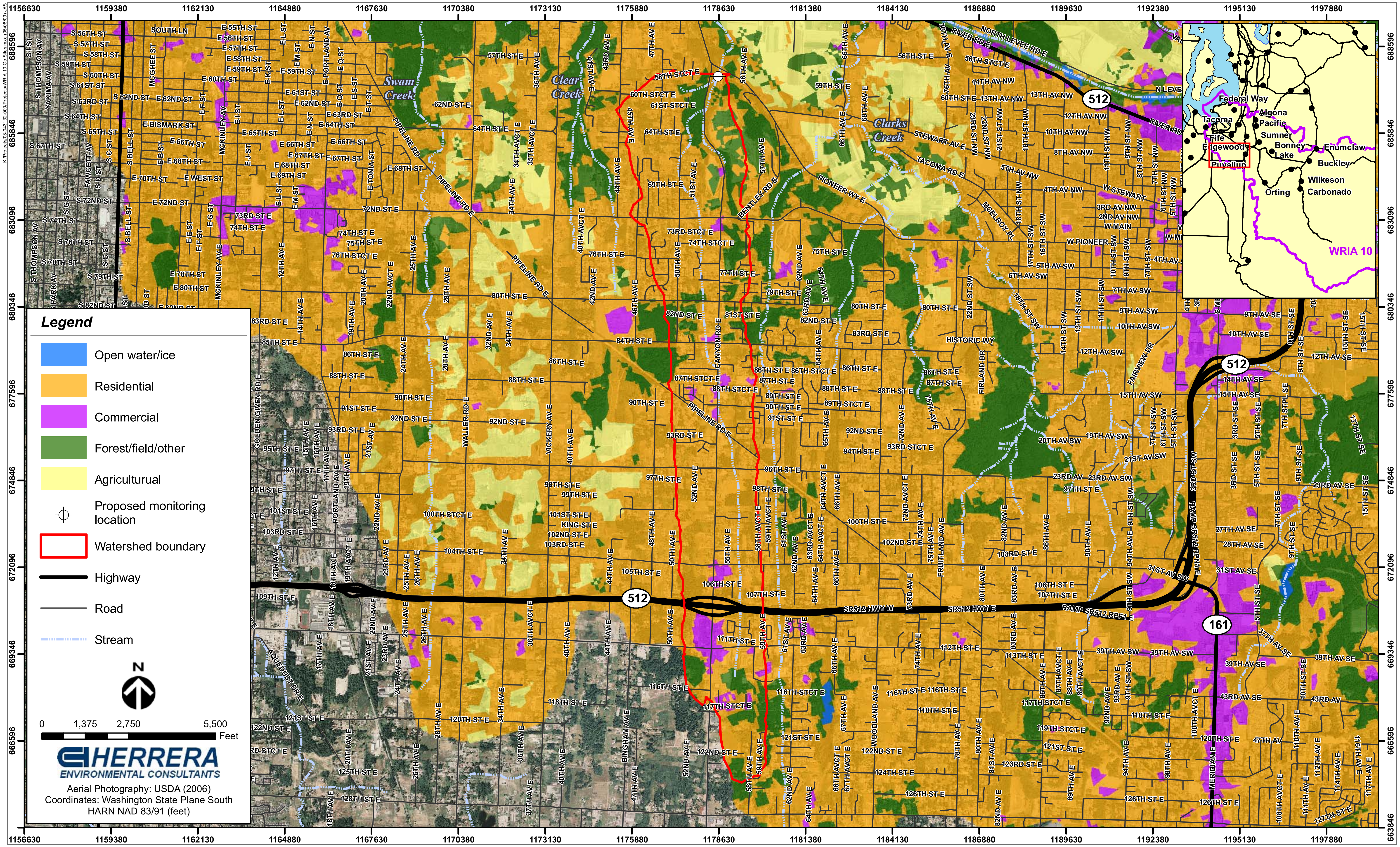


Figure E-16. Monitoring location RB209 in the Puyallup River Watershed for characterizing toxic chemicals in runoff from the residential land use category.

Figure E-17. Monitoring location AG174 in the Snohomish River Watershed for characterizing toxic chemical in runoff from the agricultural land use category.

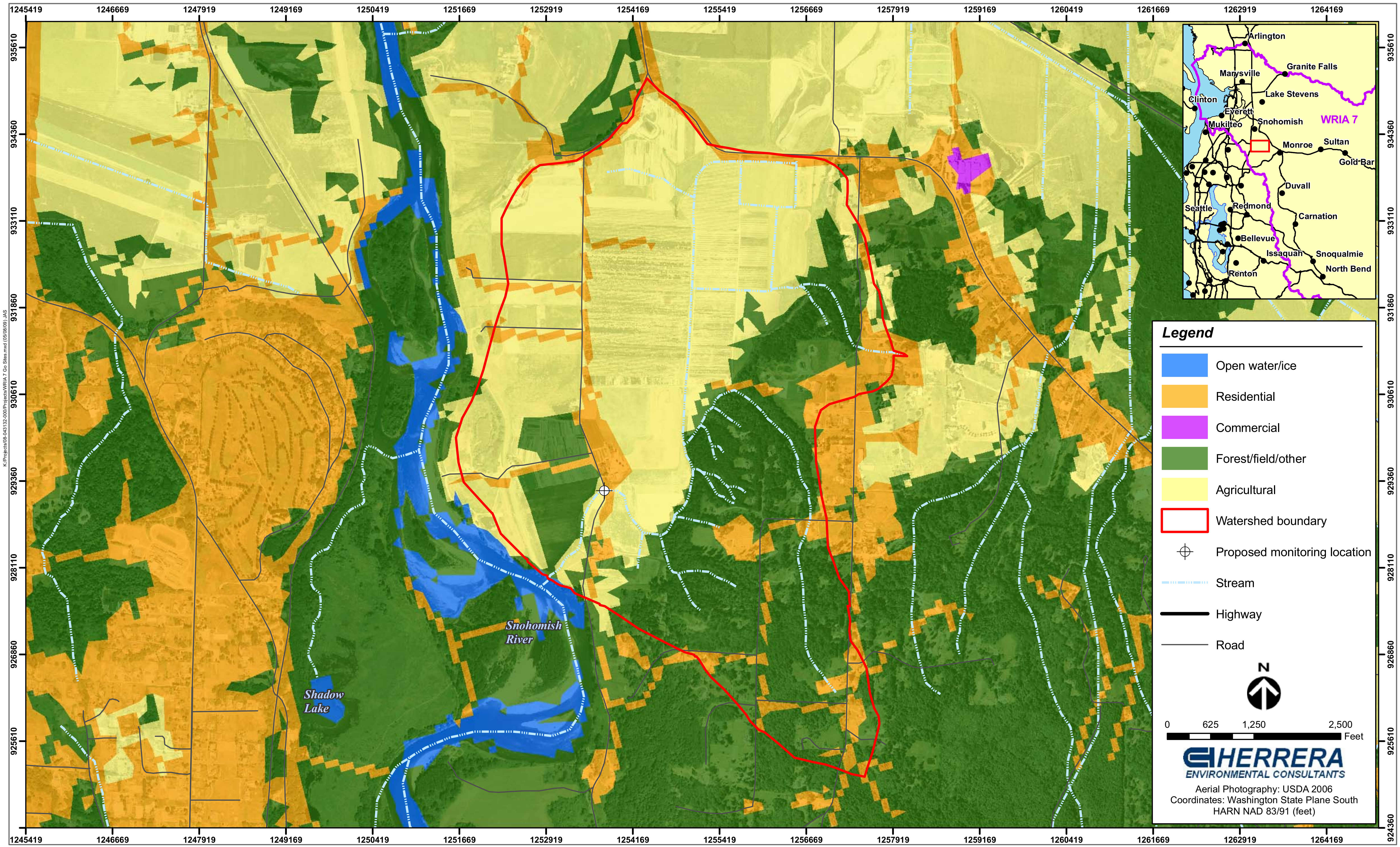


Figure E-18. Monitoring location AG174 in the Snohomish River Watershed for characterizing toxic chemical in runoff from the agricultural land use category.

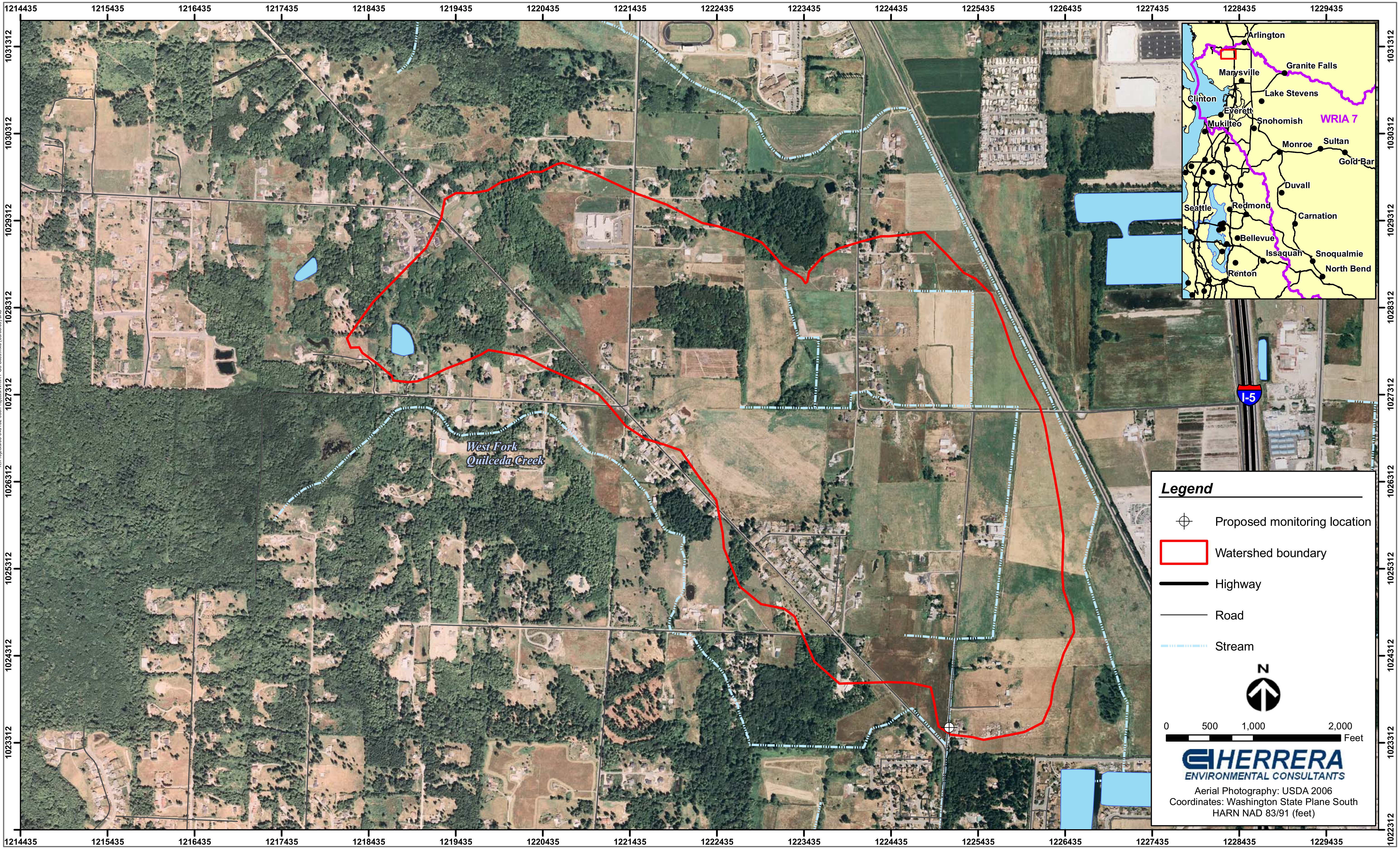


Figure E-19. Monitoring location AGG in the Snohomish River Watershed for characterizing toxic chemical in runoff from the agricultural land use category.

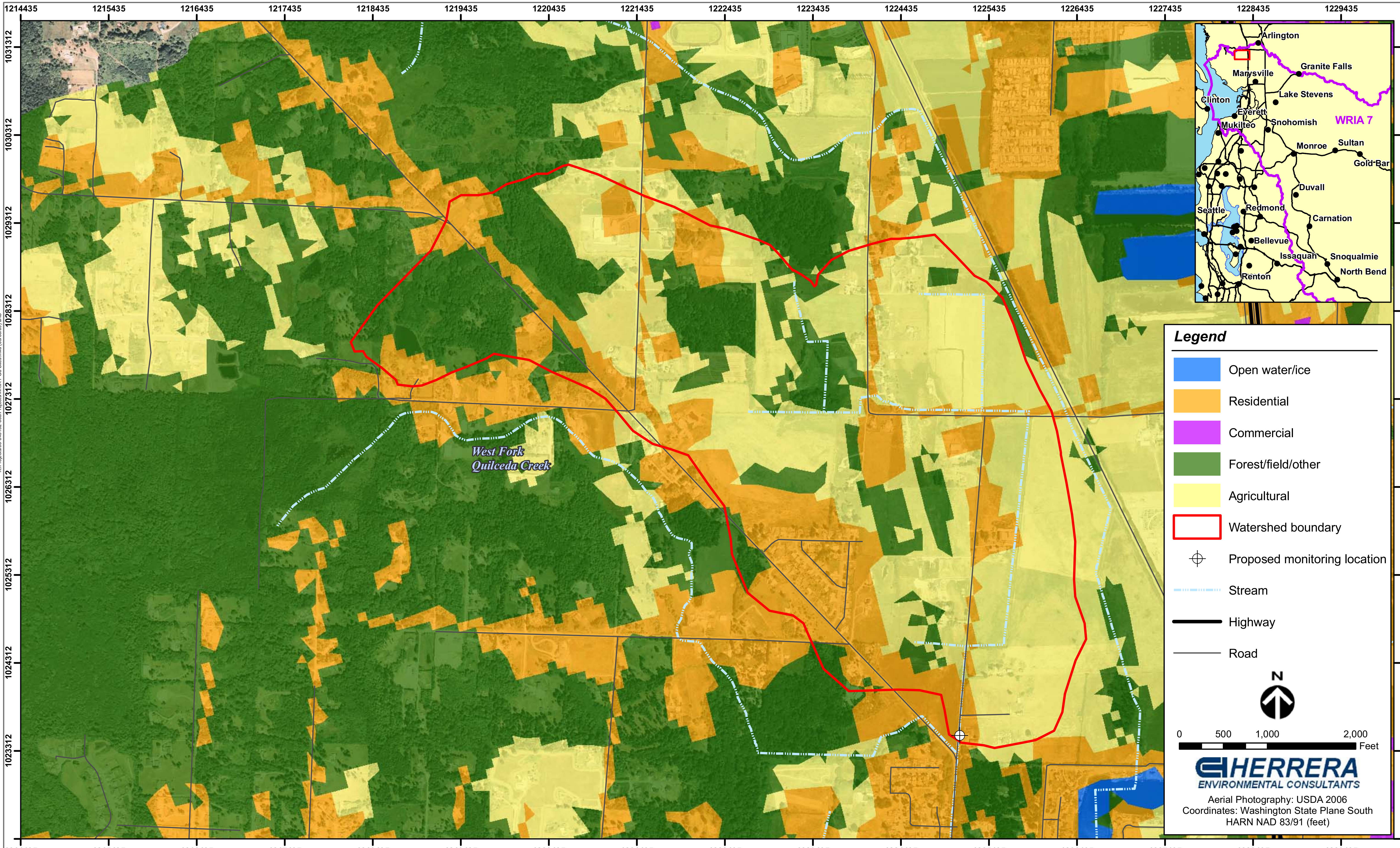


Figure E-20. Monitoring location AGG in the Snohomish River Watershed for characterizing toxic chemical in runoff from the agricultural land use category.

