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State of Washington

Quality Assurance Project Plan

Cherry and Ames Creeks (Snoqualmie River Tributaries) Dissolved Oxygen Study

November 2011

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Publication Information

Each study conducted by the Washington State Department of Ecology (Ecology) must have an approved Quality Assurance Project Plan. The plan describes the objectives of the study and the procedures to be followed to achieve those objectives. After completing the study, Ecology will post the final report of the study to the Internet.

The plan for this study is available on Ecology's website at www.ecy.wa.gov/biblio/1103115.html.

Data for this project will be available on Ecology's Environmental Information Management (EIM) website at www.ecy.wa.gov/eim/index.htm. Search User Study ID, jkar0003.

Ecology's Activity Tracker Code for this study is 11-047.

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Quality Assurance Project Plan

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November 2011

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Signatures are not available on the Internet version.
NWRO: Northwest Regional Office
EAP: Environmental Assessment Program
EIM: Environmental Information Management database

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Abstract

Water quality in the Cherry Creek watershed is degraded (Kaje, 2009), with measurable impacts on the fish communities that use the creek and associated flood plain habitat (Wild Fish Conservancy, 2008 unpublished data).

Dissolved oxygen (DO) concentrations have frequently failed to meet Washington State water quality standards in flood plain drainage channels that contribute to Cherry Creek, Ames Creek, and other tributaries to the Snoqualmie River (Sargeant and Svrjcek, 2008; Tulalip Tribes, unpublished data 2008).

However, Cherry and Ames Creeks are not on the federal Clean Water Act Section 303(d) list for DO. Low DO conditions have been documented during varying temperature and discharge conditions. This suggests an independent mechanism may drive this condition, and emphasizes the need to understand the physical, biological, and hydraulic properties that affect DO in the flood plain. Seasonal depletion of DO in the flood plain habitats of Cherry Valley is at times severe enough to kill fish or otherwise make those habitats inhospitable.

It is critical to understand what causes the depletion if it is to be addressed. Identifying the mechanism behind the impaired DO conditions is paramount to protecting important salmon rearing and migration corridors in the lower Snoqualmie River watershed.

This study is part of a larger cooperative effort with the Wild Fish Conservancy (WFC) and King County:

- The Washington State Department of Ecology will assess continuous DO conditions in Cherry and Ames Creeks, and selected agricultural waterways.
- WFC will characterize groundwater contributions to surface-water drainage and investigate if low DO conditions in surface water coincide with high groundwater/surface-water ratios during late spring following long periods of saturation in the Snoqualmie Valley flood plain.
- King County will advise all parties on the study design.

The results of this study will promote a better understanding of the mechanisms causing DO depletion and thus provide better direction for management and restoration actions.

Background

The Snoqualmie River watershed provides excellent wildlife habitat and is valued for recreation, aesthetics, agriculture, and residence. Many environmental studies have been conducted throughout the watershed, but data gaps still remain. Low dissolved oxygen (DO) has been observed in Cherry Creek, Tuck Creek, Ames Creek, Patterson Creek, and Kimball Creek, all tributaries to the Snoqualmie River. This study will assess water quality parameters including DO, temperature, pH, and conductivity.

The Washington State Department of Ecology (Ecology) will deploy continuous data loggers at selected sites in Cherry Creek, Ames Creek, and their associated agricultural waterways. The Wild Fish Conservancy (WFC) will assess streamflow and local groundwater characteristics. The final report will be jointly written by WFC and Ecology including all study results.

Snoqualmie River

The Snoqualmie River system drains 700 square miles (mi^2), or 1813 square kilometers (km^2), in King and Snohomish Counties before meeting the Skykomish River to create the Snohomish River. Most of the Snoqualmie River basin is in King County. Snoqualmie Falls, with a vertical height of 268 feet (81.7 m), is a predominant feature of the Snoqualmie River at river mile (RM) 40.4. The Tolt River, which drains a 101 mi^2 (262 km^2) basin, is a large tributary to the lower mainstem Snoqualmie (Joy, 1994). The Tolt provides 30% of the drinking water for the 1.3 million people in the Seattle area (Sargeant and Svrjcek, 2008).

The lower valley, below Snoqualmie Falls, is characterized by several major population centers and mixed agriculture. The population centers are the cities of Duvall and Carnation and the unincorporated towns of Fall City and Preston. Agriculture includes dairies, berry fields, pastures, and row crop fields. In addition, golf courses, wildlife reserves, and other recreational facilities are present along the mid to lower end of the river. Many areas along the slopes and upland of the lower valley are being converted to residential and commercial developments. Stormwater from a number of residential developments, towns, and agricultural fields discharges into the Snoqualmie River through tributaries, drainage systems, or by direct pipeline (Onwumere and Batts, 2004).

Figure 1 shows an overview of the study areas in Water Resource Inventory Area (WRIA) 07.

