Quality Assurance Project Plan

Phase II: Protection & Restoration Plans for Select B-IBI Basins

Water Quality NEP Stormwater Initiative Interagency Agreement No. WQNEP-2016-KCWLRD-00016

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Prepared by

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

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Next-Phase Protection & Restoration Plans for Select B-IBI Basins

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2.0 Abstract

The purpose of this project is to address Puget Sound Partnership (PSP) recovery goals related to freshwater quality and protection and restoration of streams in the Puget Sound Basin. This project addresses two current near-term action initiatives by prioritizing areas for restoration and protection (Stormwater A1.1) and supporting local governments to adopt and implement plans consistent with recovery targets (Habitat A1.2, PSP 2016).

The primary objectives of the project are to:

- Identify 10 healthy basins needing protection and three degraded basins needing restoration, as indicated by regional stream macroinvertebrate data.
- Evaluate candidate environmental stressors for each degraded basin and develop restoration plans to target those stressors.
- Develop protection plans for healthy basins to ensure their long-term health.

Select basins will be chosen from over 1200 potential sites throughout the Puget Sound Basin that have been routinely characterized using the Puget Lowland benthic index of biotic integrity (B-IBI). B-IBI scores are based on the aquatic macroinvertebrate community present at each site. Low B-IBI scores indicate impaired stream conditions, while high scores indicate healthy stream conditions. B-IBI scores at a site typically reflect land use conditions in the upstream contributing drainage area ("basin"). Thus, information from each site is meant to inform plans developed for its basin.

King County will enhance existing basin characterization and mapping information in 13 basins through collection of macroinvertebrate and physical habitat data, and a thorough assessment of potential stressors within each basin. Physical habitat conditions at each B-IBI site will be assessed during field surveys, and macroinvertebrate samples will be collected to confirm the current B-IBI score. For degraded sites, an assessment of potential stressors will be based on these new data, a review of existing data related to water or habitat quality, and relevant information available regarding land use, hydrologic conditions, and previous disturbances. King County will also work with local land and water resource managers who are familiar with the history and future plans for the selected basins.

Results will be used to develop restoration plans that address identified stressors with the goal of improving B-IBI scores in three degraded basins. Protection plans will be developed for 10 basins that are currently in excellent condition. These basin-specific plans will serve as guides for future restoration and protection actions.

3.0 Background

3.1 Introduction and problem statement

Puget Sound Partnership Recovery Targets

The overall goal of the Puget Sound Partnership (PSP) is to restore Puget Sound. Many streams that drain into Puget Sound are threatened from pollutant runoff and altered flow regimes. Such

threats may result in extinction of aquatic species or a decline in biodiversity. This project implements priority work consistent with the PSP Action Agenda for the protection and restoration of Puget Sound by addressing the Ecosystem Recovery Target associated with freshwater quality and benthic macroinvertebrates (PSP 2012).

Specifically, this project addresses the targets for one of PSP's Freshwater Quality indicators, the Puget Lowland Benthic Index of Biotic Integrity (B-IBI):

> *By 2020, 100% of Puget Sound lowland stream drainage areas monitored with baseline B-IBI scores of 42-46 or better retain these "excellent" scores and mean B-IBI scores of 30 Puget Sound lowland drainage areas improve from "fair" to "good".* [1]

Benthic macroinvertebrates play a crucial role in stream ecosystems and are good indicators of ecological health. The multi-metric B-IBI is a standardized scoring system applied to benthic macroinvertebrates collected from streams. The B-IBI was developed in the early 1990's, and recalibrated in 2012, and is widely used to report stream health by cities, counties, tribes and state agencies in the Puget Sound Basin.

To maintain "excellent" B-IBI scores, protection plans are needed to maintain the physical, chemical, and biological conditions and processes that support a diverse community at a site. Protection of intact and high quality watersheds has been an effective and efficient strategy for managing regional water resources and water quality. For example, cities around the world have long recognized that protecting their water supply often requires protection of the watershed that delivers that supply.

To improve "fair" sites, restoration plans are needed to improve the degraded conditions and processes that have led to the decline or loss of sensitive macroinvertebrate species. The presumption is that if stressors can be identified and ameliorated, sensitive taxa will recolonize the site or increase in density resulting in improved B-IBI scores. Improved B-IBI scores are thought to be an indicator reflective of improved stream health and ecological integrity for the entire basin.