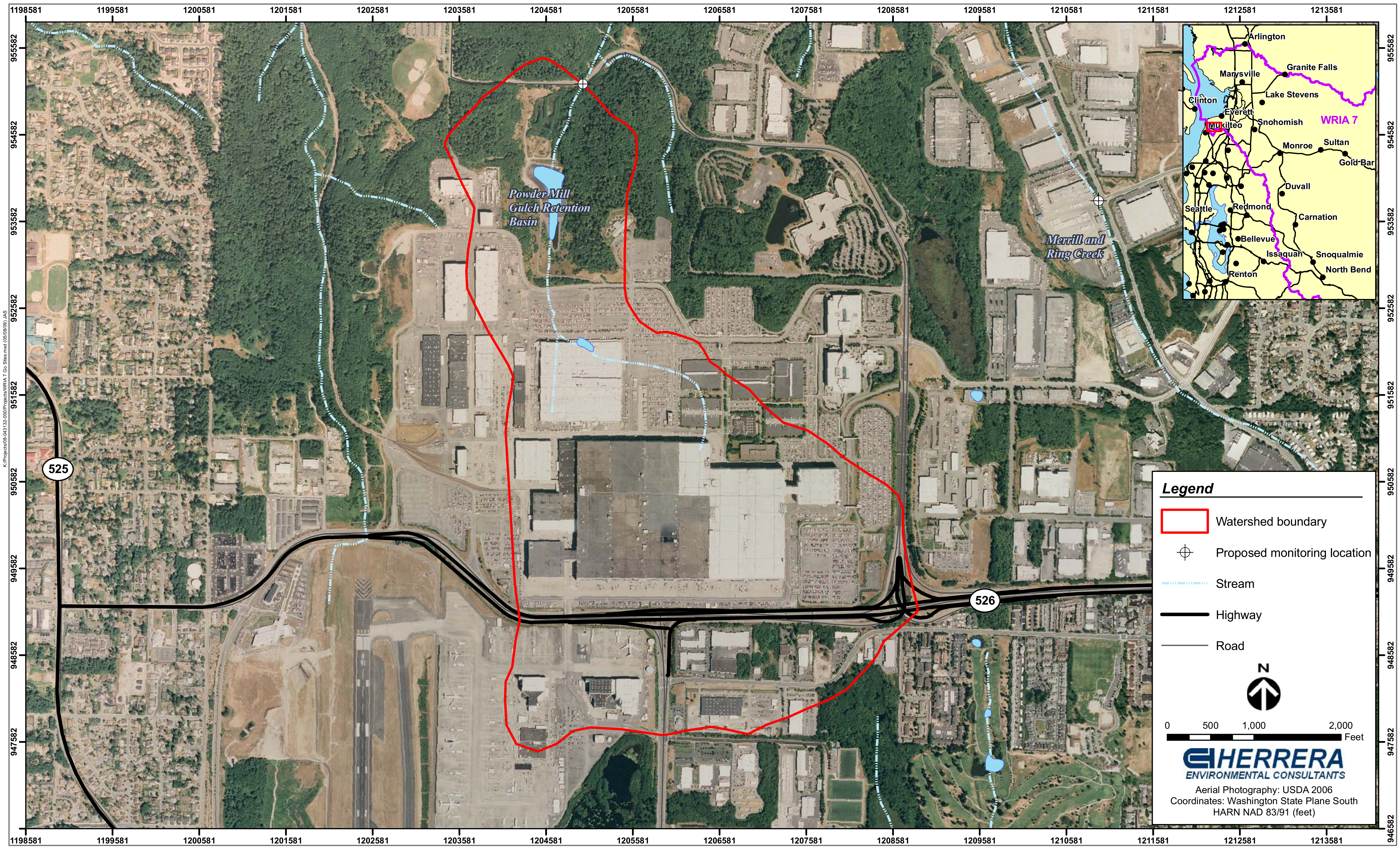


Figure E-21. Monitoring location CB335 in the Snohomish River Watershed for characterizing toxic chemical in runoff from the commercial land use category.

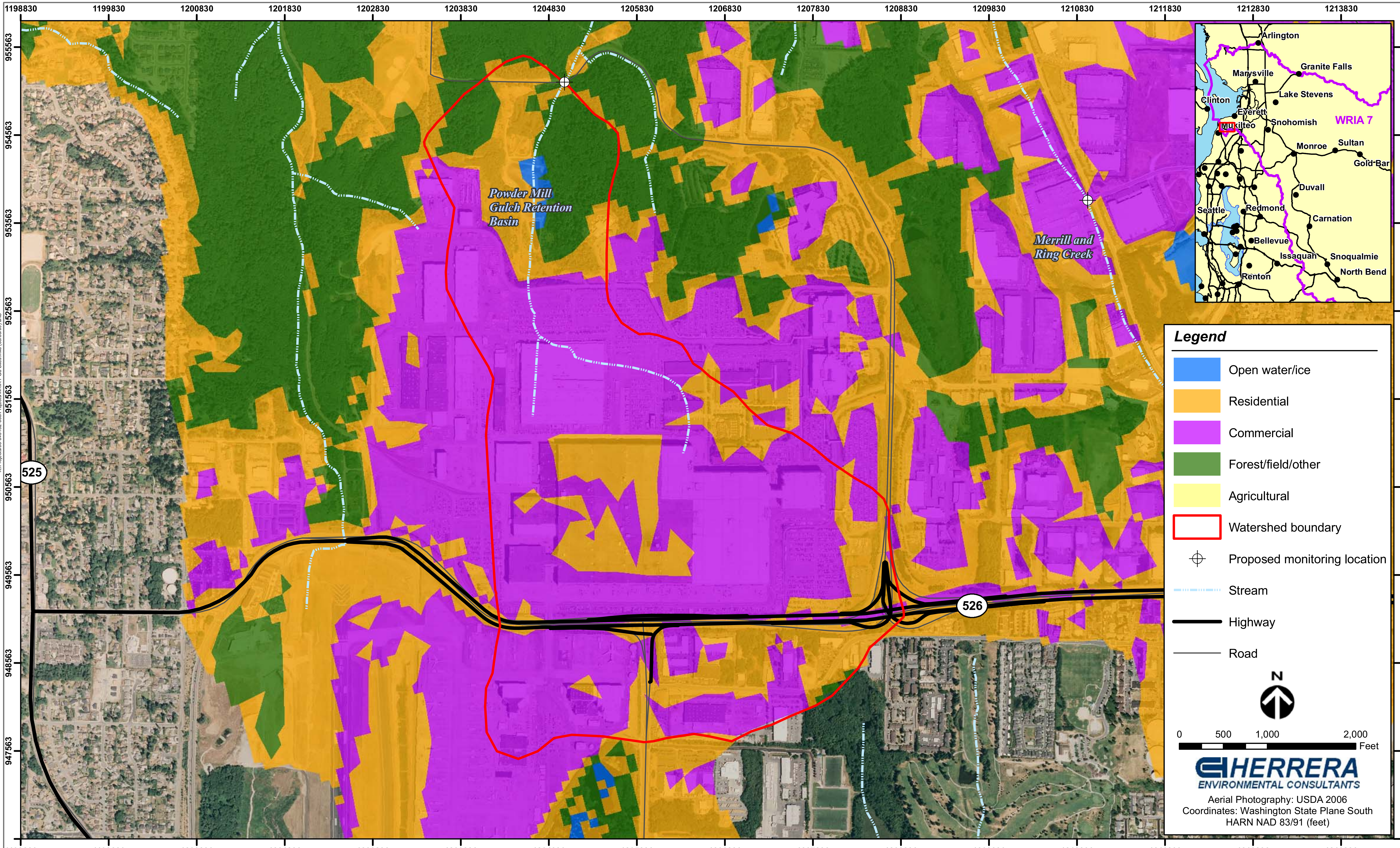


Figure E-22. Monitoring location CB335 in the Snohomish River Watershed for characterizing toxic chemical in runoff from the commercial land use category.

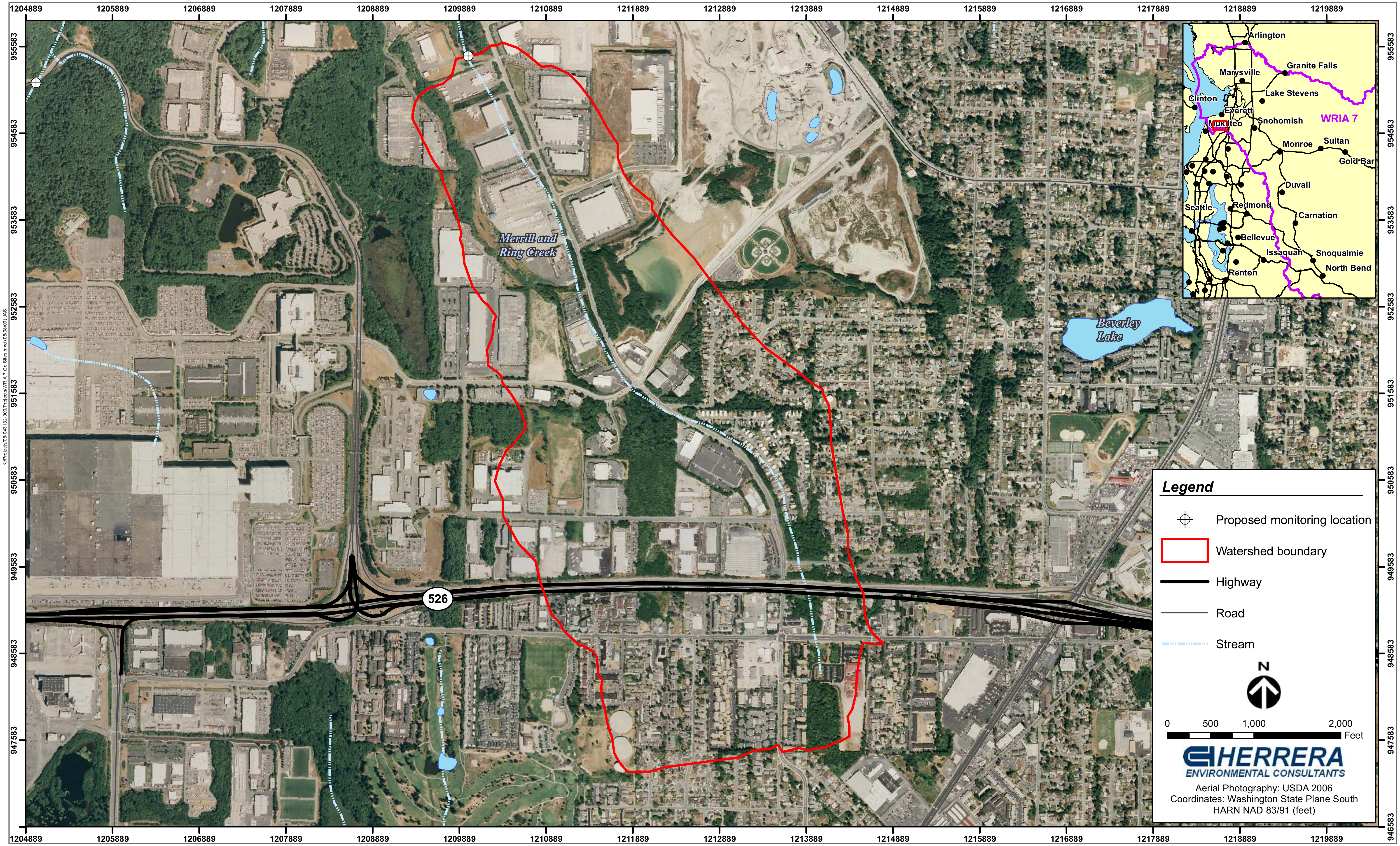


Figure E-23. Monitoring location CBX in the Snohomish River Watershed for characterizing toxic chemical in runoff from the commercial land use category.

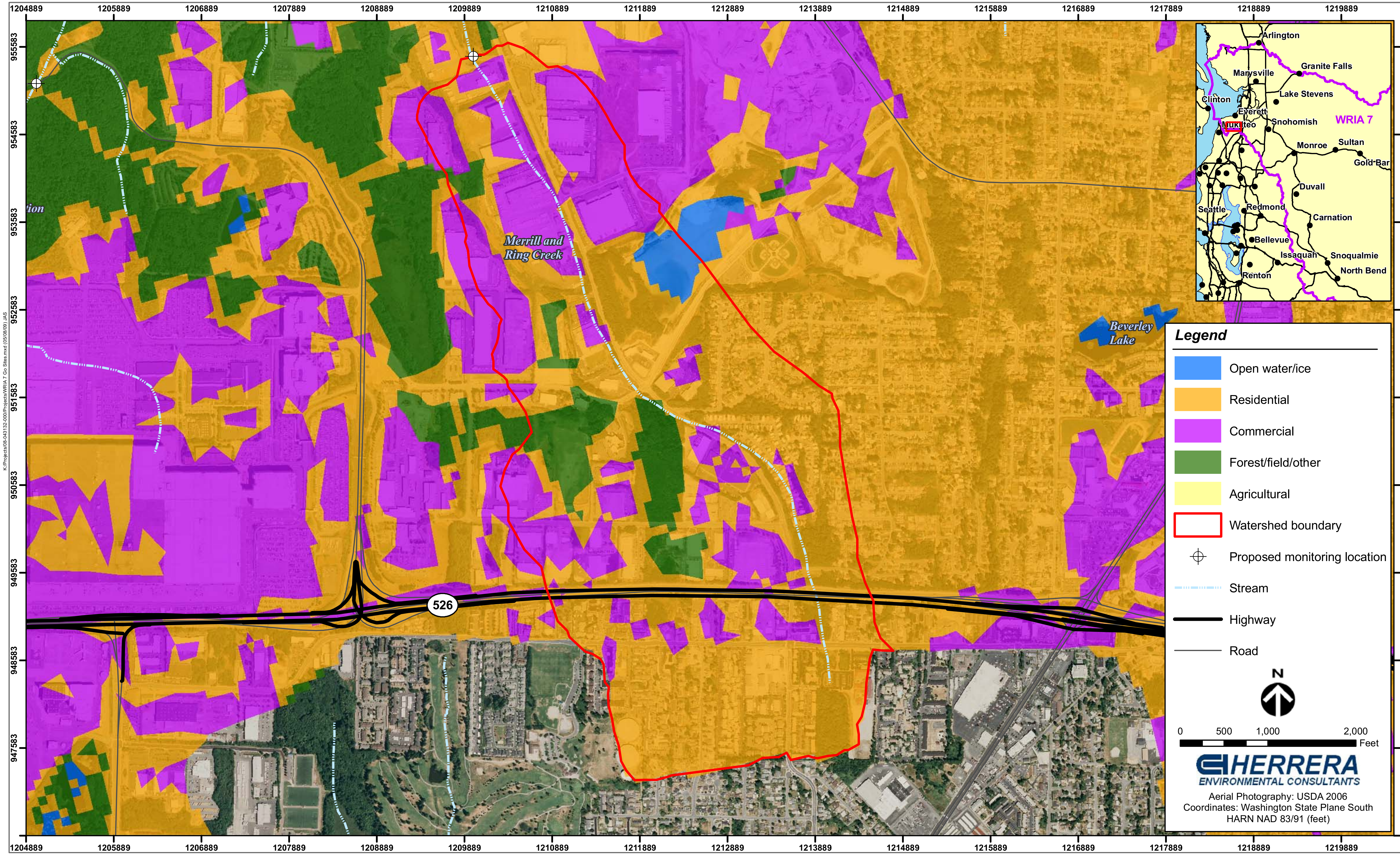


Figure E-24. Monitoring location CBX in the Snohomish River Watershed for characterizing toxic chemical in runoff from the commercial land use category.

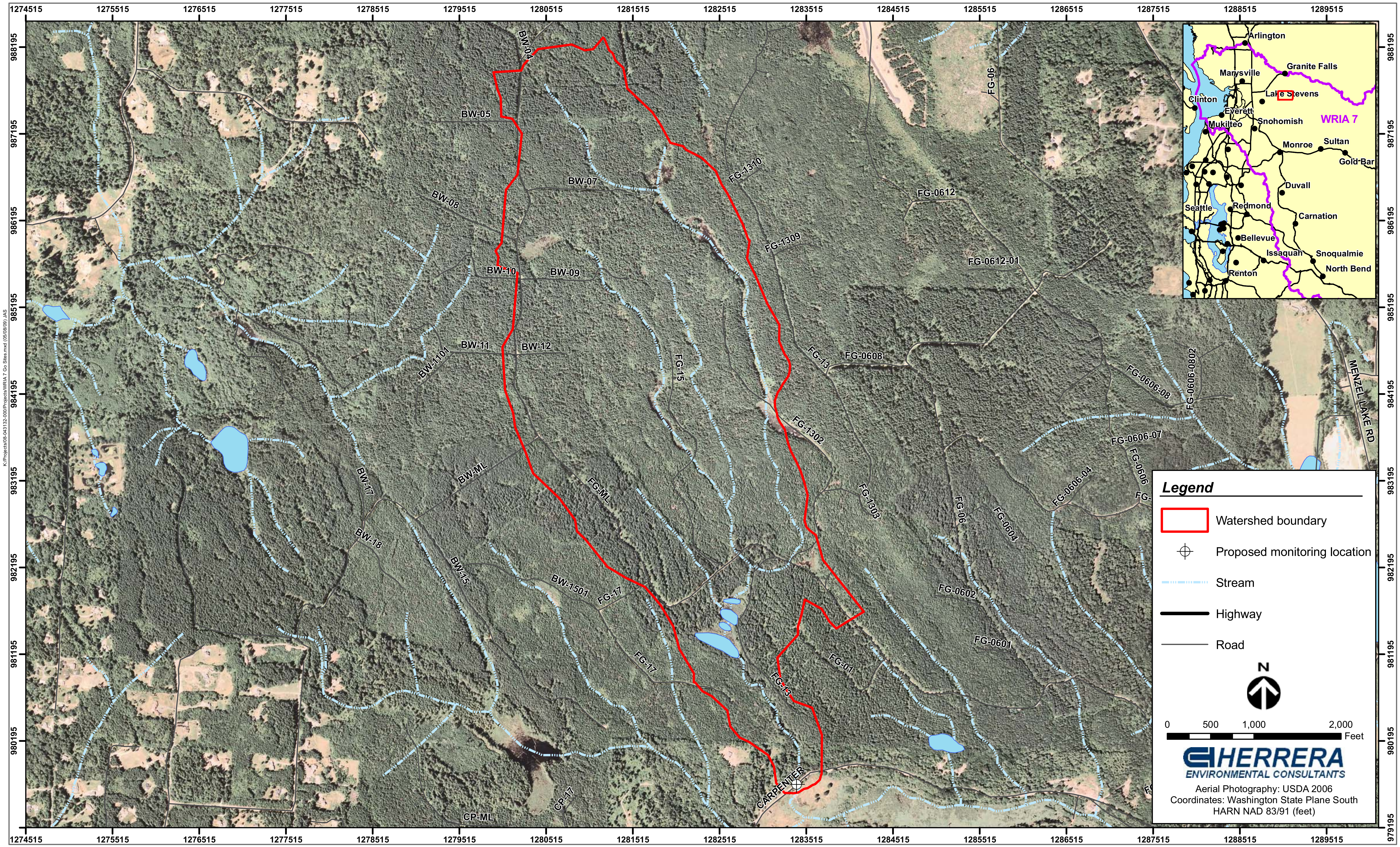


Figure E-25. Monitoring location FB200 in the Snohomish River Watershed for characterizing toxic chemical in runoff from the forest/field/other land use category.