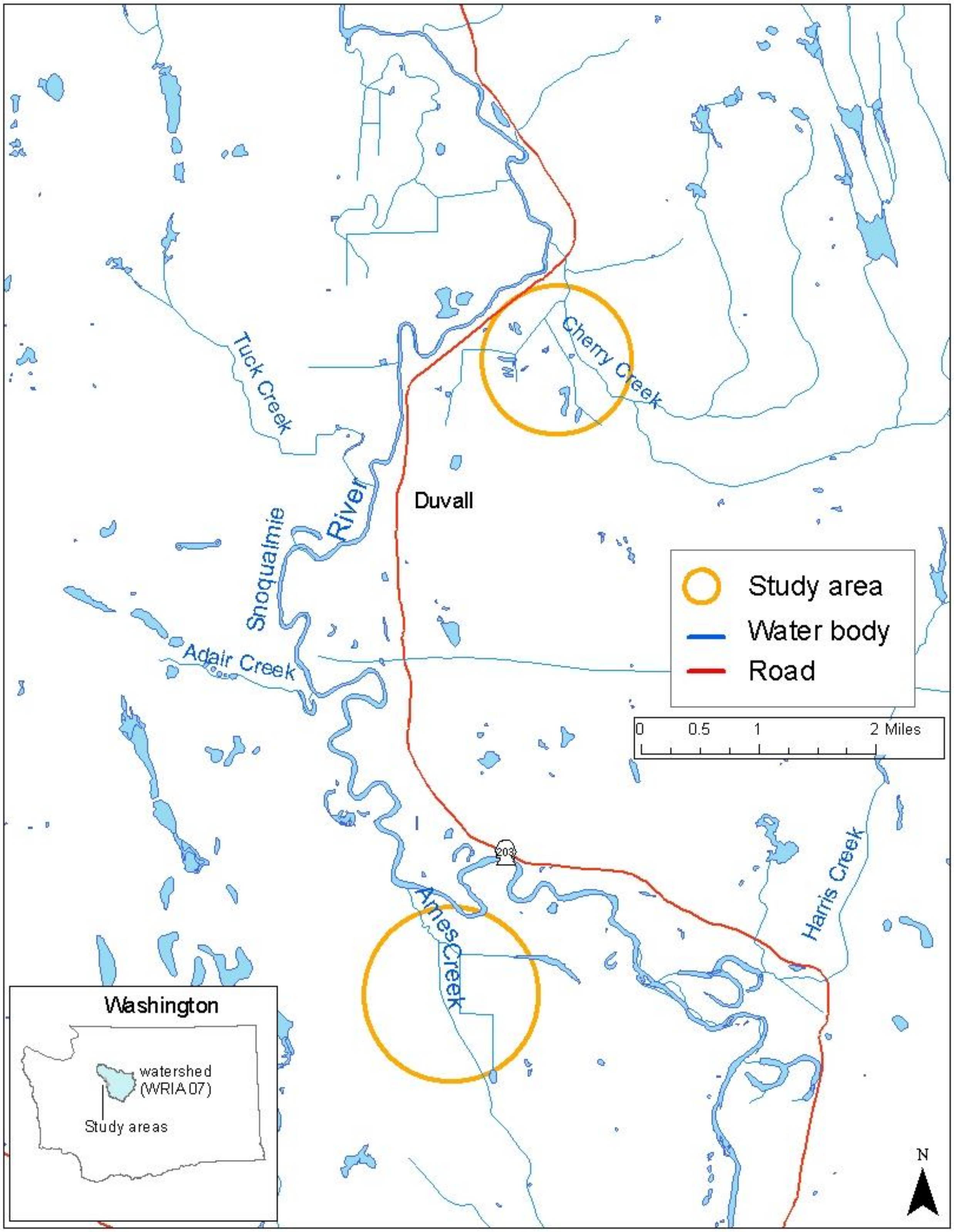

Figure 1. Cherry and Ames Creek subbasin study areas in the Snoqualmie River watershed.

Cherry Creek

The Cherry Creek watershed is 28.1 mi^2 (72.8 km^2) with its mainstem oriented east-to-west entering the Snoqualmie River at RM 7 downstream of Duvall (Figure 2). Land use in the watershed includes agriculture in the lower portion, rural residential, and forestry along the headwaters. Lake Margaret (53 acres) is a water supply for the lake area residence. Margaret Creek drains the lake and flows mostly through forested land with limited residential land use. The Margaret/Cherry Creek confluence is the approximate midway point on Cherry Creek from its mouth to headwaters (Kaje, 2009).

The Snoqualmie River 100-year flood plain extends approximately 2 miles into the Cherry Creek watershed. The Snoqualmie River floods the valley portion of Cherry Creek during high-flow conditions. A pump station within the flood plain regulates the water levels of Lateral A, a drainage channel that conveys tributary inflow and field drainage into Cherry Creek (Kaje, 2009).

Ames Creek

The Ames Creek (also known as Ames Lake Creek) watershed is 8.1 mi^2 (20.9 km^2) and primarily drains rural residential uplands before traversing the agricultural production district (APD) across the flood plain of the Snoqualmie River at RM 17.1 (Figure 3). The upper reach drains fairly steep topography before entering Ames Lake, which is 76 acres surrounded by homes and over 100 lots ranging in size from 1/3 acre to over 1 acre. From the outlet of the lake, Ames Creek continues north to the valley floor. Like many other tributaries in the APD, the flood plain portions of Ames Creek and its tributaries have been deepened and straightened over several decades to benefit agriculture along the valley floor.

Sikes Lake Creek is a key tributary that drains the northeast portion of the basin and Sikes Lake before joining the mainstem in the flood plain a short distance upstream from the confluence with the Snoqualmie River. As detailed in the Snoqualmie Watershed Water Quality Synthesis Report (Kaje, 2009), Sikes Lake Creek drainage differs from the mainstem for some parameters. For example, King County data show DO impairments in Ames Creek while Sikes Lake Creek DO levels meet water quality criteria.

The Ames Creek flood plain is low-lying and thus prone to flooding when the Snoqualmie River is running high. Even when the Snoqualmie River has not overtopped its banks, the water level in the river can be high enough to flood Ames Creek, beginning at the creek mouth and flooding back into the valley (Kaje, 2009). The majority of the APD within the Ames Creek basin is within the 100-year flood plain of the Snoqualmie River.