A Multi-phased Approach

The work described here represents the second phase of a five-phase project (Table 1). The first phase (funded by Ecology and completed in 2015) identified Puget Sound basins that were candidates for restoration and protection and outlined general restoration and protection strategies (King County 2015a) for these basins. In this second phase, King County will develop basin-specific strategies to restore three "fair" basins and protect 10 "excellent" basins.

Table 1. Phases of the Restoration and Protection Project for Select Puget Sound Basins.

[1] Original PSP targets used the 10-50 B-IBI scale. The project described here uses the recently recalibrated B-IBI that includes the same narrative ratings (e.g., "very poor" to "excellent"), but is based on a 0-100 scale. On this scale, "excellent" is defined as scores greater than or equal to 80.

Phase	Description
1	Develop framework to select basins and complete initial evaluation of actions that may be needed to restore and/or protect basins.
2	**This Project: Complete more detailed analysis and mapping, and develop basin-specific plans to restore 3 basins and protect 10 basins.**
3	Complete detailed basin-specific plans (with pre-build designs as needed, complete budget) for each basin.
4	Implementation of restoration and protection actions in each basins.
5	Effectiveness monitoring and dissemination of results.

This project addresses regional priorities for stormwater; specifically, King County will improve watershed characterization assessments and create maps that identify areas within each selected basin that are most likely important for protection and/or restoration. This project is the next step necessary to implement and meet freshwater B-IBI recovery targets.

3.2 Study area and surroundings

The Puget Sound Basin encompasses all land in Washington State that drains to Puget Sound, South of the Strait of Georgia and East of the Strait of Juan de Fuca, bounded by the Cascade Mountains in the East and the Olympic Mountains on the West. For the purposes of this study, sites will be selected from watersheds/basins within the Puget Sound Lowland Ecoregion (Figure 1), and not be limited to ones within King County.

The Puget Lowland Ecoregion is characterized by a mild maritime climate with annual precipitation averaging 800-900 mm (31.5-35.5 inches). Most non-forest land use (urban, rural, and agriculture) in the Puget Sound Basin is located within this ecoregion. Approximately 4 million people live within the area's 12 counties, and the population is projected to increase to over 5 million by 2040 (Puget Sound Regional Council 2015).

The project study area will include thirteen stream sites within the portion of the Puget Lowlands Ecoregion that is within the Puget Sound Basin (Figure 1). Site selection is one of the first project tasks (see Project Description). A complete description of each site and its contributing basin will be included in the final reports.

Figure 1. Study area is the portion of the Puget Lowlands Ecoregion (outlined in green) that is within the Puget Sound Basin (outlined in purple).

3.2.1 History of study area

Many streams that drain into Puget Sound are threatened from pollutant runoff and altered flow regimes. Aquatic communities, including macroinvertebrates and fish, have been impacted by these degraded conditions. BIBI scores in more than half of the stream sites within the Puget Sound lowlands score "fair" or below, and several fish species are listed as threatened (e.g., Hood Canal Summer-run Chum salmon, Puget Sound Chinook salmon and Puget Sound Steelhead.

Puget Sound area streams are affected by historic and current land use practices including urbanization, resource extraction (logging and mining), and agriculture. These practices have led to loss of habitat, increased sedimentation, altered flow regimes, increased temperatures, and the introduction of pollutants. These stressors have negatively impacted macroinvertebrate community structure and ecological integrity.

3.2.2 Summary of previous studies and existing data

B-IBI scores have been used extensively since the mid-1990s as an integrated measure of stream health, and the index is now being used by PSP as an indicator for freshwater quality. A key strength of the index is that scores reflect the cumulative impacts of stressors on stream communities. However, a limitation is that scores do not indicate the specific causal factor of impairment.

Phase I of this effort (King County 2015a) developed a framework for identifying and prioritizing "fair" sites for restoration. Based on B-IBI data available at the time and additional information about the basins, 54 "fair" sites were prioritized for restoration. Phase 1 also identified a process to select basins with "excellent" B-IBI scores to be targeted for protection. Based on the analysis of 1294 sites, 101 stream basins were identified for protection. Potential restoration and protection actions were discussed in Phase I (King County 2015a); however, no field data were collected and no stressor analyses were conducted to determine specific actions necessary to protect or restore each basin.