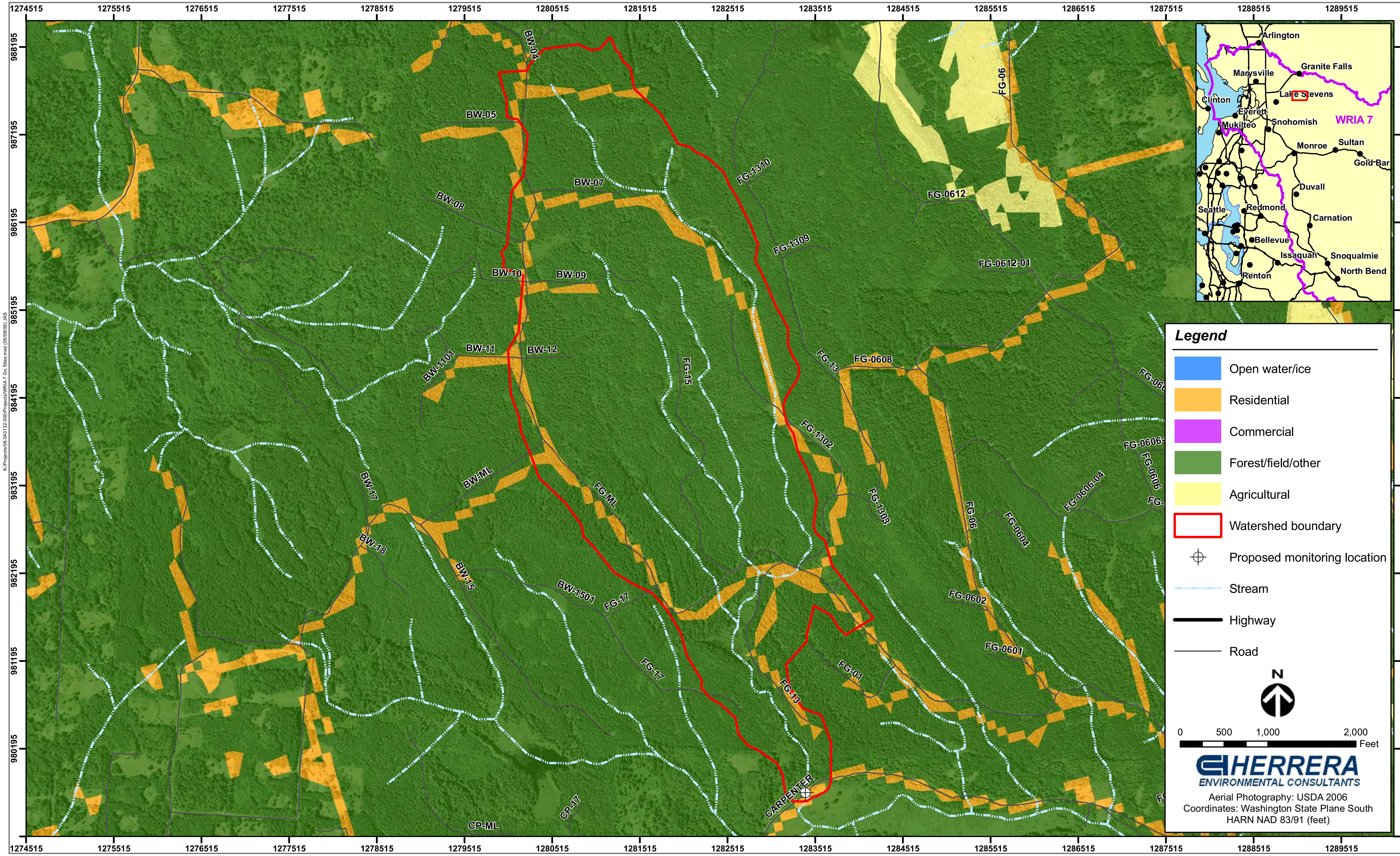


Figure E-26. Monitoring location FB200 in the Snohomish River Watershed for characterizing toxic chemical in runoff from the forest/field/other land use category.

Figure E-27. Monitoring location FB203 in the Snohomish River Watershed for characterizing toxic chemical in runoff from the forest/field/other land use category.

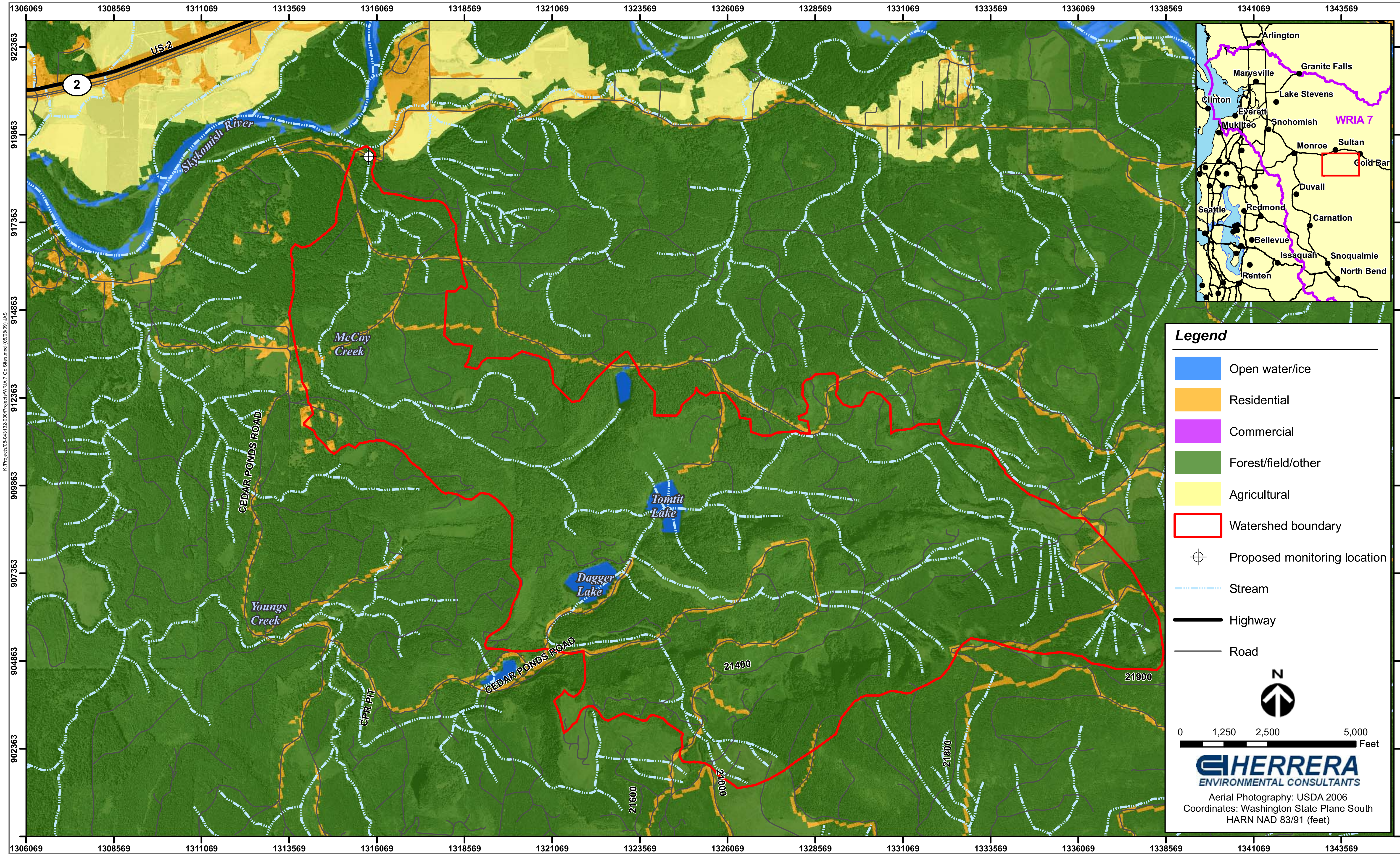


Figure E-28. Monitoring location FB203 in the Snohomish River Watershed for characterizing toxic chemical in runoff from the forest/field/other land use category.

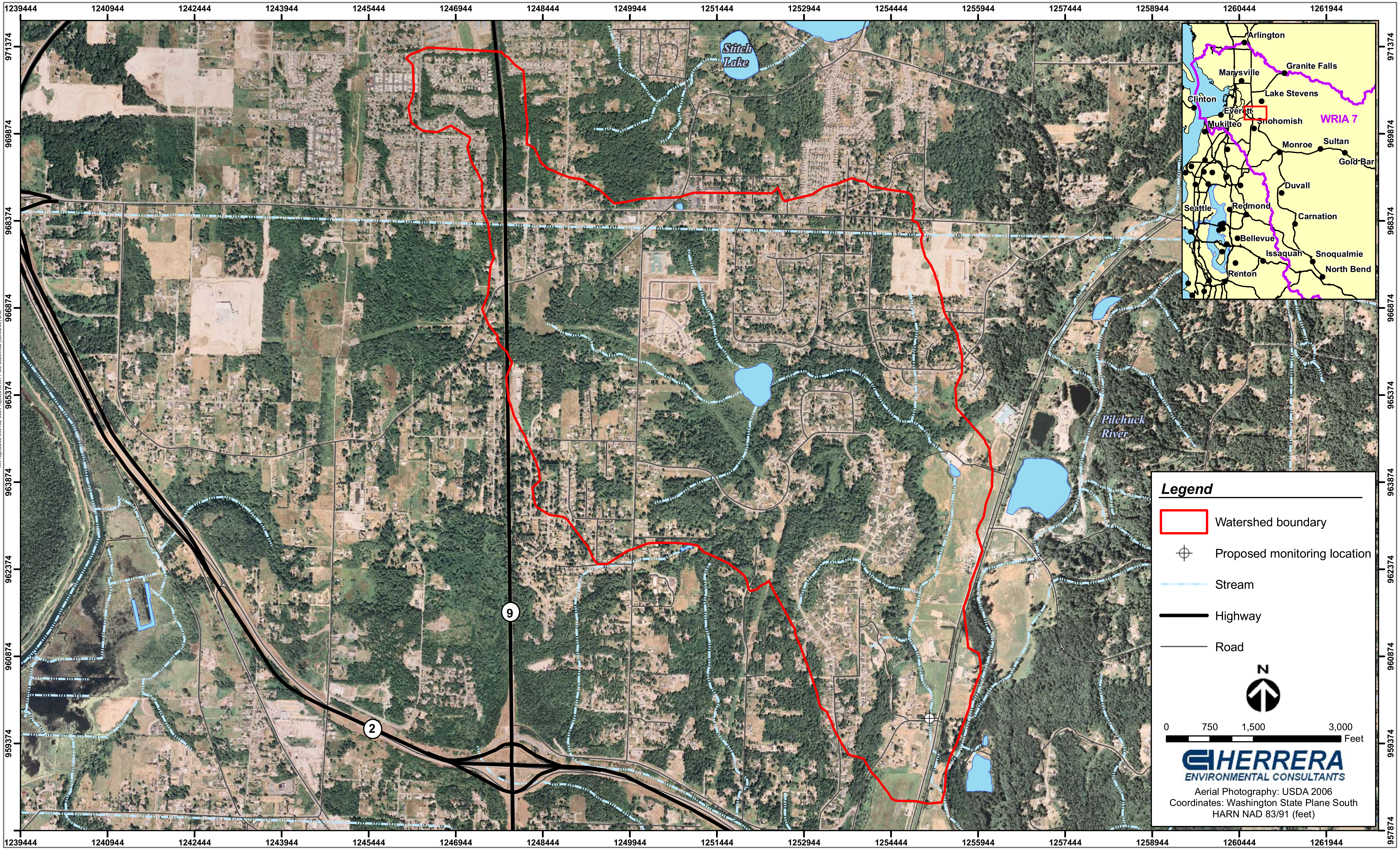


Figure E-29. Monitoring location RB111 in the Snohomish River Watershed for characterizing toxic chemical in runoff from the residential land use category.

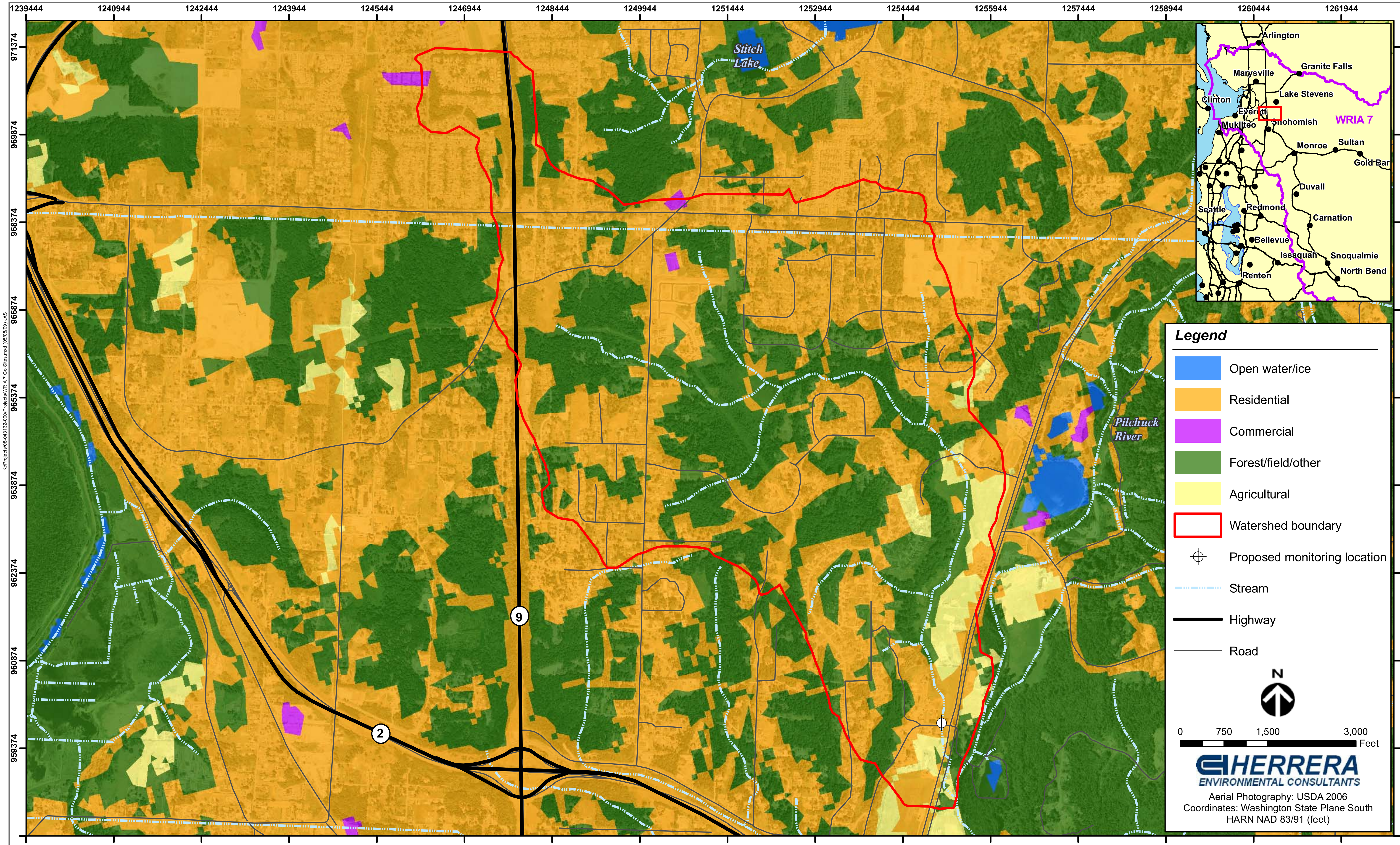


Figure E-30. Monitoring location RB111 in the Snohomish River Watershed for characterizing toxic chemical in runoff from the residential land use category.