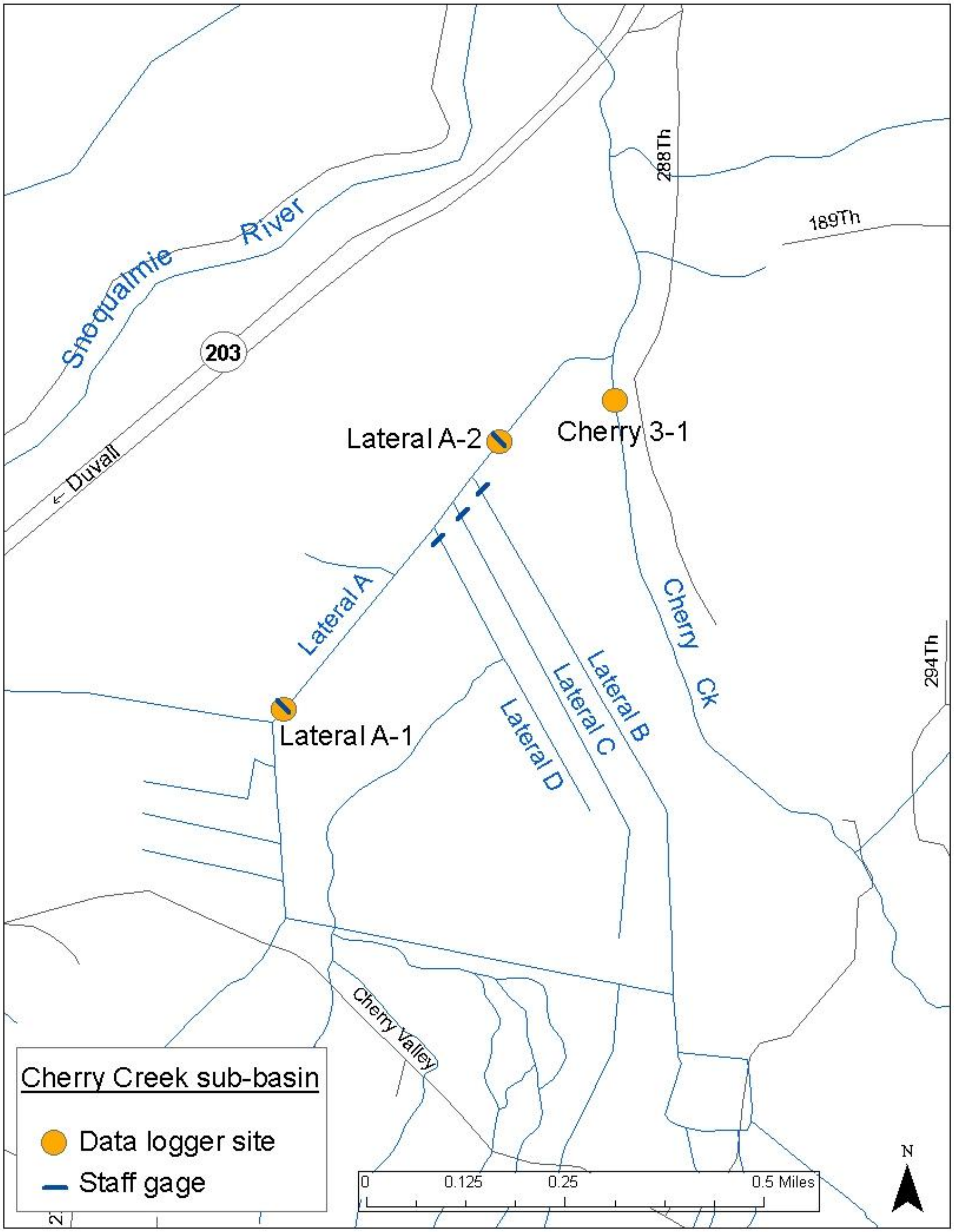

Figure 2. Lower Cherry Creek and agricultural waterways draining the Snoqualmie River flood plain.

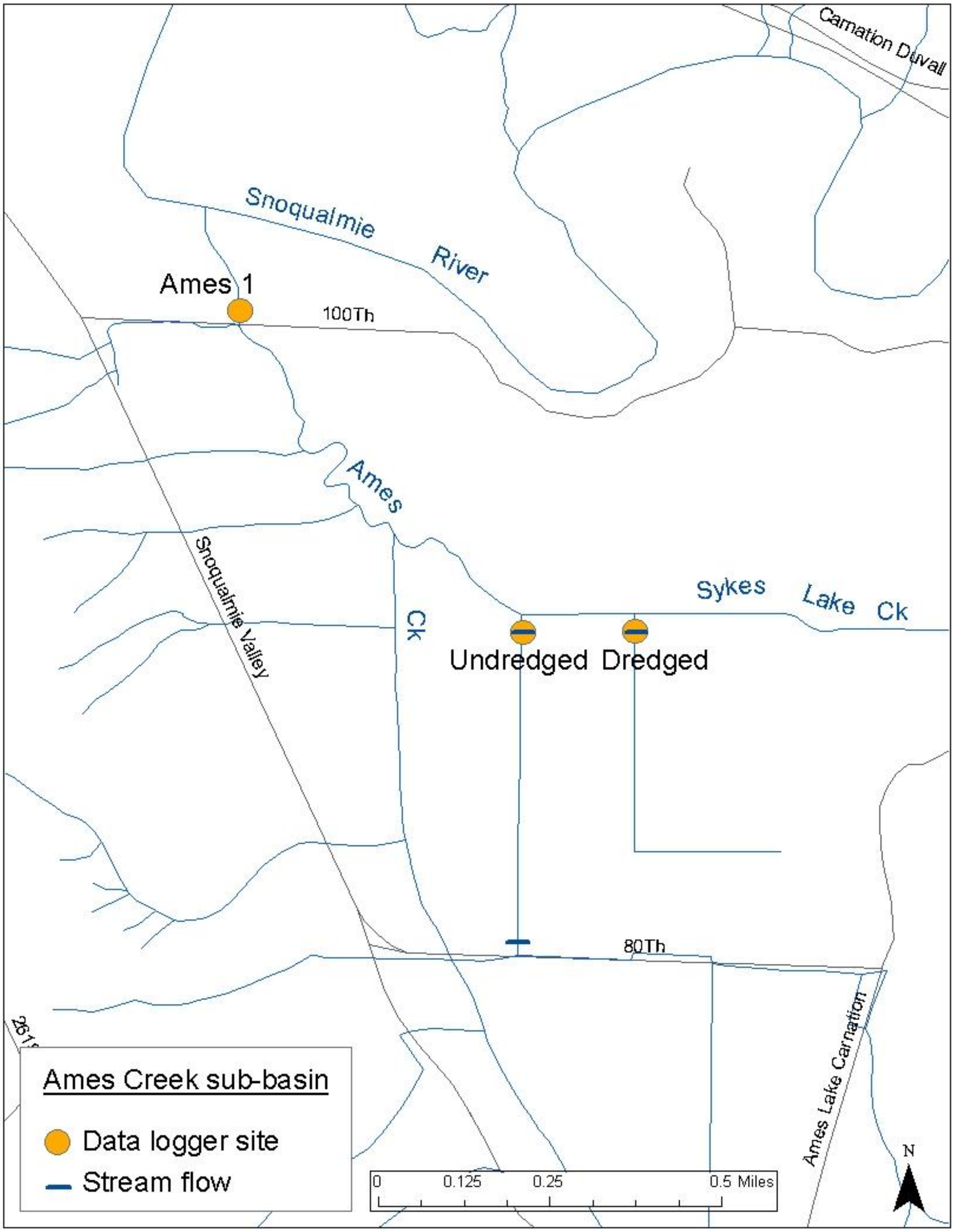

Figure 3. Ames Creek and agricultural waterways draining the Snoqualmie River flood plain.