Recommendations from Phase I included the development of basin-specific plans for select basins. The report outlined the general rationale for restoration and protection actions, but it was clear that each basin had unique combination of stressors that affect the macroinvertebrate community at the sampling site.

Phase I was a broad-brush approach, describing potential management, restoration and conservation actions to meet PSP's protection and restoration targets associated with B-IBI. Further investigation and updated information on the effectiveness of specific actions, plus continued engagement with local stakeholders on the basins is needed to further the project and shift the focus towards implementation.

3.2.3 Parameters of interest and potential sources

This project will collect new data and review existing data for a number of parameters (Table 2). This project does not directly measure water quality or pollutants, though if water quality data were readily available for the selected basins they will be included in the analysis.

Table 2. Summary of the data types to be collected or reviewed for the 13 select basins.

Type of Data	Source	Process
Macroinvertebrate data	Field sampling at each of the 13 select B-IBI sites	New data will be collected in 2017 and 2018; available historical data will be reviewed
Physical habitat data	Field surveys (using Ecology SOPs), including: temperature, reach slope, bearing, thalweg profile, habitat unit, channel dimensions, fish cover, bank erosion, substrate and embeddedness, human influence, riparian vegetation structure, riparian cover, large woody debris, discharge	New data will be collected in 2017 and 2018; existing data will be reviewed for usability
Geospatial data	Land use/land cover, city/county jurisdictions, surficial geology, and land ownership data from national, state and local data sources (see 7.4 for details)	Geospatial data will be reviewed at multiple scales for each select basin
Hydrologic data	Continuous flow data from newly installed or existing gages at the 3 fair sites	If not already present at a site, gages will be installed and flow measured at the 3 fair sites from Oct 1, 2017 through September 30, 2018; any additional data available will be reviewed
Water quality data	EIM, King County Environmental Laboratory, other local jurisdictions if select basins are outside of King County	No new water quality data will be collected, but existing data will be reviewed for usability
Historical information about area and basins (e.g., history of landslides, industrial activities, timber harvest activities)	Outreach to local and state managers familiar with the select basins	Information will be gathered throughout 2017 and 2018

4.0 Project Description

This project implements priority work consistent with the PSP Action Agenda for the protection and restoration of Puget Sound by addressing the PSP's Ecosystem Recovery Targets associated with freshwater benthic macroinvertebrates. The Puget Lowland B-IBI is a PSP vital sign indicator used to evaluate whether progress is being made towards restoring Puget Sound. The PSP has two ecosystem recovery targets related to freshwater benthic macroinvertebrates: one involves protecting all streams and small rivers throughout Puget Sound currently with "excellent" B-IBI scores (e.g., ≥80) and the second calls for improving conditions in 30 streams with "fair" B-IBI scores (e.g., 40-60).

This is the second phase of a five-phase project (Table 1). Analysis of basins was initiated in Phase I and included watershed characterization (using the Puget Sound Watershed Characterization [PSWC] model, Ecology 2012) and review of GIS-based land use data. Candidate basins were identified, and general strategies for improving or protecting ecological integrity were presented (i.e., increase riparian buffers or implement stormwater best management practices).

Basin Selection

For this phase (Phase II) of the project, King County will select three "fair" basins for restoration planning and ten "excellent" basins for protection.

Three "fair" basins will be selected using the decision framework developed in Phase I of the project. The framework was used previously to generate a list of 54 candidate sites; however, more recent data are now available for these and additional sites. To ensure the most current data are used for decision making it will be necessary to update the candidate site list. Therefore, data from the Puget Sound Stream Benthos (PSSB) database (http://www.pugetsoundstreambenthos.org/) will be downloaded, and a new candidate site list will be generated using the original decision framework. The decision framework includes filtering criteria that exclude a site if: 1) the B-IBI data are limited or collected more than five years ago, 2) the basin is too small or too large (<200 acres or >3000 acres), 3) the site is outside of the Puget Lowlands Ecoregion, or 4) the basin is hydrologically unimportant and already degraded (based on the PSWC water flow model). Details of how the PSWC model is used to filter sites are outlined in the "B-IBI Restoration Decision Framework and Site Identification" document (King County 2014a).