Figure E-31. Monitoring location RB202 in the Snohomish River Watershed for characterizing toxic chemical in runoff from the residential land use category.

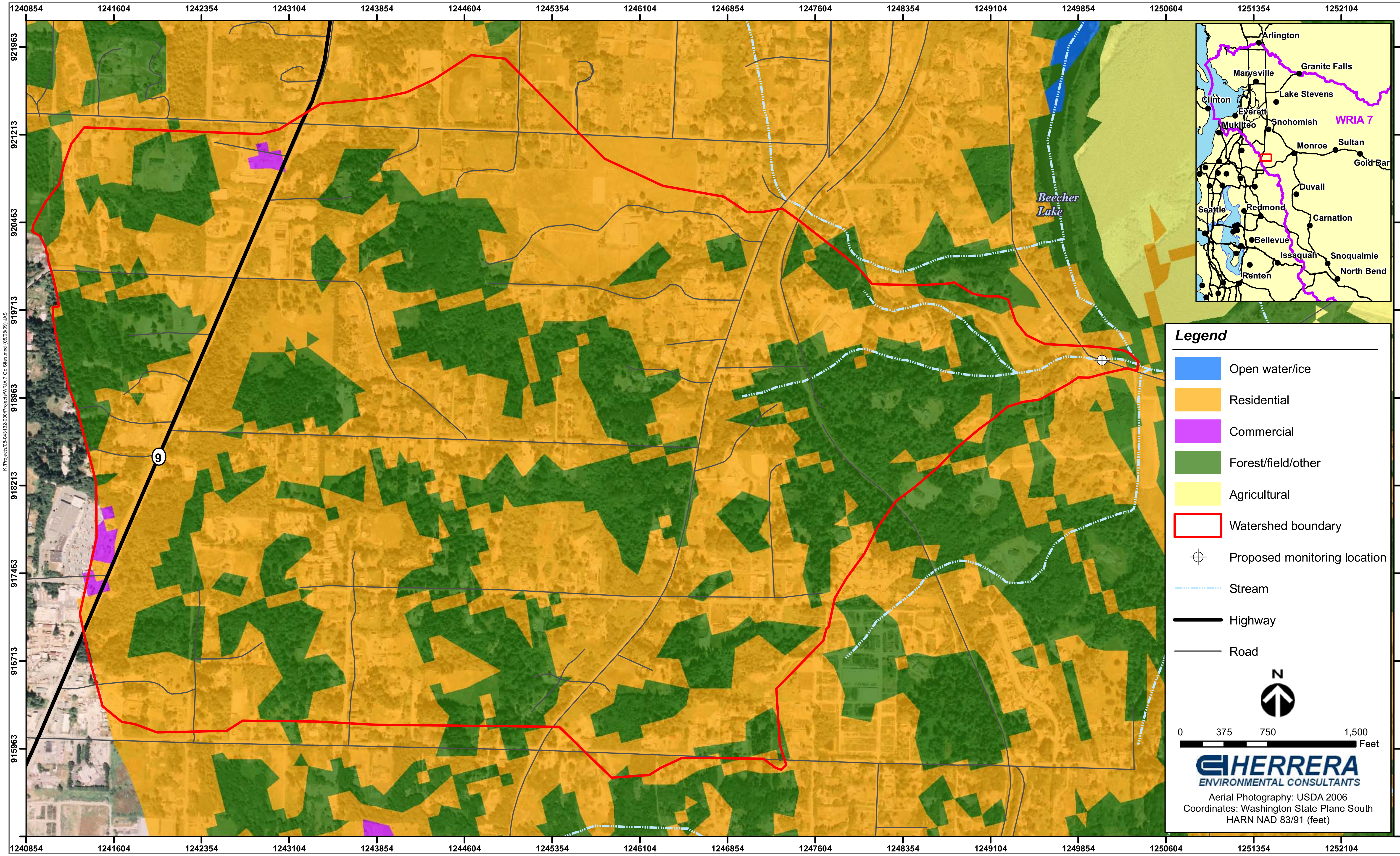


Figure E-32. Monitoring location RB202 in the Snohomish River Watershed for characterizing toxic chemical in runoff from the residential land use category.

APPENDIX F

Photographic Documentation for Monitoring Locations

Phase 3 Characterization of Toxic Chemical Loadings to Puget Sound via Surface Runoff
Photographic Log for Monitoring Locations

Photo Number	Photo Description
1	WRIA 7: Agricultural Basin 174 – Stream flowing from the culvert outlet downstream of Shorts School Road.
2	WRIA 7: Agricultural Basin G–- Stream flowing in the roadside ditch along 23rd Avenue NE.
3	WRIA 7: Commercial Basin 335 – Powder Mill Creek flowing from the culvert outlet downstream of Seaway Boulevard.
4	WRIA 7: Commercial Basin X – Box culvert conveying Merrill and Ring Creek beneath Federal Express driveway bridge.
5	WRIA 7: Forest Basin 200 – Stream flowing from the culvert outlet beneath North Carpenter Road.
6	WRIA 7: Forest Basin 203 – Stream flowing from the culvert outlet beneath Ben Howard Road.
7	WRIA 7: Residential Basin 111 – Stream flowing from the culvert outlet beneath Old Machias Road.
8	WRIA 7: Residential Basin 202 – Stream channel downstream of Connely Road.
9	WRIA 10: Agricultural Basin 62 – Stream flowing from the culvert outlet beneath 212th Avenue SE.
10	WRIA 10: Agricultural Basin 143 – Stream flowing downstream of SE 472nd Street.
11	WRIA 10: Commercial Basin A – Four culverts conveying the stream beneath Butte Avenue.
12	WRIA 10: Commercial Basin B – Hylebos Creek flowing in a ditch alongside South 344th Street.
13	WRIA 10: Forest Basin 130 – Stream flowing from the culvert outlet downstream of SR-410
14	WRIA 10: Forest Basin 372 – Coppler Creek flowing from the culvert outlet downstream of 190th Avenue E.
15	WRIA 10: Residential Basin 209 – Stream flowing from the box-culvert outlet downstream of Pioneer Way.
16	WRIA 10: Residential Basin 53 – Stream flowing from the culvert outlet downstream of Freeman Road.


1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APPENDIX G

Specifications for the Pressure Transducer and Data Logger to be Installed at Stream Gauging Stations

PT2X SUBMERSIBLE PRESSURE/TEMPERATURE SMART SENSOR

WITH DATALOGGING

Measure AND **Record**

Pressure AND **Temperature**

with this easy-to-use

yet powerful and accurate

AquiStar® PT2X Smart Sensor!

Great almost anywhere you need to measure level and temperature – whether it be in a lake, in a tank, or in a well.

FEATURES

SENSOR

- Pressure, temperature, time
- Absolute, gauge, or sealed gauge
- Thermally compensated – *great where water temperatures vary, such as in streams or in industrial tank applications*
- ± 0.06% FSO typical accuracy
- Low power – *2 internal AA batteries*
- External power options (12 VDC) with AA's acting as backup
- 316 SS, Viton®, Teflon® construction (titanium optional)
- Small diameter – 0.75"

DATALOGGER

- 130,000 record, 260,000 record, and 520,000 record versions
- Non-volatile memory – *data will not be lost in the event of a power failure*
- Flexible, multi-phase logging sequences – *save sequences to disk to reuse in the future*
- Pause logging feature – *temporarily pause the logging while repositioning or transporting sensor*
- Delayed start feature – *state a specific future start time, making it easy to set several sensors to start at the same time*

CABLING AND NETWORKING

- Wireless connectivity – radios *and/or cellular*
- RS485 network – *allows several sensors to be networked together and allows much longer cable leads than does RS232*
- Field serviceable connectors – *easily remove the connector, route cable through well seals, walls, or conduit, and then replace connector*
- Available cableless or with a variety of cable options – *polyethylene, polyurethane, or FEP Teflon®*

SOFTWARE - FREE, EASY-TO-USE

- Real time viewing
- Easy export to spreadsheets and databases
- Barometric compensation utility for use with absolute sensors
- Ability to update sensor via firmware while in the field – *great for future updates or custom development*

APPLICATIONS

- Pump and slug tests
- Stormwater runoff monitoring
- Well, tank, tidal levels
- River, stream, reservoir gauging
- Wetland monitoring
- Resource administration

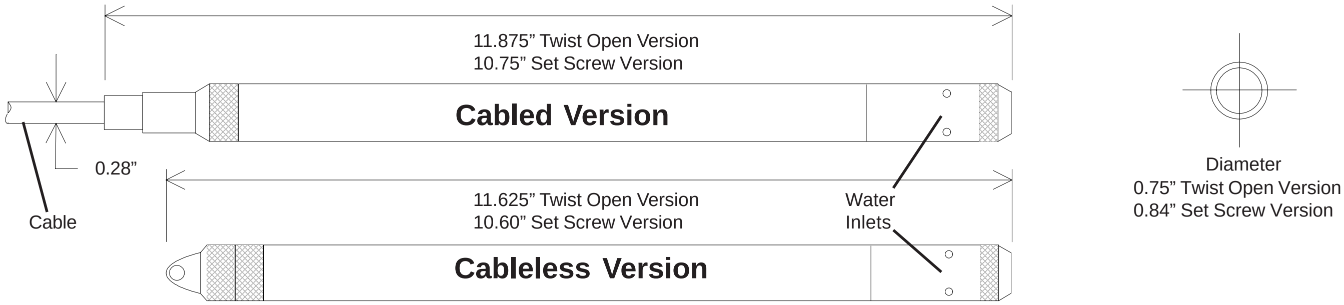
Instrumentation Northwest, Inc.

1-800-776-9355

http://www.inwusa.com

PT2X SUBMERSIBLE PRESSURE/TEMPERATURE SMART SENSOR

DIMENSIONS, SPECIFICATIONS, and ORDERING INFORMATION



MECHANICAL

TRANSMITTER

Body Material	316 stainless *Call for titanium availability*
Wire Seal Materials	Viton® and Teflon®
Desiccant	High- & Standard-capacity packs
Terminating Connector	Available
Weight	.80 lbs.

CABLE

OD	0.28" maximum
Break Strength	138 lbs
Maximum Length	2000 feet
Weight	4 lbs. per 100 feet

ELECTRICAL

PRESSURE

Static Accuracy *(B.F.S.L. 25° C)*	± 0.1% FSO (maximum) ± 0.06% FSO (typical) *± 0.06% available on request*
Maximum Zero Offset *at 25° C*	± 0.25% FSO
Resolution	16 bit
Over Range Protection	2x (except 300 PSI and higher)
Compensated Temp. Range	0° C to 40° C
Operating Temp. Range	-5° C to 70° C
Storage Temp. Range	-20° C to 100° C

Contact factory for extended temperature ranges.

---- Sensors ----

Ranges (call for others)	316 Stainless Steel – Cabled – Twist Open 0.75" diam. 0.1% FSO	316 Stainless Steel – Cabled – Set Screw 0.84" diam. 0.1% FSO	316 Stainless Steel – Cableless – Twist Open 0.75" diam. 0.1% FSO	316 Stainless Steel – Cableless – Set Screw 0.84" diam. 0.1% FSO	316 Stainless Steel – Cableless – Twist Open 0.75" diam. 0.25% FSO	316 Stainless Steel – Cableless – Set Screw 0.84" diam. 0.25% FSO	Titanium – Cabled – Twist Open 0.75" diam. 0.1% FSO	Titanium – Cableless – Twist Open 0.75" diam. 0.1% FSO
1 PSIG	--	3C348	--	--	--	--	--	--
2.5 PSIG	3C349T*	3C349	--	--	--	--	--	--
5 PSIG	3C351T*	3C351	--	--	--	--	3C351TTi**	--
15 PSIG	3C352T	3C352	--	--	--	--	3C352TTi	--
20 PSIA	3C363T	3C363	3C370T	3C370	3C377T	3C377	--	--
30 PSIG	3C353T	3C353	--	--	--	--	3C353TTi	--
30 PSIA	3C354T	3C354	3C371T	3C371	3C378T	3C378	3C354TTi	3C371TTi
50 PSIG	3C355T	3C355	--	--	--	--	--	--
50 PSIA	3C356T	3C356	3C372T	3C372	3C379T	3C379	--	--
100 PSIG	3C357T	3C357	--	--	--	--	--	--
100 PSIA	3C358T	3C358	3C373T	3C373	3C380T	3C380	--	--
300 PSIG	3C359T	3C359	--	--	--	--	--	--
300 PSIA	3C360T	3C360	3C374T	3C374	3C381T	3C381	--	--

* 0.16% ** 0.25%

---- Cable ----

6E540 9-conductor PU
6E542 9-conductor PE
6E543 9-conductor FEP
6E544 9-conductor Tefzel

---- Options and Accessories ----

- 6E410 1/4" NPT adapter
- 6E517 Cable strain relief kit
- 6E475 Desiccant tube refill
- 6E520 200' capacity reel
- 6E525 500' capacity reel
- 6E530 1500' capacity reel
- 3P902 4" well seal adapter
- 3P904 4" well seal adapter
- 3B830 RS485/RS232 adapter
- 3B385 Interface cable
- 6D150 Aqua4Palm Kit with Palm®
- 6D151 Aqua4Palm Kit w/o Palm®
- 3B847 Communication kit (RS485/RS232 adapter), Interface cable, Aqua4Plus Software Media Kit)

Information in this document is subject to change without notice.

Instrumentation Northwest, Inc.

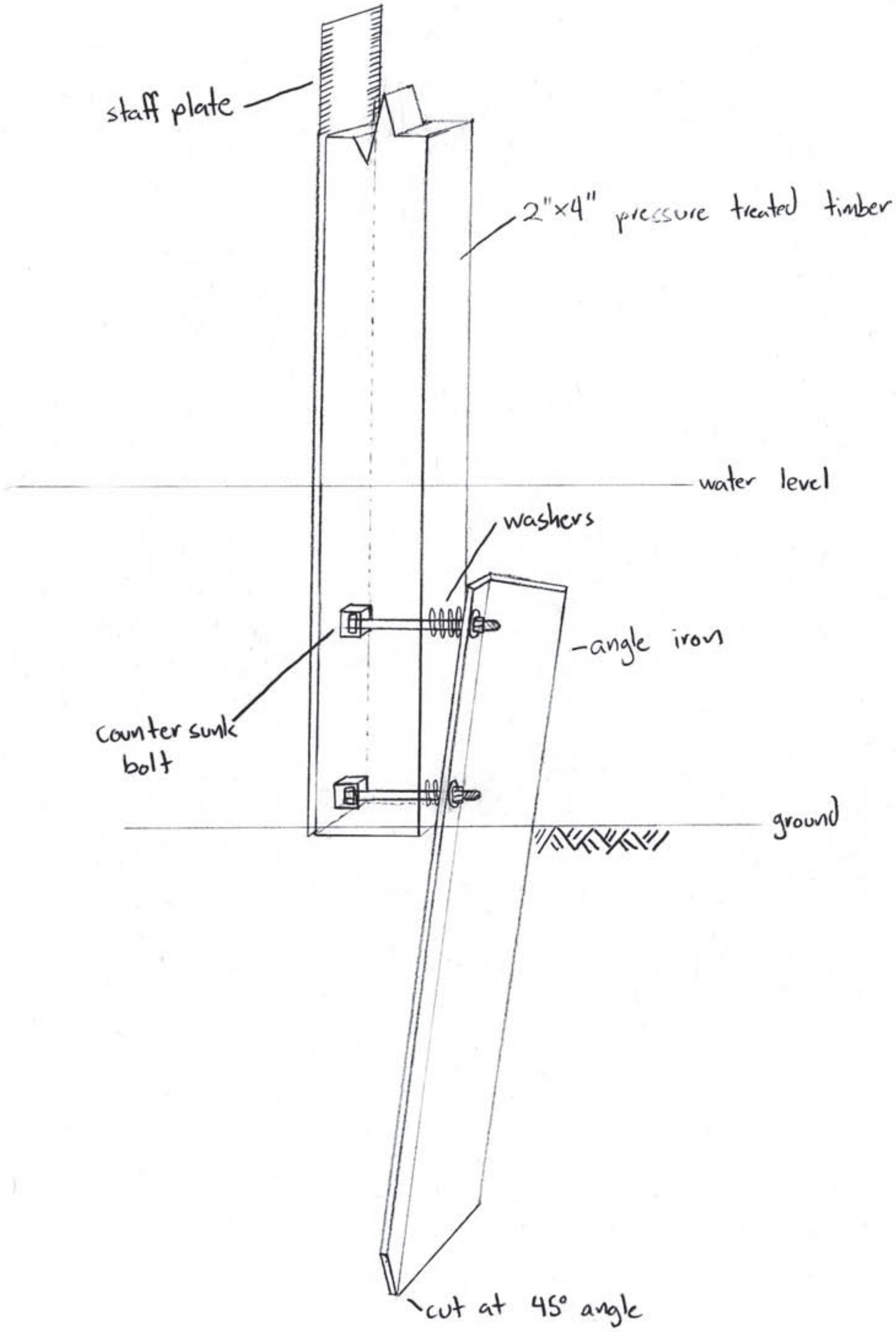
Sales and Service Locations
8902 122nd Avenue NE, Kirkland • Washington 98033 USA
(425) 822-4434 • (425) 822-8384 FAX • info@inwusa.com
4620 Northgate Boulevard, Suite 170 • Sacramento, California 95834
(916) 922-2900 • (916) 648-7766 FAX • inwsw@inwusa.com