Water Quality Criteria and Aquatic Life

Poor water quality has been observed within the Snoqualmie River watershed and in some of its tributary subbasins. Cherry Creek, Tuck Creek, Ames Creek, Patterson Creek, Raging River, and Kimball Creek have exhibited DO levels below the Washington State water quality criteria (Kaje, 2009). Limited continuous DO data exist for the Snoqualmie River watershed. Continuous water quality data showing diurnal trends will be useful. Also, continuous data results will help systematically identify characteristics specific to each subbasin within the Snoqualmie River watershed.

Table 1 shows water quality criteria applicable to the scope of this study within the Snoqualmie River watershed (WAC 173-201A). Table 1 has been modified from Kaje (2009), pages 7 and 8 by omitting standards beyond the scope of this study.

Table 1. Washington State water quality criteria and aquatic life uses specific to each water body (adapted from WAC 173-201A including Table 602.)

Aquatic Life Uses	Water Quality Criteria	Watershed Description
Core summer salmonid habitat. The key identifying characteristics of this use are summer (June 15 - September 15) salmonid spawning or emergence, or adult holding; use as important summer rearing habitat by one or more salmonids; or foraging by adult and sub-adult native char. Other common characteristic aquatic life uses for waters in this category include spawning outside of the summer season, rearing, and migration by salmonids.	Temperature: (7-DADMax) 16°C Dissolved oxygen: (1-Dmin) 9.5 mg/L pH: pH shall be within the range of 6.5 to 8.5, with a human-caused variation within the above range of < 0.2 units	Cherry Creek watershed and its tributaries. Snoqualmie River and tributaries from and including Harris Creek to the west boundary of Twin Falls State Park on the South Fork (RM 9.1). Tributaries to all waters designated Core summer salmonid habitat, or an Extraordinary primary contact for recreation. All lakes and all feeder streams to lakes, where reservoirs with a mean detention time > 15 days are treated as lakes for use designation. All surface waters not listed in Table 602 lying within National Forests, National Parks, or Wilderness Areas.
Salmonid spawning, rearing, and migration. The key identifying characteristic of this use is salmon or trout spawning and emergence that only occurs outside of the summer season (September 16 - June 14). Other common characteristic aquatic life uses for waters in this category include rearing and migration by salmonids.	Temperature: (7-DADMax) 17.5°C Dissolved oxygen: (1-Dmin) 8.0 mg/L pH: pH shall be within the range of 6.5 to 8.5, with a human-caused variation within the above range of < 0.5 units	Snoqualmie River from mouth to junction with Harris Creek (RM 21.3). All other surface waters.

7-DADMax is the 7 day rolling maximum average.

1-Dmin is the single day minimum.

Water quality criteria also help protect all natural biota living in our waters. The Snoqualmie River watershed supports many species of salmon, trout, whitefish, suckers, and more. The watershed is home to the threatened chinook and steelhead, as well as other salmon species like coho, pink, and chum.

The wide range of plants, insects, and other organisms that live in the watershed provides the underlying support for fish and other species. From the plant level with algae to zooplankton and macroinvertebrates, each organism is part of a properly functioning ecosystem. Sufficient DO concentrations, low water temperatures, proper nutrient levels, and adequate streamflows are all important to the good health of the animal species associated with the Snoqualmie River and its tributaries.

When a stream or river experiences pollution, native plants and bugs often fail to flourish and are replaced by non-native plants and bugs. Fish that have used those native species as food over their thousands of years in the stream often do not adjust to the new food sources and can suffer from a lack of nutrition. Malnourished fish do not compete as well and become more susceptible to predation. In extreme cases, young fish could die from malnutrition. Inappropriate oxygen, nutrient, or temperature levels can cause this problem. In addition, young fish that experience excessively high temperatures during rearing are more susceptible to diseases and can suffer developmental problems that can reduce their ability to spawn successfully in the future (Meyers et al., 1998).

Previous Studies

The following is a brief summary of recent studies conducted in the Snoqualmie River watershed. Not all studies are mentioned here and only relevant conclusions are presented. Ongoing investigations and water quality improvement projects continue in the watershed.

King County

The *Snoqualmie Watershed Water Quality Synthesis Report* provides water quality information, identifies data gaps, and presents future recommendations (Kaje, 2009). This report is the most up-to-date synthesis of existing water quality information covering most of the watershed.

> Kimball, Patterson, Ames, Cherry, and Tuck Creeks stand out for the prevalence of water quality impairments relative to other tributaries in the watershed. Each stream violates multiple water quality criteria, according to more than one study. High levels of nutrients, low dissolved oxygen, and low pH (i.e., acidic conditions) are prevalent in many of these streams, along with high bacterial counts. A commons pattern across many of the flood plain tributaries that feature extensive agricultural land use is that water quality worsens as the stream flows from the upstream edge of the flood plain to the Snoqualmie River. In many streams, water quality at the mouth shows higher temperature, higher bacterial concentration, lower dissolved oxygen, higher nutrient levels, and lower pH than locations further upstream (Kaje, 2009).

> In the many sub-basins that feature agriculture in flood plain areas, we need to better understand the legacy effects of a century of farming in a formerly forested flood plain. Changes in soils and in drainage patterns may have as much to do with some of the observed impairments as current agricultural practices themselves. There is still much room for improvement, especially in terms of restricting livestock access to streams, management of manure and other fertilizers, and the need to restore riparian areas. But meaningful improvements will only occur with the help of incentives and technical assistance to improve farming practices while maintaining economic viability (Kaje, 2009).

This study also states that low DO concentrations in Ames and Cherry Creeks often persist during winter, suggesting high temperatures are not a primary cause for low DO levels.

Wild Fish Conservancy

During 2006, the Wild Fish Conservancy (WFC) conducted fish passage research in Cherry Creek. DO levels were below water quality criteria and possibly causing juvenile fish kills during the study. As a result, the WFC and the Tulalip Tribe collected water quality data in the lateral drain to further understand the problem and the possible pollution sources involved. (Wild Fish Conservancy and Tulalip Tribes of Washington, 2009). Twelve sites in the Cherry Creek watershed were sampled extensively for DO, temperature, pH, and conductivity. The diurnal fluctuation was captured through instantaneous measuring twice a day, once at dawn and once in afternoon or evening. Data show water quality criteria violations for DO in the Cherry Creek watershed at many sampling locations. A couple of sites often exhibited DO levels around 1 mg/L. The study recommended additional data collection.

WFC manages riparian restoration projects as well. For example, the proposed draft report *Waterwheel Creek Restoration Project* (Glasgow, 2011) is designed to improve wildlife habitat by abandoning laterals, creating a new meandering channel, and removing fish barriers on the tributaries to Cherry Creek.

Department of Ecology

The *Snoqualmie River Basin Fecal Coliform Bacteria, Dissolved Oxygen, Ammonia-Nitrogen, and pH Total Maximum Daily Load Water Quality Effectiveness Monitoring Report* (Sargeant and Svrjcek, 2008), was conducted in 2003-2005. This was a follow-up study of the Snoqualmie River TMDL conducted in 1989-1991 (Joy, 1994). This study also established guidelines for mainstem and tributary nutrient concentrations stating that excess nutrients are one of many potential causes of DO problems.

The purpose of this study was to: (1) determine how much water quality had improved, and (2) assess which areas need more resources and funds to improve water quality. Study results show that the water quality in the Snoqualmie River has improved, but more effort is needed to ensure that water quality criteria and TMDL targets are met. DO levels in the mainstem Snoqualmie have generally remained the same. Patterson, Tuck, and Cherry Creeks showed low DO levels at times including the critical period of August – October. More study is needed to determine if DO TMDL targets are met. The study indicated that water quality has been protected in many areas and is getting better in others. A variety of organizations continue to conduct many watershed improvement projects throughout the Snoqualmie River Basin. Ecology's TMDL Effectiveness Monitoring provides an excellent summary of restoration activities and water quality monitoring projects.

Federal Clean Water Act Requirements

The federal Clean Water Act established a process to identify and clean up the nation's polluted waters. Under the Clean Water Act, every state and many tribes have their own water quality standards designed to protect, restore, and preserve water quality. Water quality standards consist of designated uses for protection, such as cold water biota and drinking water supply, and criteria, usually numeric criteria, to achieve those uses.

Every two years, states are required to prepare a list of waterbodies that do not meet water quality standards. This list is called the Clean Water Act 303(d) list. In Washington State, this list is part of the Water Quality Assessment (WQA) process.

To develop the WQA, the Washington State Department of Ecology (Ecology) compiles its own water quality data along with data from local, state, and federal governments, tribes, industries, and citizen monitoring groups. All data in this WQA are reviewed to ensure that they were collected using appropriate scientific methods before they are used to develop the assessment. The list of waters that do not meet standards [the 303(d) list] is the Category 5 part of the larger assessment.

The WQA divides water bodies into five categories. Those not meeting standards are given a Category 5 designation, which collectively becomes the 303(d) list].

Category 1 – Waters that meet standards for parameter(s) for which they have been tested.

Category 2 – Waters of concern.

Category 3 – Waters with no data or insufficient data available.

Category 4 – Polluted waters that do not require a TMDL because they:

- 4a. – Have an approved TMDL being implemented.
- 4b. – Have a pollution-control program in place that should solve the problem.
- 4c. – Are impaired by a non-pollutant such as low water flow, dams, culverts.

Category 5 – Polluted waters that require a TMDL – the 303(d) list.

Project Description

Goal

The study goal is to gain a more complete understanding of DO concentrations in selected tributary subbasins of the Snoqualmie River valley flood plain. The study area includes the lower reaches of Cherry and Ames Creeks and their contributing agricultural waterways. Study results will be used for future water quality improvement projects and help form a basis for continuing investigations.

Objectives

The project objective is to monitor springtime DO concentrations in selected agriculture waterway networks and identify potential contributing variables. The following are detailed project objectives:

- Provide information about the possibility of low DO coinciding with high groundwater-to-surface water ratios during late spring following long periods of soil saturation.
- Continuous monitoring of DO, temperature, pH, and conductivity at selected sites from May – June 2011.
- Compare continuous water quality data collected from recently dredged and un-dredged agricultural waterways.
- Locate tile drains and collect DO grab samples from the runoff.
- Compare continuous water quality results between the Cherry and Ames subbasins.
- Compare results to water quality criteria.
- Note fish presence and fish kills when apparent.
- Provide a data summary/analysis report for use by collaborators and other interested parties.

Six surface water monitoring locations have been chosen in consultation with King County, Wild Fish Conservancy, and Ecology's Water Quality Program (Figures 2, 3, and Table 3). The six sites will be distributed in the lower extent of Cherry and Ames Creeks and in their contributing drainages. Comparisons between the subbasins will be possible based on data collection results. Comparisons between agricultural drainage waterways within the Ames subbasin will also be possible.

Field sampling details and specific site locations are discussed in the *Sampling Process Design (Experimental Design)* section of this project plan.

Potential constraints to field data collection and interpretation include: limited site accessibility, determining background conditions, equipment failure, equipment drift from calibration, flooding, sediment deposition on deployed equipment, surface water becoming stagnant or too shallow for proper data logging, or equipment loss due to vandalism or entrainment from high stream velocities. We will minimize the potential constraints on data collection.