1-800-776-9355
http://www.inwusa.com

Doc# 6D0015r16 03/09

APPENDIX H

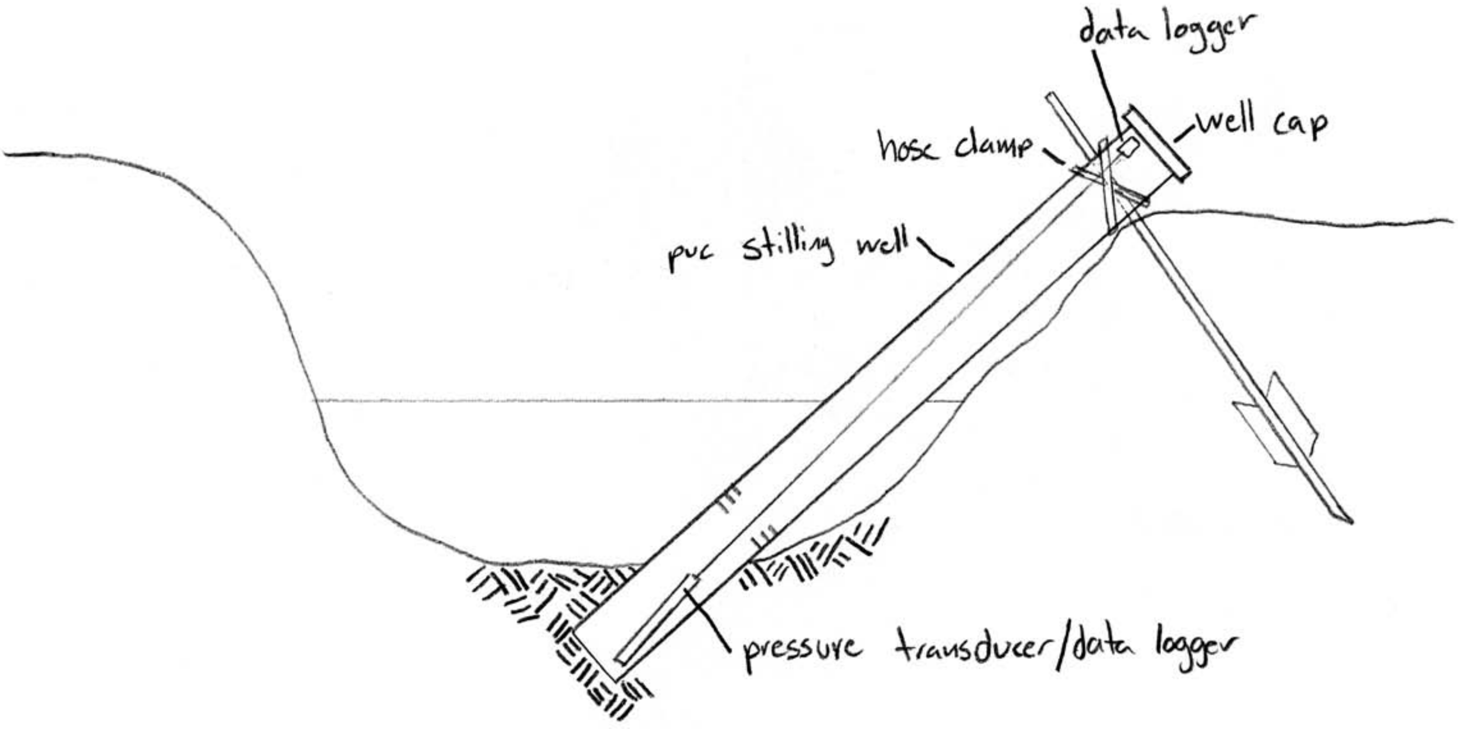
Typical Installation Configurations for Both the Staff Gauge and Stilling Well/Pressure Transducer Combination



Typical Staff Gauge Installation.

HERRERA
ENVIRONMENTAL CONSULTANTS

graphics-06-01-09/sm/HEC-R/06-03509-002



Typical Stream Gauging Station Installation: Option 1.

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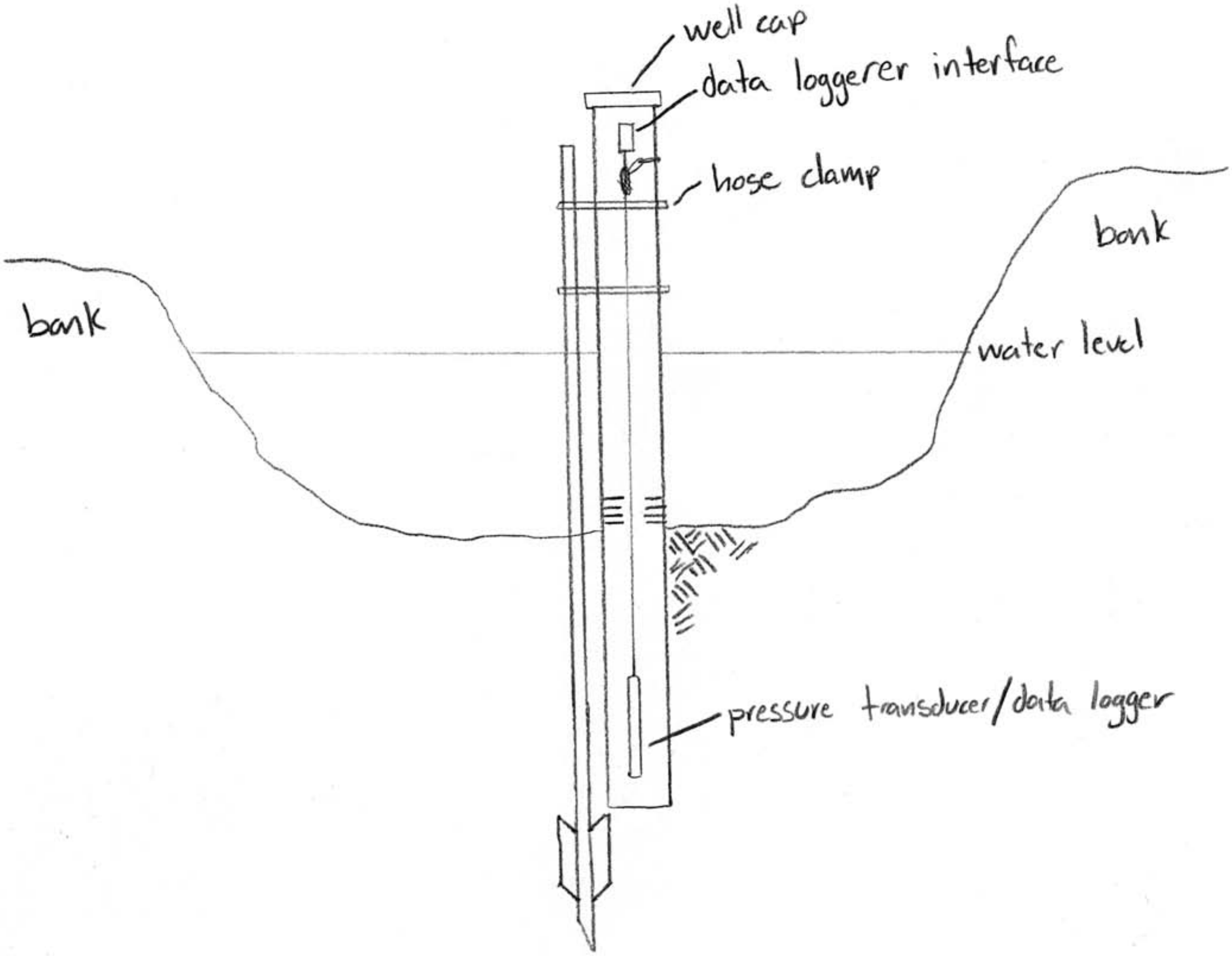
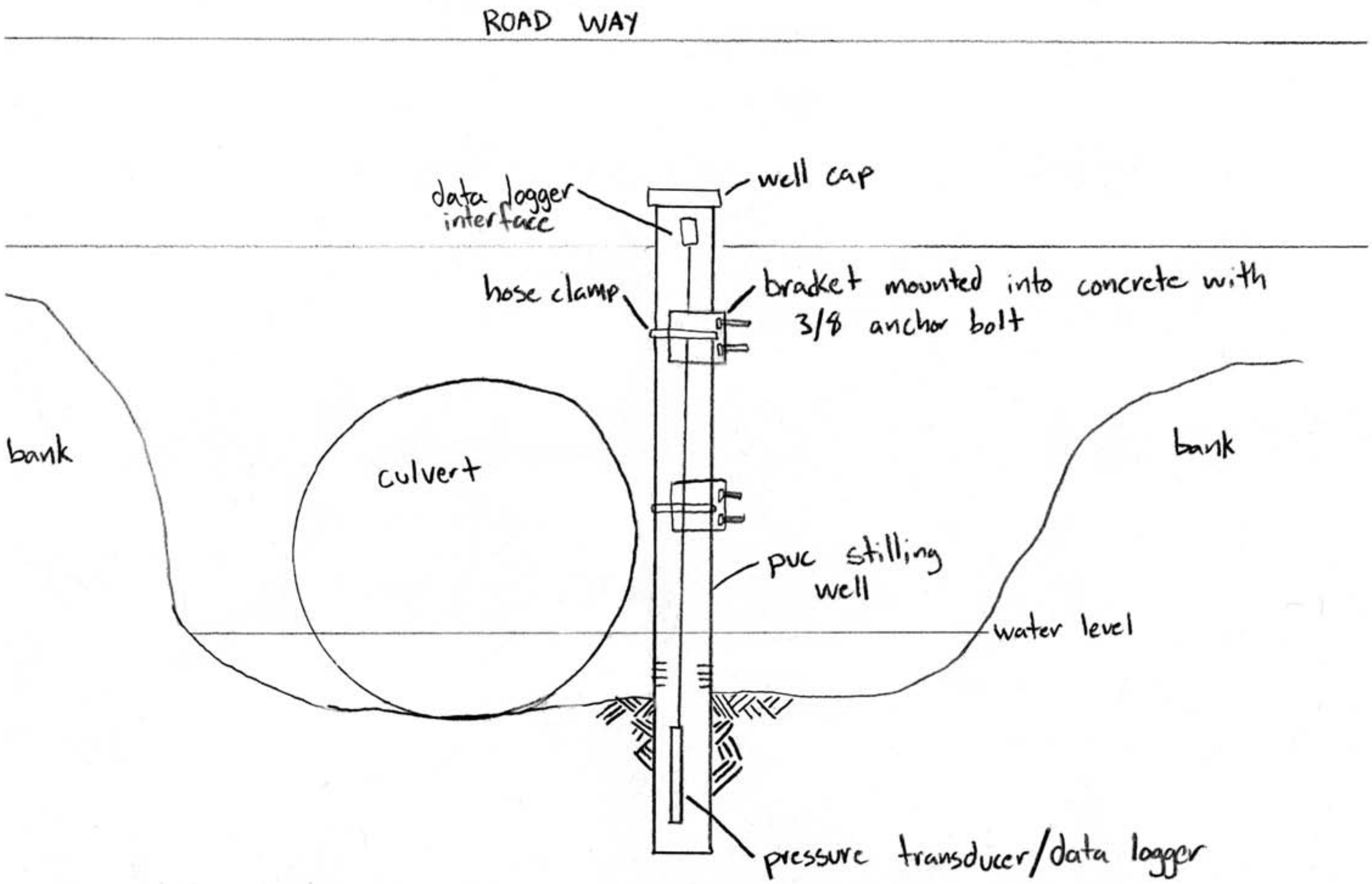
graphics-06-01-09/sm/HEC-R/06-03509-002



Typical Stream Gauging Station Installation: Option 2.

HERRERA
ENVIRONMENTAL CONSULTANTS

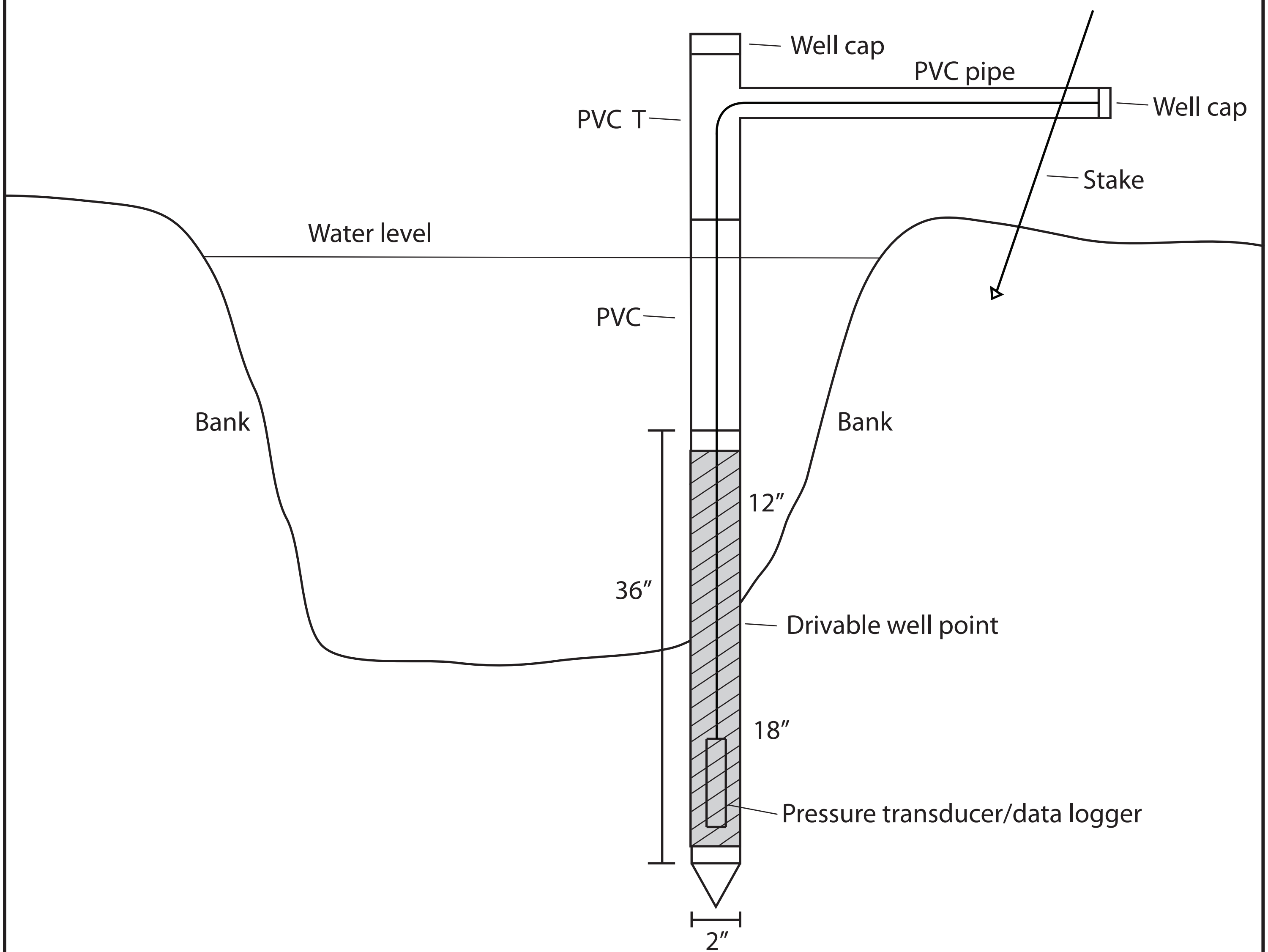
graphics-06-01-09/sm/HEC-R/06-03509-002



Typical Stream Gauging Station Installation: Option 3.