Organization and Schedule

Table 1 lists employees involved in this project. Table 2 presents the proposed schedule for this project.

Table 1. Organization of project staff and responsibilities.

Staff (all are EAP except client)	Title	Responsibilities
Ralph Svrjcek Water Quality Program Northwest Regional Office Phone: (425) 649-7165	EAP Client	Clarifies scopes of the project. Provides internal review of the QAPP and approves the final QAPP.
Wendy Marsh Research Ecologist Wild Fish Conservancy Phone: (425) 788-1167	Project Manager/ Principal Investigator	Writes the QAPP. Oversees/conducts field sampling. Conducts QA review of data, analyzes and interprets data. Writes the draft report and final report.
James Kardouni Directed Studies Unit Western Operations Section Phone: (360) 407-6517	Project Manager/ Principal Investigator	Writes the QAPP. Oversees/conducts field sampling. Conducts QA review of data, analyzes and interprets data, and enters data into EIM. Writes the draft report and final report.
George Onwumere Directed Studies Unit Western Operations Section Phone: (360) 407-6730	Unit Supervisor for the Project Manager	Provides internal review of the QAPP and approves the final QAPP and final technical report. Reviews the project scope, budget, and tracks progress.
Robert F. Cusimano Western Operations Section Phone: (360) 407-6596	Section Manager for the Project Manager	Reviews the draft QAPP and approves the final QAPP.
William R. Kammin Phone: (360) 407-6964	Ecology Quality Assurance Officer	Reviews the draft QAPP and approves the final QAPP.

EAP: Environmental Assessment Program.
EIM: Environmental Information Management database.
QAPP: Quality Assurance Project Plan.

Table 2. Proposed schedule for completing field work, data entry into EIM, and reports.

Field and laboratory work	Due date	Lead staff
Field work completed	October 2011	Wendy Marsh and James Kardouni
Environmental Information System (EIM) database		
EIM user study ID	jkar0003	
Product	Due date	Lead staff
EIM data loaded	January 2012	James Kardouni
EIM quality assurance	February 2012	George Onwumere
EIM complete	March 2012	James Kardouni
Final report		
Author lead / Support staff	James Kardouni	
Schedule		
Draft due to supervisor	January 2012	
Draft due to client/peer reviewer	February 2012	
Draft due to external reviewer(s)	March 2012	
Final (all reviews done) due to publications coordinator	April 2012	
Final report due on web	May 2012	

Quality Objectives

To meet the objectives of this study, all field sampling and lab analysis will follow strict protocols outlined in this Quality Assurance (QA) Project Plan to ensure data credibility and usability.

Quality objectives are statements of the precision, bias, and lower reporting limits necessary to address project objectives (Table 5). Precision and bias together express data accuracy. Other considerations of quality objectives include representativeness and completeness. Quality objectives apply to field data collected by Ecology and WFC, and analysis methods used in this study.

Measurement quality objectives (MQO) state the acceptable accuracy for the data collected for a project. MQOs are discussed in detail in the *Quality Control* section. Sampling methods, protocols, and data analysis are discussed in detail in following sections.

Precision

Precision is defined as the measure of variability in the results of replicate measurements due to random error. Random error is imparted by the variation in concentrations of samples from the environment as well as other introduced sources of variation (e.g., field procedures). Precision for DO QA will be expressed as percent relative standard deviation (RSD). RSD = (standard deviation of the sample population) X 100 / (mean of the sample population).

Bias

Bias is defined as the difference between the sample value and true value of the parameter being measured. Bias affecting measurement procedures can be inferred from the results of quality control (QC) procedures involving the use of blanks, check standards, and spiked samples. Bias in field measurements and samples will be minimized by strictly following measurement, sampling, and handling protocols. Field measurement bias for DO is further discussed in the *Quality Control* section.

Sampling Process Design (Experimental Design)

This study will assess continuous water quality parameters in the lower portions of the Cherry and Ames watersheds. Data collection is targeted for late spring following long periods of water saturation in the Snoqualmie River flood plain. We will compare water quality results between the Cherry and Ames watersheds in order to assess different sub-regions and agricultural practices. We will also compare monitoring sites within each watershed. For example, in the Ames watershed there will be a side-by-side comparison between the dredged and un-dredged waterways assessing two different agriculture management practices.

Site Selection

Figures 2 and 3 and Table 3 display the sampling locations. Site selection is based on the following criteria and watershed characteristics:

- Sites located within the Snoqualmie River valley flood plain, with proximity within the APD.
- Presence of an unmaintained agricultural waterway with known water quality impairments (for example low DO).
- Replicate study site with similar soil, vegetation, and hydrologic characteristics that is managed with the same approach (unmaintained, undredged) waterway with or without drain tile influence, as in B.
- Comparison study sites with similar soil, vegetation, and hydrologic characteristics that are managed with an alternate approach (maintained, dredged) waterway, with or without tile drain influence.

Table 3. Cherry and Ames Creek monitoring locations.

Site Name	Site Description	Latitude	Longitude
Cherry 3-1	Cherry Creek above pump house	47.76039	-121.95702
Lateral A-2	Cherry Valley Lateral A, below all other laterals	47.76005	-121.95960
Lateral A-1	Cherry Valley Lateral A, above other laterals	47.75451	-121.96597
Ames 1	Ames Creek at 100th	47.68679	-121.98321
Dredged	Dredged waterway with drain tiles	47.68028	-121.97072
Undredged	Undredged waterway without drain tiles	47.68025	-121.97420

Latitude and Longitude coordinates derived from digital orthophotos, NAD 83 HARN datum.

Data Collection Procedures

WFC and Ecology will share field data collection duties. WFC will focus on collecting surface water and groundwater data. Ecology will focus on collecting continuous water quality data.