HERRERA ENVIRONMENTAL CONSULTANTS

graphics-06-01-09/sm/HEC-R/06-03509-002



Typical Stream Gauging Station Installation: Option 4.

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ENVIRONMENTAL CONSULTANTS

graphics-06-01-09/sm/HEC-R/06-03509-002

APPENDIX I

Standard Operating Procedure for Low-Level Metals Sampling

STANDARD OPERATING PROCEDURES

Low-Level Metals Water Sampling

SOP No. 2007

Herrera Environmental Consultants, Inc.
2200 Sixth Avenue, Suite 1100
Seattle, Washington 98121
Telephone: 206/441-9080

Rev. #1 2/5/02

June 5, 2009

Contents

1.0 Scope and Application

This standard operating procedure (SOP) is applicable to the collection of low-level metals water samples from streams, rivers, lakes, ponds, and wells. It includes samples collected from depth, as well as samples collected from the surface. These are standard (i.e., typically applicable) operating procedures which may be varied or changed as required, dependent upon site conditions, equipment limitations or limitations imposed by the procedure or other procedure limitations. In all instances, the ultimate procedures employed should be documented and associated with the final report.

The purpose of this SOP is to establish a uniform procedure for collecting low-level metal concentrations water samples. In developing these methods, one of the greatest difficulties in measuring low-level metals in water was precluding sample contamination during collection, transport, and analysis (USEPA 1996). The degree of difficulty, however, is highly dependent on the metal and site-specific conditions. This SOP, therefore, is designed to provide the level of protection necessary to preclude contamination in nearly all situations. It is also designed to provide the procedures necessary to produce reliable results at the lowest possible water quality criteria.

The ease of contaminating ambient water samples with the metal(s) of interest and interfering substances cannot be overemphasized. This SOP includes "clean" sampling techniques that should maximize the ability of the sampler(s) to collect water samples reliably and eliminate sample contamination, thus providing the highest quality data.

2.0 Method Summary

Sampling situations vary widely, therefore, no universal sampling procedure can be recommended. However, sampling water for low-levels metals analysis is generally accomplished through the use of the clean hands and dirty hands protocol, including:

- Clean hands and dirty hands protocol performed by one field technician
- Clean hands and dirty hands protocol performed by two field technicians.

These sampling techniques will allow for the collection of representative samples from the majority of surface waters and impoundments encountered.

3.0 Sample Preservation, Containers, Handling, and Storage

Once samples have been collected, the following procedure should be followed:

1. Use clean hand and dirty hand procedure for one or two technicians (see Procedures section)

2. Transfer the sample(s) into suitable sample containers.

3. Preserve the sample if appropriate

4. Do not overfill bottles if they are pre-preserved.

5. Cap the container, place in two Ziploc plastic bags and cool to 4°C.

6. Label inner Ziploc bag (which can be performed prior to sampling) with sample ID information.

7. Record all pertinent data in the site logbook and on field data sheets.

8. Complete the Chain of Custody record.

9. Attach custody seals to cooler prior to shipment.

10. Decontaminate all sampling equipment prior to the collection of additional samples.

4.0 Interferences and Potential Problems

There are numerous routes by which water samples may become contaminated with trace metals. Potential sources of trace metals contamination during sampling include metallic or metal-containing sampling equipment, containers, talc (powdered) gloves, and improperly cleaned and stored equipment, labware, and reagents. Atmospheric inputs pose another potential source of contamination, including dirt and dust from automobile exhaust, cigarette smoke, nearby roads, bridges, wires, and poles. Even human contact can be a source of trace metals contamination. For example, it has been demonstrated that dental work (e.g., mercury amalgam fillings) in the mouths of laboratory personnel can contaminate samples that are directly exposed to exhalation (USEPA 1996).

Contamination by carryover is another source of potential trace metal contamination. Contamination may occur when a sample containing low concentrations of metals is processed immediately after a sample containing relatively high concentrations of these metals. At sites where more than one sample will be collected, the sample known or expected to contain the lowest concentration of metals should be collected first with the sample containing the highest levels collected last. This will help minimize carryover of metals from high concentration samples to low concentration samples. If the sampling team does not have prior knowledge of the waterbody, or when necessary, the sample collection system should be rinsed with dilute acid and reagent water or be replaced with a new clean sample collection system between samples and followed by collection of a field blank.

5.0 Equipment/Apparatus

Equipment needed for collection of low-level metals water samples may include:

- Sample bottles/preservatives
- Ziploc bags
- Powder-free gloves
- Field portable glove bag
- Ice
- Coolers
- Filters
- Chain of Custody records, custody seals
- Field data sheets
- Decontamination equipment
- Maps/plot plan
- Safety equipment
- Peristaltic pump
- Peristaltic batteries (i.e., 12 volt batteries)
- Precleaned fluoropolymer or styrene/ethylene/butylene/ silicone (SEBS) tubing
- Tyvek® coveralls
- Depth sounder
- Compass
- Tape measure
- Survey stakes, flags, or buoys and anchors
- Camera
- Logbook/waterproof pen
- Sample bottle labels.

6.0 Reagents

Reagents will be utilized for preservation of samples and for decontamination of sampling equipment. The preservatives required are specified in the sampling plan for each analysis to be performed.

7.0 Procedures

7.1 Preparation

1. Determine the extent of the sampling effort, the sampling methods to be employed, and the types and amounts of equipment and supplies needed.

2. Obtain the necessary sampling and monitoring equipment.

3. Clean all sampling equipment and sample containers in a laboratory or cleaning facility using detergent, mineral acids, and reagent water.

4. All sampling equipment and sample containers should be nonmetallic or free from any material that may contain metals.

5. Determine the appropriate number and type of blanks (i.e., field blanks, filter blanks, equipment blanks, etc.)

6. Prepare scheduling and coordinate with staff, clients, and regulatory agency, if appropriate.

7. Perform a general site survey prior to site entry, in accordance with the site specific Health and Safety Plan.

8. Stakes, flagging, or buoys may be used to mark sampling locations. Care should be taken not to disturb sediment at the sample location. If required, the proposed locations may be adjusted based on site access, property boundaries, and surface obstructions.

7.2 Sample Collection

7.2.1 Clean Hands and Dirty Hands Protocol Performed by One Field Technician

Prior to sample collection, the field technician will put on a new set of gloves (i.e., clean powder-free gloves made of polyethylene, latex, or vinyl) for each sequence of clean and dirty hands operations that is required for proper implementation of the protocol. The sequence of clean and dirty hands operations that will be used by one technician during sampling is described in detail as follows:

1. Dirty hands (two sets of new gloves):

    a. Open the cooler with sample bottles.
    b. Remove double-bagged sample bottle from cooler.
    c. Unseal outer bag.

2. Clean hands (remove outer set of gloves):

    a. Unseal inner bag containing the sample bottle.
    b. Remove bottle and unscrew cap.
    c. Rinse inside of bottle three times with water to be sampled (if sample contains no preservative).
    d. Fill sample bottle, keeping sample bottle upwind and away from technician exhalation pathway (do not breathe near sample bottle).
    e. Return sample bottle to inner bag.
    f. Reseal inner bag.
    g. Reseal outer bag.
    h. Return double-bagged sample to cooler.

7.2.2 Clean Hands and Dirty Hands Protocol Performed by Two Field Technicians

Prior to sample collection, both field technicians will put on a two sets of new gloves (i.e., clean powder-free gloves made of polyethylene, latex, or vinyl) for each sequence of clean and dirty hands operations that is required for proper implementation of the protocol. The sequence of clean and dirty hands operations that will be used by two technicians during sampling is described in detail as follows:

1. Dirty hands technician (remove outer set of gloves):

    a. Open the cooler with sample bottles.
    b. Remove double-bagged sample bottle from cooler.
    c. Unseal outer bag.

2. Clean hands technician (remove outer set of gloves):

    a. Unseal inner bag containing the sample bottle.
    b. Remove bottle and unscrew cap.
    c. Rinse bottle three times in water to be sampled (if sample contains no preservative).
    d. Fill sample bottle, keeping sample bottle upwind and away from technician exhalation pathway (do not breathe near sample bottle).
    e. Return sample bottle to inner bag.
    f. Reseal inner bag.
    g. Reseal outer bag (either technician).
    h. Return double-bagged sample to cooler (either technician).

8.0 Calculations

This section is not applicable to this SOP.

9.0 Quality Assurance/Quality Control

There are no specific quality assurance (QA) activities which apply to the implementation of these procedures. However, the following general quality control (QC) procedures apply:

1. All field conditions must be documented on field data sheets or within site logbooks.

2. All instrumentation must be operated in accordance with operating instructions as supplied by the manufacturer, unless otherwise specified in the work plan. Equipment checkout and calibration activities must occur prior to sampling or operation and they must be documented.

3. The appropriate number and type of blanks need to be included in the sampling plan to confirm that the low-levels metals water sampling procedures were adequate.

10.0 Data Validation

This section is not applicable to this SOP.

11.0 Health and Safety

When working with potentially hazardous materials, follow U.S. EPA, OSHA and corporate health and safety procedures.

The sampling team member collecting the sample should not get too close to the edge of the impoundment where bank failure may cause him/her to lose his/her balance. The person performing the sampling should be on a lifeline and wear adequate protective equipment. When conducting sampling from a boat in an impoundment or flowing waters, appropriate boating safety procedures should be followed.

12.0 References

USEPA. 1996. Method 1669: Sampling ambient water for trace metals at EPA water quality criteria levels. U.S. Environmental Protection Agency, Office of Science and Technology, Washington, D.C. (EPA-821/R-96-008).

APPENDIX J

Example Field Forms

FIELD SAMPLING AND FLOW MONITORING LOG SHEET

Field Personnel:

Baseflow Sample Date: **Time:**

SITE ID:

EVENT ID:

Project Number: 06-03509-002

Project Name: Ecology Surface Loading

Current Weather:

Flow Conditions:

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Water Quality Sampling

Sample ID:

Parameter	Bottle Type	Bottle Volume	# Bottles	Included in Rounds?	Preservation?
Org - nutr - Sed	stainless	12 L	1	NA	
Gasoline	Glass	120 mL	1	NA	
Dsl. Lube Oil	Amb Glass	1 L	1	NA	
Oil & Grease	Amb Glass	1 L	1	NA	
Oil & Gr l.d.	Amb Glass	1 L	4	NA	
tot metals	teflon	2 L	1	NA	
diss metals	teflon	2 L	1	NA	field filter

Visual Conditions:

Odor:

SAMPLE DELIVERY

Date: **Time:**

Sample Temperature (°C):

COC signed? YES NO

FIELD MEASURMENTS

	Value	Units	Meter Calibration OK?
pH:		pH scale	
Dissolved Oxygen:		% sat.	
Temperature:		°C	
Specific Conductivity:		µS/cm	

Quality Assurance

Checked By: **Signature:**

Date Checked: **Time:**

Data Entered into Database? YES NO **initials:**

Date Entered: **Time:**

Notes:

Flow Measurement

METER & CALIBRATION

Meter Make:	Marsh McBirney
Meter Model:	Flowmate 2000 **S/N:** 2006081
SWFR Propeller ID:	N/A
SWFR Blow Count:	N/A
MMB Zero Reading (cfs):	
HEC Cal. Date:	**Time:**
Factory Cal. Date:	12/15/2006

MEASUREMENT INFORMATION

Start Date:	**Time:**
Stop Date:	**Time:**
Staff Gauge- Start (ft):	
Staff Gauge- Stop (ft):	
Continuous Gauge?	YES NO **ID:**
Stream Width (ft):	
Method:	Mid-Section Velocity Method

	Distance from right bank (ft)	Depth (ft)	Velocity (ft/s) 2/10	6/10	8/10
RB					
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					

Cross section sketch (not to scale)

Calculated Stream Discharge (cfs):

Notes (equipment problems, blockages, unusual stream conditions, etc.):

Instrument Calibration History

Type of Instrument:______________________________ **S/N:**______________________________

Instrument Make/Model:__________________________ **Manufacture year:**________________

HERRERA ENVIRONMENTAL CONSULTANTS

Date	Time	Field Tech Name	Calibration Type	Calibration Temperature	Reading Before Adjustment	Standard Value	Reading After Adjustment	Units	Notes

FIELD SAMPLING AND FLOW MONITORING LOG SHEET

Field Personnel:

Round 1 **Sample Date:** **Time:**

SITE ID:

EVENT ID:

Project Number: 06-03509-002

Project Name: Ecology Surface Loading

Current Weather:

Flow Conditions:

HERRERA ENVIRONMENTAL CONSULTANTS

Water Quality Sampling

Sample ID:

Parameter	Bottle Type	Bottle Volume	# Bottles	Included in Rounds?	Preservation?
Organ. - nutr - TSS	stainless	12 L	1/rnd	yes	
Gasoline	Glass	120 mL	1	no	
Dsl. Lube Oil	Amb Glass	1 L	1	no	
Oil & Grease	Amb Glass	1 L	1	no	
Oil & Gr l.d.	Amb Glass	1 L	4	no	
tot metals, hard.	teflon	2 L	1/rnd	yes	
diss metals, DOC, PO4	teflon	2 L	1/rnd	yes	field filter

Visual Conditions:

Odor:

SAMPLE DELIVERY

Date: **Time:**

Sample Temperature (°C):

COC signed? YES NO

FIELD MEASURMENTS

	Value	Units	Meter Calibration OK?
pH:		pH scale	
Dissolved Oxygen:		% sat.	
Temperature:		°C	
Specific Conductivity:		µS/cm	

Quality Assurance

Checked By: **Signature:**

Date Checked: **Time:**

Data Entered into Database? YES NO **initials:**

Date Entered: **Time:**

Notes:

Flow Measurement

METER & CALIBRATION

Meter Make:	Marsh McBirney
Meter Model:	Flowmate 2000 **S/N:** 2006081
SWFR Propeller ID:	N/A
SWFR Blow Count:	N/A
MMB Zero Reading (cfs):	
HEC Cal. Date:	**Time:**
Factory Cal. Date:	12/15/2006

MEASUREMENT INFORMATION

Start Date:	**Time:**
Stop Date:	**Time:**
Staff Gauge- Start (ft):	
Staff Gauge- Stop (ft):	
Continuous Gauge?	YES NO **ID:**
Stream Width (ft):	
Method:	Mid-Section Velocity Method

	Distance from right bank (ft)	Depth (ft)	Velocity (ft/s) 2/10	6/10	8/10
RB					
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					

Cross section sketch (not to scale)

Calculated Stream Discharge (cfs):

Notes (equipment problems, blockages, unusual stream conditions, etc.):

FIELD SAMPLING AND FLOW MONITORING LOG SHEET

Field Personnel:
Round 2 Sample Date: **Time:**

SITE ID:

EVENT ID:

Project Number: 06-03509-002
Project Name: Ecology Surface Loading

Current Weather:
Flow Conditions:

HERRERA ENVIRONMENTAL CONSULTANTS

Water Quality Sampling

Sample ID:

Parameter	Bottle Type	Bottle Volume	# Bottles	Included in Rounds?	Preservation?
Organ. - nutr - TSS	stainless	12 L	1/rnd	yes	
tot metals, hard.	teflon	2 L	1/rnd	yes	
diss metals, DOC, PO4	teflon	2 L	1/rnd	yes	field filter

Visual Conditions:

Odor:

SAMPLE DELIVERY

Date: **Time:**
Sample Temperature (°C):
COC signed? YES NO

FIELD MEASURMENTS

	Value	Units	Meter Calibration OK?
pH:		pH scale	
Dissolved Oxygen:		% sat.	
Temperature:		°C	
Specific Conductivity:		µS/cm	

Quality Assurance

Checked By: **Signature:**
Date Checked: **Time:**
Data Entered into Database? YES NO **initials:**
Date Entered: **Time:**
Notes:

Flow Measurement

METER & CALIBRATION

Meter Make:	Marsh McBirney
Meter Model:	Flowmate 2000 **S/N:** 2006081
SWFR Propeller ID:	N/A
SWFR Blow Count:	N/A
MMB Zero Reading (cfs):	
HEC Cal. Date:	**Time:**
Factory Cal. Date:	12/15/2006

MEASUREMENT INFORMATION

Start Date:	**Time:**
Stop Date:	**Time:**
Staff Gauge- Start (ft):	
Staff Gauge- Stop (ft):	
Continuous Gauge? YES NO	**ID:**
Stream Width (ft):	
Method:	Mid-Section Velocity Method

	Distance from right bank (ft)	Depth (ft)	Velocity (ft/s) 2/10	6/10	8/10
RB					
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					

Calculated Stream Discharge (cfs):

Notes (equipment problems, blockages, unusual stream conditions, etc.):

APPENDIX K

Standard Operating Procedure for YSI 556 Multi-Parameter Meter

Standard Operating Procedures

YSI 556 Handheld Multi Probe System

Capabilities

1. Measures dissolved oxygen concentrations in water (mg/L or % saturation).

2. Measures temperature in either ºF or ºC.

3. Measures pH / ORP.

4. Measures conductivity / salinity / total dissolved solids.

5. Stores over 49,000 data sets, time and date stamped.

Equipment

1. YSI Model 556 Multimeter, probe, 4-m cable

2. Probe sensor guard

3. Carrying case

4. DI water and wash bottle

5. 4 ‘C’ alkaline batteries

6. Membrane Replacement Kit (probe-membranes and electrolyte solution)

7. Transport/calibration cup

Meter Setup

1. <u>Check Meter.</u> Turn the meter on by pressing the button in upper left corner of the keypad (wait a few seconds for self test procedure to complete). You should now see a variety of parameters (i.e. temperature, pH, salinity, etc.) and the data/time and battery status at the lower portion of the display. If batteries need to be replaced, the battery icon on the lower right portion of the display will begin blinking (and will be nearly empty). Replace 4 C batteries by unscrewing the four lower screws on the back of the meter. In the unlikely event that an error message is displayed, consult the troubleshooting manual in the instrument file. Also check the

"Field Meter Use / Calibration / Maintenance Log" kept in the meter case to see when the meter was last used and how it performed.

2. Check the Probes. There should be three probes inside the probe sensor guard (which is removed by twisting it counterclockwise). The DO sensor is the smallest probe out of the three, and is blue in color. The membrane over the sensor should be clean, taught, and full of electrolyte solution. If the membrane is loose, wrinkled, damaged, or fouled, or air bubbles are observed in the electrolyte solution under the membrane, then the membrane needs to be changed. The pH sensor is the longest sensor. The pH bulb should be clean; any film on the bulb should be removed gently with a Kim wipe and cleaned with DI water. The conductivity/temperature sensor is slightly shorter than the pH sensor. The sensor should be clean and the openings should be free of any obstructions.

3. Choose the Report Mode. The run screen will be displayed when the meter is turned on; showing all of the parameters the meter is measuring at the time. Press the **Escape** key to display the main menu screen. Use the arrow keys to highlight the **Report** selection and press enter. In the report setup screen, select the various parameters desired by toggling with the arrow keys and pressing enter to select/unselect (a black dot on the left indicates that the parameter is selected for display). Press the **Escape** key to return to the **Main Menu**.

Calibration

1. Press the **On/off** key to display the run screen.

2. Press the **Escape** key to display the main menu screen.

3. Use the arrow keys to highlight the **Calibrate** selection and press enter.

Dissolved Oxygen:

1. Use the arrow keys to highlight the DO% selection.

2. Press **Enter**. The DO Barometric Pressure Entry Screen is displayed **–** press **Enter** and do **not** change the Barometric Pressure

3. Place approximately 3 mm (1/8 inch) of water in the bottom of the transport/calibration cup.

4. Place the probe module into the transport/calibration cup. **NOTE:** Make sure that the DO and temperature sensors are **not** immersed in the water.

5. Press **Enter**. The DO% saturation calibration screen is displayed.

6. Allow approximately **10** minutes for the air in the transport/calibration cup to become water saturated and for the temperature to equilibrate before proceeding. The current values of all enabled sensors will appear on the screen and will change with time as they stabilize.

7. Observe the reading under DO %. When the reading shows no significant change for approximately 30 seconds, press **Enter**. The screen will indicate that the calibration has been accepted and prompt you to press **Enter** again to Continue.

pH:

1. Use the arrow keys to highlight the **pH** selection.

2. Use the arrow keys to highlight the **2-point** selection. Select the **2-point** option to calibrate the pH sensor using only two calibration standards. Use this option if the media being monitored is known to be either basic or acidic. For example, if the pH of a pond is known to vary between 7.0 and 8.0, a two-point calibration with pH 7 and pH 10 buffers is sufficient.

3. Always start with the 7 buffer solution first.

4. Completely immerse the sensor end of the pH probe module into the buffer solution.

5. Gently rotate and/or move the probe module up and down to remove any bubbles from the pH sensor.

6. Screw the transport/calibration cup on the threaded end of the probe module and securely tighten.

7. Allow at least 1 minute for temperature equilibration before proceeding. Observe the reading under pH, when the reading shows no significant change for approximately 30 seconds, press **Enter**.

8. The screen will indicate that the calibration has been accepted and prompt you to press **Enter** again to Continue.

9. Repeat steps 3 through 6 above using a second pH buffer.

10. Rinse the probe module and sensors in tap or purified water after calibration has concluded.

Storing Sample Measurements

1. Turn instrument on by pressing **On/off** key to display the run screen
2. Calibrate in % saturation.
3. Change modes to read concentrations in mg/L.

Uploading Data to PC

Storage

1. The meter and carrying case should be dry. Leave carrying case open if equipment is still wet after being wiped clean.
2. Place approximately 3 mm (1/8 inch) of tap water in the bottom of the transport/calibration cup.
3. Place the probe in the probe storage chamber on the back of the instrument.

APPENDIX L

Standard Operating Procedure for Instantaneous Discharge Measurements

STANDARD OPERATING PROCEDURES

Instantaneous Discharge Measurement in Streams and Pipes

Herrera Environmental Consultants, Inc.
2200 Sixth Avenue, Suite 1100
Seattle, Washington 98121
Telephone: 206/441-9080

Rev. #1 2/7/08

July 16, 2008

Contents

Tables

Figures

1.0 Introduction, Scope and Applicability

This document describes Herrera Environmental Consultants' Standard Operating Procedures (SOP) for collecting discharge measurements in streams and pipes. It incorporates the USGS approved method (USGS 1969) for measuring discharge in channels and an adapted version for measuring discharge in pipes. Supplementary criteria and procedures are tailored from the "Recommended Protocols for Measuring Conventional Water Quality Variables and Metals in Fresh Water of the Puget Sound Region" (PSEP 1996). Additionally, a method for the use of a top-setting wading rod is presented. Appendices to this SOP include methods for the use of three types of velocity meters used by Herrera Environmental Consultants: a Marsh McBirney Flo-Mate Model 2000 Portable Flowmeter, a Swoffer Model 2100-13 propeller velocity meter, and an Aquacalc Model #1205 mini pygmy velocity meter.

2.0 Training

The procedures in this SOP are for use only by personnel who have received specific training and demonstrated a minimum level of competency. Documentation of training will be kept on file and be readily available for review.

3.0 General Considerations

Because cross sectional profile and velocity gradients are not uniform across pipes and channels it is necessary to compartmentalize the cross sectional area and measure an average velocity within each compartment. The method presented herein describes how to divide the cross section into compartments, how to estimate an average velocity within each compartment, and how to use this information to calculate discharge.

4.0 Equipment and Supplies

Each of the method described in this SOP must be conducted with appropriate field equipment. Table 1 provides a list of field equipment and identifies the equipment required for each flow measurement method.

5.0 Procedures

5.1 Stream Discharge Measurement Procedures

The procedures below are adapted from the "Recommended Protocols for Measuring Conventional Water Quality Variables and Metals in Fresh Water of the Puget Sound Region" (PSEP 1996) and the "Discharge Measurements at Gaging Stations" (USGS 1969).

Table 1. Required equipment for each flow measurement method.

Required Equipment	Pipe: Velocity and Depth	Pipe: Depth and Slope	Pipe: Calibrated Bucket	Stream: Mid-section Velocity
Flow measurement SOP	✓	✓	✓	✓
Field notebook/form, clipboard and pen	✓	✓	✓	✓
Clock with stopwatch	✓	✓	✓	✓
Velocity meter [a]	✓			✓
Wading rod	✓			✓
Measuring tape/ruler	✓	✓		✓
Anchors (spikes) and clips				✓
Four-foot straight edge and bubble level		✓		
Calibrated bucket			✓	

[a] Descriptions and operating procedures of the various approved velocity meters are provided in appendix A

5.1.1 Site Selection Criteria

It is important to select a representative location to establish a station for monitoring discharge. Proper site selection will improve the accuracy of flow measurements at all stream discharge levels. The following criteria should be considered when establishing a discharge measurement station. However, it is rarely possible to meet all the criteria listed. Be aware of the limitations of the site selected and possible effects on measurement.

5.1.1.1 Stream Reach Criteria

The station should be located in a stream reach (i.e., longitudinal section of the stream) with the following characteristics:

- The stream should be relatively straight and free flowing upstream and downstream of the monitoring location.
- Flow should be confined to one channel at all stages of discharge (i.e., there should be no surface or subsurface bypasses).
- Streambed should be subject to minimal scour and relatively free of plant growth.
- Streambanks should be stable, high enough to contain maximum flows, and free of brush.
- The station should be located a sufficient distance upstream so that flow from tributaries and tides does not affect stage/discharge measurements.
- All discharge stages should be measurable somewhere within the reach. It is not necessary to measure low and high flows at the identical cross section.
- The site should be readily and safely accessible.

5.1.1.2 Cross Section Criteria

The cross section in which a station is located within a stream reach should have the following characteristics:

- Streambanks should be relatively high and stable.
- The stream should be straight with parallel banks.
- Depth and velocity must meet minimum requirements of the method and instruments being used.
- The streambed should be relatively uniform with a minimal number of boulders and without heavy aquatic growth.
- Flow should be uniform and free of eddies, slack water, and excessive turbulence.
- Sites should not be located downstream of areas with rapid changes in stage or velocity.

5.1.2 Stream Flow Measurement Procedures – Mid-Section Velocity Method

1. Check that the current meter is functioning properly (see Appendix A).
2. Extend a measuring tape at right angles to the direction of flow and measure the width of the cross section. Record measurements on a data sheet. Leave the tape strung across the stream.
3. Divide the width into segments using at least 20 points of measurement. If previous flow measurements have shown uniform depth and velocity, fewer points may be used. *Smaller streams may also require fewer points.* Measuring points should be closer together where depths or velocities are more variable. Cross sections with uniform depth and velocity can have equal spacing.
4. Record the distance from the initial starting bank and the depth at each observation point.
5. Record the current velocity at each observation point (see Figure 1). Horizontal (from right to left bank) and vertical (top to bottom) variation of stream velocity may influence stream flow measurements. To correct for vertical differences, hydrologists have determined depths that can yield acceptable estimates of the mean velocity over a vertical profile. If the depth exceeds 0.5 m (1.5 feet), it is recommended that velocities be measured at 20 percent and 80 percent of full depth and averaged to estimate mean velocity. In the depth range 0.1-0.5 m (0.3-1.5 feet), take the velocity at 60 percent of the full depth (measured from the surface) as

an estimate of the mean over the profile. Measuring velocity in water shallower than 0.1 m (0.3 feet) is difficult with conventional current meters. If much of the reach of interest is very shallow, or flow is too slow for current meter measurement, consider installing a control section and V-notch weir.

6. Use Equation 1 to calculate total stream discharge.

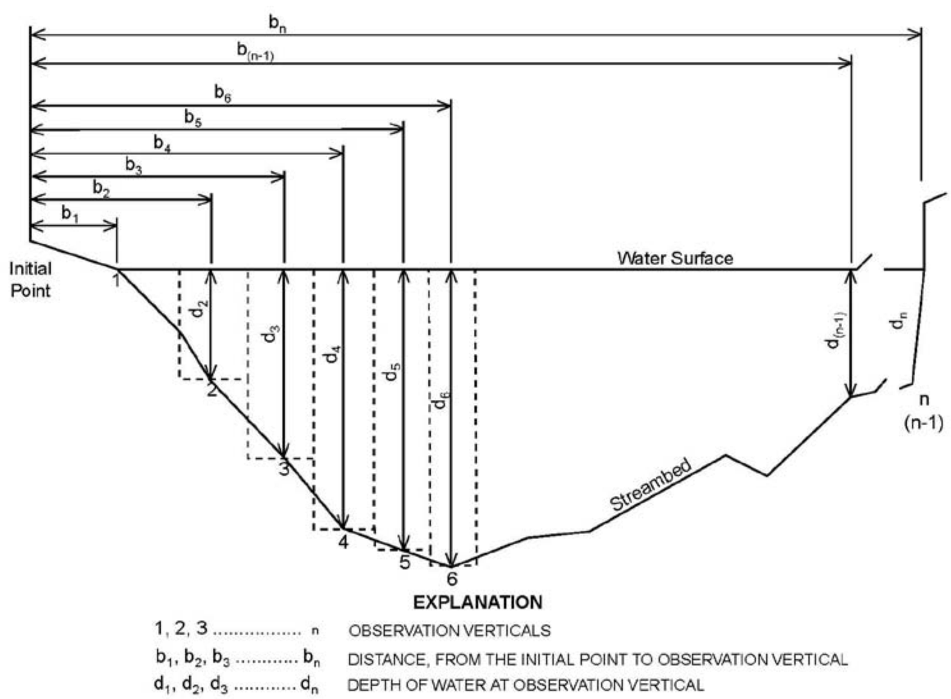

Figure 1. Sketch of midsection method of computing cross section area for discharge measurements.

Calculate flow as a summation of flows in partial areas using the following equation:

Equation 1

$$Q_n = V_n \times d_n \left(\frac{b_{n+1} - b_{n-1}}{2} \right)$$

Where: b_{n-1} = distance from initial point to the preceding point (m or ft)

b_{n+1} = distance from the initial point to the following point (m or ft)

d_n = depth at location n (m or ft)

V_n = mean velocity at location n (m/sec or ft/sec)

Q_n = discharge through partial section n (m^3/sec or ft^3/sec).

5.1.2 High Flow Stream Discharge Measurement Method

Streams should only be waded when the field technician's safety is assured. If a stream is deemed unwadeable then alternated methods are required to estimate stream discharge. When measuring discharge during elevated flow conditions, the following method should be employed:

1. Locate a nearby bridge.
2. Depending upon traffic conditions, weather, and bridge geometry traffic control measures should be employed to assure field technician and driver safety.
3. Extend a measuring tape at a right angle to the direction of flow and measure the width of the cross section. Record measurements on a data sheet. Leave the tape strung along the bridge railing.
4. Divide the width into segments using at least 20 points of measurement. If previous flow measurements have shown uniform depth and velocity, fewer points may be used. Smaller streams may also require fewer points. Measuring points should be closer together where depths or velocities are more variable. Cross sections with uniform depth and velocity can have equal spacing.
5. Record the distance from the initial starting bank and the depth.
6. Lower a graduated extension rod with attached velocity meter until the rod touches the surface of the water. Record distance on the rod. Lower rod until the rod touches the bed of the stream. Record distance on the rod. Subtract the two measure distance and multiply by 0.6 to determine the 60% depth level. Lower rod to 60% depth and record velocity.
7. Repeat process for each increment and then use Equation 1 to calculate discharge.

This method applicable if the distance from the bridge structure to channel bottom is less than 20 feet, and if the maximum water velocity within the channel is less than 20 feet/second. Where this method is not applicable, the slope-area method can be used to estimate flow as described in Gore (1996).

5.2 Pipe Discharge Measurement Procedures

The procedures below are adapted from the "Recommended Protocols for Measuring Conventional Water Quality Variables and Metals in Fresh Water of the Puget Sound Region" (PSEP 1996).

5.2.1 Site Selection Criteria

Site selection is of primary importance when measuring discharge. The majority of flow measurements in pipes will be conducted at outfalls or within catch basins. A rule of thumb is that velocity and depth measurements should be made upstream of the outfall at a distance equivalent to 5 times the depth at the outfall. This is to avoid the complex hydraulic conditions near the outfall that may affect the discharge calculation results.

5.2.2 Pipe Measurement Procedures

Flow in pipes is determined by one of the following methods:

- Velocity and depth method
- Depth and slope method
- Calibrated bucket method.

5.2.2.1 Velocity and Depth Method

Velocity (V) and depth (h) is measured in unobstructed pipes at the mid-point of the pipe. Velocity is measured with a current meter positioned at 60 percent of the water depth. Depth of flow is measured with the current meter or a ruler positioned in parallel to flow. The inside pipe diameter is measured by measuring across the center of the pipe. If flow depth is less than the radius of the pipe, flow area is determined according to equations 2 and 3.

Equation 2

$$A = \frac{r^2(\theta - \sin\theta)}{2}$$

Where: A = flow area

r = radius of the pipe

θ is defines in equation 3.

Equation 3

$$\theta = 2\arccos\left(\frac{r-h}{r}\right)$$

Where: h is flow depth.