Multiprobe Data Logging Procedure

Deployed *Hydrolab*® data loggers will record DO (mg/L), temperature (°C), pH, and conductivity (µS/cm) at three locations in the Cherry and Ames watersheds. One data logger will be located in the Mainstem of Cherry Creek and another in the Mainstem of Ames Creek. Data loggers will be deployed recording continuously at 30 minute intervals during the spring freshet run-off cycle (May - June). On a weekly basis, *Hydrolab*® data will be saved and transferred to a laptop for data preservation and checked for proper logging. Data loggers not functioning properly will be replaced by a backup logger. Internal batteries will be refurbished on an as-needed basis. Data loggers will be cleaned during each site visit. Spot check measurements will be taken using a calibrated *Hydrolab*® for QA purposes. Additional DO grab samples will also be taken at discrete tile drain discharge locations to monitor surface water parameters.

Surface Water and Groundwater

A surface water budget will be conducted within isolated segments of drainage waterways contributing to Ames Creek to quantify the increase of volume that occurs from groundwater inputs. A handheld acoustic Doppler velocimeter (ADV), Marsh McBirney flow meter, or boat mounted acoustic Doppler profiler (ADP) will be used to obtain discharge measurements.

In Cherry Valley, staff gages will be used to monitor changes in surface water levels, and regional groundwater levels will be measured using local monitoring wells. As a result, relative elevations of surface water and groundwater levels will be established. In addition, a surface water budget will be conducted for mainstem Cherry Creek above and below the pump house (Figure 2) to quantify the discharge from the pump stations when water levels and conditions allow.

Observations and Data Collection

Other relevant data, e.g., precipitation and soil type, will be obtained from available sources. Observations of fish and their apparent condition will be recorded.

Where possible, the location and configuration of tile drains influencing drainage in the selected study sites will be documented.

Routine site visits will occur once or twice a week depending on data collection objectives. In general, Ecology will focus on *Hydrolab*® data retrieval. The WFC will focus on surface water discharge measurements and groundwater data collection. King County will focus on tile drain identification. In many cases these tasks will be shared as needed.

During each site visit, DO samples will be collected at each *Hydrolab*® station for quality assurance/quality control (QA/QC) purposes. The DO samples will be analyzed in the laboratory using the Winkler titration method. Instantaneous *Hydrolab*® readings will also be recorded at each sampling location and checked against the logged continuous data record.

Study results will help support ongoing and future investigations by many organizations involved in the Snoqualmie River watershed. This study may be extended by collecting data during November and December. The extension of data collection will depend on data needs, resources, and feasibility of sampling during potentially high surface water levels.

Sampling Procedures

Field sampling and measurement procedures will follow Standard Operating Procedures (SOP) developed by Ecology's Environmental Assessment Program including:

- EAP033 *Hydrolab DataSonde and MiniSonde Multiprobes* (Swanson, 2007).
- EAP023 *Collection and Analysis of Dissolved Oxygen (Winkler Method)* (Ward and Mathieu, 2011).
- EAP024 *Estimating Streamflow* (Sullivan, 2007).
- EAP071 *Minimizing the Spread of Aquatic Invasive Species from areas of Moderate Concern* (Ward et al., 2010).

SOP documents can be found on the web at: www.ecy.wa.gov/programs/eap/quality.html.

Measurement Procedures

Instantaneous streamflow measurements, water quality measurements, and relative water level measurements (groundwater/surface water) will be taken during each visit to a site whenever safe and practical. Flooding can back up surface water flow and may make streamflow difficult to assess. In contrast, low flow can cause stagnation or water too shallow to accurately measure streamflow. Additional water quality parameters will be measured using a multi-probe/data-Sonde following the *Standard Operating Procedure (SOP) for Hydrolab® DataSonde® and MiniSonde® Multiprobes* (Swanson, 2007). Parameters measured by the *Hydrolab®* and recorded in the field log include: temperature (°C), DO (mg/L), specific conductivity (uS/cm), pH, and percent battery voltage (IBP) of logging instruments.

Quality Control Procedures

Field

Before each sampling event, field instruments will be assessed for proper function. Table 4 shows the general specifications of field instruments used for this study. The SonTek FlowTracker Handheld-ADV (Acoustic Doppler Velocimeter), SonTek/YSI ADP (Acoustic Doppler Profiler), and Marsh McBirney streamflow meters will be checked and adjusted according to factory specifications. The *Hydrolab*® multi-meters will be calibrated to standards both before and after long-term deployment or sampling event. The *Hydrolabs*® under long-term deployment may be recalibrated in the field as needed.

Table 4. Field instrument specifications.

Analysis	Instrument	Method	Range	Accuracy	Resolution
Stream Velocity	Marsh McBirney Flow Mate	EAP056	0.01 to 5.00 feet/second (ft/s)	± 0.05 ft/s	0.01 ft/s
	SonTek Flow Tracker Handheld-ADV		0.003 to 13 ft/s	±1% of measured velocity, ±0.008 ft/s	0.0003 ft/s
	SonTek/YSI ADP		0 to 32.8 ft/s	±1% of measured velocity, ±0.016 ft/s	0.003 ft/s
Water Temperature	Hydrolab Sonde®	SM2550B-F	-5C° to 50°C	± 0.10°C	0.01°C
Specific Conductivity	Hydrolab Sonde®	EPA120.1M	1 to 100,000 µS/cm	± (0.5% of reading + 1 µS/cm)	0.1 to 1 µS/cm
Dissolved Oxygen	Hydrolab Sonde®	Hach 10360	1 to 60 mg/L	± 0.1 mg/L at ≤ 8 mg/L, ± 0.2 mg/L at > 8 mg/L	0.01 mg/L
pH	Hydrolab Sonde®	EPA150.1M	0 to 14 pH units	± 0.2 units	0.01 units

ADV: Acoustic Doppler Velocimeter.
ADP: Acoustic Doppler Profiler.
YSI: Yellow Spring Illinois.

Table 5 shows the precision MQO for the *Hydrolab*® post field calibration. If any of these QC procedures are not met, the associated results will be qualified and used with caution, or not used at all.

Table 5. Field instrument calibration measurement quality objectives (MQO) for precision.

Measured Field Parameter	Units	Data Qualifier and Definition		
		accept	estimate	reject
Specific Conductivity (SpCond)	uS/cm	≤ ± 5%	> ± 5% and ≤ ± 10%	> ± 10%
Dissolved Oxygen (DO)	% saturation	≤ ± 5%	> ± 5% and ≤ ± 15%	> ± 15%
pH	standard units	≤ ± 0.25	> ± 0.25 and ≤ ± 0.5	> ± 0.5

The *Hydrolab*® DO probe will be checked against grab samples for QA/QC. All *Hydrolab*® monitoring sites will include a DO grab sample to be analyzed using the Winkler titration method (SM4500OC) described in Ecology's SOP manuals. The results from the titration and *Hydrolab*® will be compared using RSD. RSD values greater than 10% will result in using a data qualifier to flag the field data fulfilling precision MQOs for DO. Bias will be evaluated between *Hydrolab*® readings and Winkler titrations by the calculated average residual. *Hydrolab*® DO data will be corrected if significant bias is calculated.

DO results from spot-check measurements and Winkler titrations will be evaluated against the logged DO values. If the results are greater than 10% RSD, then the logging *Hydrolab*® will be replaced or recalibrated in the field.

Data Management Procedures

Field measurement data will be entered into a notebook of waterproof paper and then carefully entered into EXCEL® spreadsheets (Microsoft, 2007). WFC and Ecology will share field notes/data in printed format, EXCEL® spreadsheets, or other suitable media. Data will be checked to ensure transfer accuracy. This database will be used for preliminary analyses and QA/QC. Data will be uploaded into Ecology's Environmental Information Management (EIM) System after verification and validation.

An EIM user study (JKAR0003) has been created for this study. All monitoring data will be available via the internet. The web address for this geospatial database is: www.ecy.wa.gov/eim/. All finalized data will be uploaded to EIM by the EIM data engineer.

All spreadsheet files, paper field notes, and Geographic Information System (GIS) products created as part of the data analysis will be kept with the project data files. Data that do not meet acceptability requirements will be separated from data files and not used for analysis.

Audits and Reports

The project manager is responsible for verifying data completeness. The project manager is also responsible for writing the final technical report. The final technical report will undergo the peer review process by staff with appropriate expertise.

The final report will include analyses of results that form the basis of conclusions and recommendations. Results will include site-specific information of DO concentrations, data charts, other water quality parameters, stream/drainage discharge measurements, deployment summaries, drainage networks, and field observations.

Data Verification and Validation

Data Verification

Field data will be verified by the project manager. Staff will check field notebooks for missing or improbable measurements before leaving each site. Data entry will be checked against the field notebook data for errors and omissions.

Data Validation

Field data, once entered into EXCEL® (Microsoft, 2007), will be checked for errors against field notebooks. Corrections will be made as needed. Once data have been vetted (QA/QC) they will be ready for analytical use and report writing. They will then be loaded into EIM. *Hydrolab*® post field calibration results will be compared to quality objectives in Table 5 and qualified accordingly.

Data Quality (Usability) Assessment

The project manager will verify that all measurement and data quality objectives have been met for each monitoring station. If the objectives have not been met, consideration will be taken to qualify the data, how to use it in analysis, or whether data should be rejected. Documentation of the data quality and decisions on data usability will provide accuracy and transparency of the QA/QC procedures. The data quality assessment methods and results will be documented in individual project data files and summarized in the final technical report.

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Appendix. Glossary, Acronyms, and Abbreviations

Glossary

Clean Water Act: A federal act passed in 1972 that contains provisions to restore and maintain the quality of the nation's waters. Section 303(d) of the Clean Water Act establishes the TMDL program.

Conductivity: A measure of water's ability to conduct an electrical current. Conductivity is related to the concentration and charge of dissolved ions in water.

Dissolved oxygen (DO): A measure of the amount of oxygen dissolved in water.

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

Parameter: A physical chemical or biological property whose values determine environmental characteristics or behavior.

pH: A measure of the acidity or alkalinity of water. A low pH value (0 to 7) indicates that an acidic condition is present, while a high pH (7 to 14) indicates a basic or alkaline condition. A pH of 7 is considered to be neutral. Since the pH scale is logarithmic, a water sample with a pH of 8 is ten times more basic than one with a pH of 7.

Pollution: Contamination or other alteration of the physical, chemical, or biological properties of any waters of the state. This includes change in temperature, taste, color, turbidity, or odor of the waters. It also includes discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state. This definition assumes that these changes will, or is likely to, create a nuisance or render such waters harmful, detrimental, or injurious to (1) public health, safety, or welfare, or (2) domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or (3) livestock, wild animals, birds, fish, or other aquatic life.

Reach: A specific portion or segment of a stream.

Riparian: Relating to the banks along a natural course of water.

Salmonid: Any fish that belong to the family *Salmonidae*. Basically, any species of salmon, trout, or char. www.fws.gov/le/ImpExp/FactSheetSalmonids.htm

Stormwater: The portion of precipitation that does not naturally percolate into the ground or evaporate but instead runs off roads, pavement, and roofs during rainfall or snow melt. Stormwater can also come from hard or saturated grass surfaces such as lawns, pastures, playfields, and from gravel roads and parking lots.

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

Total Maximum Daily Load (TMDL): A distribution of a substance in a waterbody designed to protect it from not meeting (exceeding) water quality standards. A TMDL is equal to the sum of all of the following: (1) individual wasteload allocations for point sources, (2) the load allocations for nonpoint sources, (3) the contribution of natural sources, and (4) a margin of safety to allow for uncertainty in the wasteload determination. A reserve for future growth is also generally provided.

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

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

Acronyms and Abbreviations

APD	Agricultural production district
DO	(See Glossary above)
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
et al.	And others
MQO	Measurement quality objective
QA	Quality assurance
RM	River mile
RSD	Relative standard deviation
SOP	Standard operating procedures
TMDL	(See Glossary above)
WAC	Washington Administrative Code
WFC	Wild Fish Conservancy

Units of Measurement

°C	degrees centigrade
cfs	cubic feet per second
ft	feet
kcfs	1000 cubic feet per second
kg	kilograms, a unit of mass equal to 1,000 grams.
kg/d	kilograms per day
km	kilometer, a unit of length equal to 1,000 meters.
mL	milliliters
uS/cm	microsiemens per centimeter, a unit of conductivity