If flow depth is greater than the radius of the pipe then equation 4 is used to calculate flow area.

Equation 4

$$A = \pi r^2 - \left(\frac{r^2(\theta - \sin\theta)}{2}\right)$$

Flow (Q) is calculated as the product of flow area (A) and velocity (V).

5.2.2.2 Depth and Slope Method

The depth and slope method of pipe flow measurement is employed when velocity cannot be measured. This method requires measurements of depth of flow, the inside pipe diameter, and pipe slope. Under good conditions, peak discharge rates can be estimated using this method with an error rate of 10 – 20 percent (Gordon et al. 2004). Under poor conditions, error rates of up to 50 percent may be observed.

Slope of the pipe is measured by placing a four foot straight edge in the end of the pipe. A bubble level is placed on the straight edge and the straight edge is adjusted until level. The distance from the bottom of the straight edge to the inside base of the pipe is then measured. The slope is then determined by dividing the rise by the run. Flow is calculated according to Manning's equation, as follows:

Equation 5

$$Q = {1.49}\big/{N} \times R^{2/3} \times S^{1/2}$$

Where: Q = Flow in ft^3/sec

R = Hydraulic radius determined form depth of flow and pipe diameter (see Appendix B)

S = Pipe slope of the difference between pipe-invert elevation 9 feet) divided by the distance between measuring points

n = Roughness coefficient (see Table 2).

Table 2. Manning 'n' values for various types of culverts (pipes).

Type of Culvert	Roughness of Corrugation	Manning 'n'
Concrete Pipe	Smooth	0.010 - 0.011
Concrete Box	Smooth	0.012 - 0.015
Spiral Rib Metal Pipe	Smooth	0.012 - 0.013
Corrugated Metal Pipe, Pipe Arch and Box (Annular and Helical Corrugations - See Figure B-3, page 130, Manning 'n' varies with barrel size)	68 x 13 mm Annular 68 x 13 mm Helical 150 x 25 mm Helical 125 x 25 mm 75 x 25 mm 150 x 50 mm Structural Plate 230 x 64 mm Structural Plate	0.022 - 0.027 0.011 - 0.023 0.022 - 0.025 0.025 - 0.026 0.027 - 0.028 0.033 - 0.035 0.033 - 0.037
Corrugated Polyethylene	Smooth	0.009 - 0.015
Corrugated Polyethylene	Corrugated	0.018 - 0.025
Polyvinyl Chloride (PVC)	Smooth	0.009 - 0.011

Adapted from FHWA(2001)

5.2.2.3 Calibrated Bucket Method

The calibrated bucket method of pipe flow measurement is useful for low flows at pipe outfall locations. This method involves measuring the amount of water (to the nearest tenth of a gallon) that collects in a bucket placed under the outfall for a specific time period (seconds). Flow (gallons/minute or GPM) is calculated by dividing the volume (gallons) by the duration of collection (seconds) and multiplying by 60 seconds. Flow measurements should be taken over a period of at least 10 seconds.

6.0 Records and Documentation:

There are no specific quality assurance (QA) activities which apply to the implementation of these procedures. However, the following general quality control (QC) procedures apply:

All field conditions must be documented on field data sheets/ forms or within site logbooks. All instrumentation must be operated in accordance with operating instructions as supplied by the manufacturer, unless otherwise specified in the work plan. Equipment checkout and calibration activities must occur prior to sampling or operation and they must be documented.

7.0 Health and Safety

When working with potentially hazardous materials, follow U.S. EPA, OSHA and corporate health and safety procedures.

In streams of significant flow, the person performing the discharge measurements should be on a lifeline and wear adequate protective equipment. If flows are sufficiently high discharge measurements should be taken from a nearby bridge using appropriate methods.

8.0 References

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APPENDIX M

Target Analytes for the Phase 3 Characterization of Toxic Loadings via Surface Runoff Study

Target Analytes for the Phase 3 Characterization of Toxic Loadings via Surface Runoff Study

Chemical / Class	Basis	Method	Reporting Limit (ug/L)
Polyaromatic Hydrocarbons (PAHs)			
1-Methylnaphthalene		8270 SIM	0.01
2-Chloronaphthalene	PP	8270 SIM	0.01
2-Methylnaphthalene		8270 SIM	0.01
Acenaphthene	PP	8270 SIM	0.01
Acenaphthylene	PP	8270 SIM	0.01
Anthracene	PP	8270 SIM	0.01
Benzo(a)anthracene	PP	8270 SIM	0.01
Benzo(a)pyrene	PP	8270 SIM	0.01
Benzo(b)fluoranthene	PP	8270 SIM	0.01
Benzo(g,h,i)perylene	PP	8270 SIM	0.01
Benzo(k)fluoranthene	PP	8270 SIM	0.01
Carbazole		8270 SIM	0.01
Chrysene	PP	8270 SIM	0.01
Dibenzo(a,h)anthracene	PP	8270 SIM	0.01
Dibenzofuran		8270 SIM	0.01
Fluoranthene	PP	8270 SIM	0.01
Fluorene	PP	8270 SIM	0.01
Indeno(1,2,3-cd)pyrene	PP	8270 SIM	0.01
Naphthalene	PP	8270 SIM	0.01
Phenanthrene	PP	8270 SIM	0.01
Pyrene	PP	8270 SIM	0.01
Retene		8270 SIM	0.01
Base/Neutral/Acid Extractables			
1,2,4-Trichlorobenzene	PP	8270	0.25
1,2-Dichlorobenzene	PP	8270	0.25
1,2-Diphenylhydrazine	PP	8270	0.25
1,3-Dichlorobenzene	PP	8270	0.25
1,4-Dichlorobenzene	PP	8270	0.25
2,4-Dichlorophenol	PP	8270	2.5
2-Methylphenol		8270	2.5
4-Methylphenol		8270	2.5

Chemical / Class	Basis	Method	Reporting Limit (ug/L)
Base/Neutral/Acid Extractables (continued)			
2,4-Dimethylphenol	PP	8270	2.5
2,4-Dinitrophenol	PP	8270	2.5
2,4-Dinitrotoluene	PP	8270	1.0
2,6-Dinitrotoluene	PP	8270	1.0
2-Chlorophenol	PP	8270	1.0
2-Nitroaniline		8270	5.0
2-Nitrophenol	PP	8270	0.5
3,3'-Dichlorobenzidine	PP	8270	0.5
3-Nitroaniline		8270	1.0
4,6-Dinitro-o-cresol	PP	8270	1.0
4-Bromophenylphenylether	PP	8270	0.5
4-Chloro-3-methylphenol	PP	8270	2.5
4-Chloroaniline		8270	10
4-Chlorophenylphenylether	PP	8270	0.25
4-Nitroaniline		8270	1.0
4-Nitrophenol		8270	2.5
4-Nonylphenol	Hormone disruptor	8270	1.0
bis(2-Chloroethoxy)methane	PP	8270	0.25
bis(2-Chloroethyl)ether	PP	8270	0.5
bis(2-Ethylhexyl)phthalate	PP	8270	0.5
Bisphenol A	Hormone disruptor	8270	1.0
Butylbenzylphthalate	PP	8270	1.0
Caffeine		8270	0.5
Diethylphthalate	PP	8270	0.5
Dimethylphthalate	PP	8270	0.5
Di-N-butylphthalate	PP	8270	0.25
Di-N-octylphthalate	PP	8270	0.5
Hexachlorobenzene	PP	8270	0.25
Hexachlorobutadiene	PP	8270	0.25
Hexachlorocyclopentadiene	PP	8270	1.0
Hexachloroethane	PP	8270	0.25
Isophorone	PP	8270	0.5

Chemical / Class	Basis	Method	Reporting Limit (ug/L)
Base/Neutral/Acid Extractables (continued)			
Nitrobenzene	PP	8270	0.25
N-Nitrosodimethylamine	PP	8270	1.0
N-Nitrosodi-N-propylamine	PP	8270	0.3
N-Nitrosodiphenylamine	PP	8270	0.5
Phenol	PP	8270	1.0
Triclosan		8270	0.25
Triethylcitrate		8270	1.0
Pesticides			
4,4’-DDD		8081	0.002
4,4’-DDE		8081	0.002
4,4’-DDT		8081	0.002
Aldrin		8081	0.002
alpha-BHC		8081	0.002
beta-BHC		8081	0.002
delta-BHC		8081	0.002
gamma-BHC (Lindane)		8081	0.002
cis-Chlordane		8081	0.002
trans-Chlordane		8081	0.002
Chlorpyriphos		8081	0.025
Dieldrin		8081	0.002
Endosulfan I		8081	0.002
Endosulfan II		8081	0.002
Endosulfan Sulfate		8081	0.002
Endrin		8081	0.002
Endrin Aldehyde		8081	0.002
Endrin Ketone		8081	0.002
Heptachlor		8081	0.002
Heptachlor Epoxide		8081	0.002
Hexachlorobenzene		8081	0.025
Methoxychlor		8081	0.002
cis-Nonachlor		8081	0.025
trans-Nonachlor		8081	0.025

Chemical / Class	Basis	Method	Reporting Limit (ug/L)
Pesticides (continued)			
Oxychlordane		8081	0.025
Toxaphene		8081	0.008
Herbicides			
2,3,4,5-Tetrachlorophenol	PCP breakdown	8270	0.062
2,3,4,6-Tetrachlorophenol	PCP breakdown	8270	0.062
2,4,5-T		8270	0.062
2,4,5-TP (Silvex)		8270	0.062
2,4,5-Trichlorophenol	PCP breakdown	8270	0.062
2,4,6-Trichlorophenol	PP	8270	0.062
2,4-D		8270	0.062
2,4-DB		8270	0.062
3,5-Dichlorobenzoic Acid		8270	0.062
4-Nitrophenol	PP	8270	0.062
Acifluorfen (Blazer)		8270	0.062
Bentazon		8270	0.062
Bromoxynil		8270	0.062
Chloramben		8270	0.062
Clopyralid		8270	0.062
Dacthal (DCPA)		8270	0.062
Dicamba I		8270	0.062
Dichlorprop		8270	0.062
Diclofop-Methyl		8270	0.062
Dinoseb		8270	0.062
Ioxynil		8270	0.062
MCPA		8270	0.062
MCPP (Mecoprop)		8270	0.062
Pentachlorophenol (PCP)	PP	8270	0.062
Picloram		8270	0.062
Triclopyr	Current use pesticide	8270	0.062
Polybrominated Diphenyl Ethers (congeners)			
PBDE-017	Hormone disruptor	GC/HRMS 1614	0.000025
PBDE-028	Hormone disruptor	GC/HRMS 1614	0.000025

Chemical / Class	Basis	Method	Reporting Limit (ug/L)
Polybrominated Diphenyl Ethers (congeners) (continued)			
PBDE-030	Hormone disruptor	GC/HRMS 1614	0.000025
PBDE-047	Hormone disruptor	GC/HRMS 1614	0.00005
PBDE-049/71	Hormone disruptor	GC/HRMS 1614	0.00005
PBDE-066	Hormone disruptor	GC/HRMS 1614	0.00005
PBDE-077	Hormone disruptor	GC/HRMS 1614	0.00005
PBDE-085	Hormone disruptor	GC/HRMS 1614	0.00005
PBDE-099	Hormone disruptor	GC/HRMS 1614	0.00005
PBDE-100	Hormone disruptor	GC/HRMS 1614	0.00005
PBDE-119	Hormone disruptor	GC/HRMS 1614	0.00005
PBDE-126	Hormone disruptor	GC/HRMS 1614	0.00005
PBDE-138	Hormone disruptor	GC/HRMS 1614	0.00005
PBDE-139	Hormone disruptor	GC/HRMS 1614	0.00005
PBDE-140	Hormone disruptor	GC/HRMS 1614	0.00005
PBDE-153	Hormone disruptor	GC/HRMS 1614	0.00005
PBDE-154	Hormone disruptor	GC/HRMS 1614	0.00005
PBDE-156/169	Hormone disruptor	GC/HRMS 1614	0.00005
PBDE-171	Hormone disruptor	GC/HRMS 1614	0.0001
PBDE-180	Hormone disruptor	GC/HRMS 1614	0.0001
PBDE-183	Hormone disruptor	GC/HRMS 1614	0.0001
PBDE-184	Hormone disruptor	GC/HRMS 1614	0.0001
PBDE-191	Hormone disruptor	GC/HRMS 1614	0.0001
PBDE-196	Hormone disruptor	GC/HRMS 1614	0.0001
PBDE-197/204	Hormone disruptor	GC/HRMS 1614	0.0001
PBDE-201	Hormone disruptor	GC/HRMS 1614	0.0001
PBDE-203	Hormone disruptor	GC/HRMS 1614	0.0001
PBDE-205	Hormone disruptor	GC/HRMS 1614	0.0001
PBDE-206	Hormone disruptor	GC/HRMS 1614	0.0025
PBDE-207	Hormone disruptor	GC/HRMS 1614	0.0025
PBDE-208	Hormone disruptor	GC/HRMS 1614	0.0025
PBDE-209	Hormone disruptor	GC/HRMS 1614	0.0025
Polychlorinated Biphenyls (209 congeners)			
All 209 PCB congeners	PP	GC/HRMS 1668	0.0001

Chemical / Class	Basis	Method	Reporting Limit (ug/L)
Conventional Chemistry			
Total Petroleum Hydrocarbons Gas		NWTPH-Gx	140
Total Petroleum Hydrocarbons Diesel		NWTPH-Dx	150
Total Petroleum Hydrocarbons Lube Oil		NWTPH-Dx	380
Oil and Grease, HEM (gravimetric)		1664, Rev. A	5,000
Hardness		SM2340B	300
Ammonia Nitrogen		4500-NH3 H	10
Nitrate & Nitrite Nitrogen		4500-NO3 I	10
Total Nitrogen (persulfate)		4500-N B	25
Dissolved Organic Carbon		SM5310 B	1,000
Total Organic Carbon		SM5310 B	1,000
Orthophosphate Phosphorus		4500-9 G	3
Total Phosphate Phosphorus		4500-P F	5
Total Suspended Solids		SM2540 D	1,000
Metals (dissolved)			
Aluminum		200.8	50
Arsenic	PP	200.8	0.1
Barium		200.8	0.1
Beryllium	PP	200.8	0.1
Cadmium	PP	200.8	0.02
Cobalt		200.8	0.1
Copper	PP	200.8	0.1
Lead	PP	200.8	0.02
Manganese		200.8	10
Mercury	PP	245.7 or 7470	0.002
Nickel	PP	200.8	0.1
Selenium	PP	200.8	0.5
Thallium	PP	200.8	0.1
Tin		200.8	0.2
Zinc	PP	200.8	1.
Metals (total)			
Aluminum		200.8	50
Arsenic	PP	200.8	0.1

Chemical / Class	Basis	Method	Reporting Limit (ug/L)
Metals (total) (continued)			
Barium		200.8	0.1
Beryllium	PP	200.8	0.1
Cadmium	PP	200.8	0.1
Cobalt		200.8	0.1
Copper	PP	200.8	0.1
Lead	PP	200.8	0.1
Manganese		200.8	10
Mercury	PP	245.7 or 7470	0.002
Nickel	PP	200.8	0.1
Selenium	PP	200.8	0.5
Thallium	PP	200.8	0.1
Tin		200.8	0.2
Zinc	PP	200.8	5.
Field Parameters			
Dissolved Oxygen		Field probe	NA
pH		Field probe	NA
Specific Conductance		Field probe	NA
Temperature		Field probe	NA

ug/L = Micrograms per Liter

BHC = Benzene hexachloride

DDD = 1,1-Dichlorodiphenyl-dichloroethane

DDE = 1,1-Dichloro-2,2-bis(4-chlorophenyl)ethylene

DDT = 1,1,1-Trichloro-2,2-bis(4-chlorophenyl)ethane

Dx = Diesel

HEM = n-hexane extractable material

Gx = Gasoline

PBDE = Polybrominated diphenyl ether

PCBs = Polychlorinated biphenyls

PCP = Pentachlorophenol

PP = Priority Pollutant

NA = Not Applicable

APPENDIX N

USGS Rain Gauging Network in the Snohomish River Watershed and Puyallup River Watershed

U.S. Geological Society rain gauges in the Puyallup River Watershed.

Gauge ID	Gauge Location
12092000	PUYALLUP RIVER NEAR ELECTRON, WA
12094000	CARBON RIVER NEAR FAIRFAX, WA
12095000	SOUTH PRAIRIE CREEK AT SOUTH PRAIRIE, WA
12097500	GREENWATER RIVER AT GREENWATER, WA

U.S. Geological Society rain gauges in the Snohomish River Watershed.

Gauge ID	Gauge Location
12143400	SF SNOQUALMIE RIVER AB ALICE CREEK NEAR GARCIA, WA
12147900	SOUTH FORK TOLT RESERVOIR NEAR CARNATION, WA