Using the updated candidate site list, additional criteria will be considered to further refine the list to three "fair" basins. The criteria will include factors that will affect the stressor identification process, the feasibility of implementing actions and the likelihood of their future success. Criteria may include, but are not limited to:

1) Availability of sufficient environmental data to evaluate potential stressors;
2) Likelihood that King County will obtain property access to conduct sampling;
3) Likelihood that basins will benefit from other actions (e.g., salmon recovery efforts, planned stormwater retrofits, other protection or restoration actions);
4) Presence of an active community group, such as a "stream team" and
5) Other local support for restoration and protection actions.

Based on these factors, sites deemed to have the greatest likelihood to successfully meet the project objectives will be selected.

The decision framework developed in Phase I to select 10 "excellent" sites will be used to select the initial list of candidate "excellent" sites. Using the most recent data, an updated list of candidate sites will be generated. This framework applies several filters that exclude sites from further consideration if the B-IBI scores fall below "excellent" more often than not, or if recent scores have decreased. Additional criteria will be applied (i.e., setting a minimum median score or minimum number of excellent scores) to help narrow the number of candidate sites for consideration. As described above for "fair" sites selection, feasibility and potential for success will also be assessed to select the final list of 10 "excellent" sites.

Stressor Identification and Basin Planning for Selected Basins

For each selected basin, King County will enhance the previous characterization and mapping efforts conducted in Phase I by adding data from field habitat surveys, additional macroinvertebrate sampling and analysis, and a more thorough assessment of potential stressors within each basin. In-channel and riparian condition will be assessed during field surveys, and macroinvertebrate samples will be collected to confirm the current B-IBI score. King County will consult with local natural resource managers familiar with the basins to identify and better understand past disturbances that may have affected stream communities or future actions that may affect stream conditions.

For the three restoration basins, where environmental stressors are thought to impact stream communities, additional tasks will include stressor identification analysis. To assess hydrologic conditions and possible hydrologic stressors in these basins, flow gages will be installed near the B-IBI site. King County will use available hydrologic, water quality and macroinvertebrate data to identify stressors in the restoration basins. Stressor identification analysis will follow the causal analysis process used by Ecology and the Environmental Protection Agency (EPA) in the context of TMDL development (Total Maximum Daily Load) (Ecology 2013). If needed, King County will utilize additional tools such as multivariate statistics to help identify which invertebrate taxa are most sensitive to stressors and changes over time.

This project addresses regional priorities for stormwater management and is the necessary next step towards implementation to meet recovery targets. Maps identifying areas within the 13 study basins appropriate for protection, restoration and low impact development will be created. The current characterization of each basin will be expanded by the addition of macroinvertebrate and field habitat survey data, and a more in-depth assessment of priority protection areas and potential stressors in each basin. Base maps, including stream layers, catchment boundaries, and stream typing for each basin, will be assessed and improved if needed. This work should also inform strategies for stream restoration throughout Puget Sound.

This project focuses on the scientific and technical challenges associated with identification of stressors and development of appropriate solutions. Other considerations, such as identification of funding sources for implementation and securing community partnerships for long-term monitoring, will be developed in future phases.

4.1 Project goals

The overall goal of Phase II of the project is to identify stressors and develop basin-specific plans to restore three Puget Sound stream basins that have "fair" B-IBI scores to "good" B-IBI scores, and develop protection plans for ten Puget Sound stream basins that have "excellent" B-IBI scores.

4.2 Project objectives

The project objectives are to:

- Select three "fair" and ten "excellent" basins using the candidate basin selection criteria developed in Phase I of the project.
- Gather basin-specific data to help identify stressors and inform development of restoration and protection plans. These data will originate from physical habitat surveys, macroinvertebrate samples, geospatial analysis, hydrologic measures, and additional site information that can be obtained from managers familiar with the basins.
- Identify stressors that are likely affecting habitat and water quality conditions in the select basins.
- Create maps of each basin that detail stressor location and where actions should be targeted.
- Develop restoration plans for the three "fair" basins with the goal of improving B-IBI scores to "good".
- Develop protection plans for the ten "excellent" basins with the goal of maintaining their B-IBI scores.

4.3 Information needed and sources

King County will select sampling sites that have been monitored previously and are included in the PSSB database. All B-IBI data available as of August 2017 will be considered. The target sites will be selected based on previous data, as well as information about the contributing upstream drainage area. For the purposes of this project and document, the upstream drainage area that contributes flow to the site will be referred to as a "basin" (Figure 2).

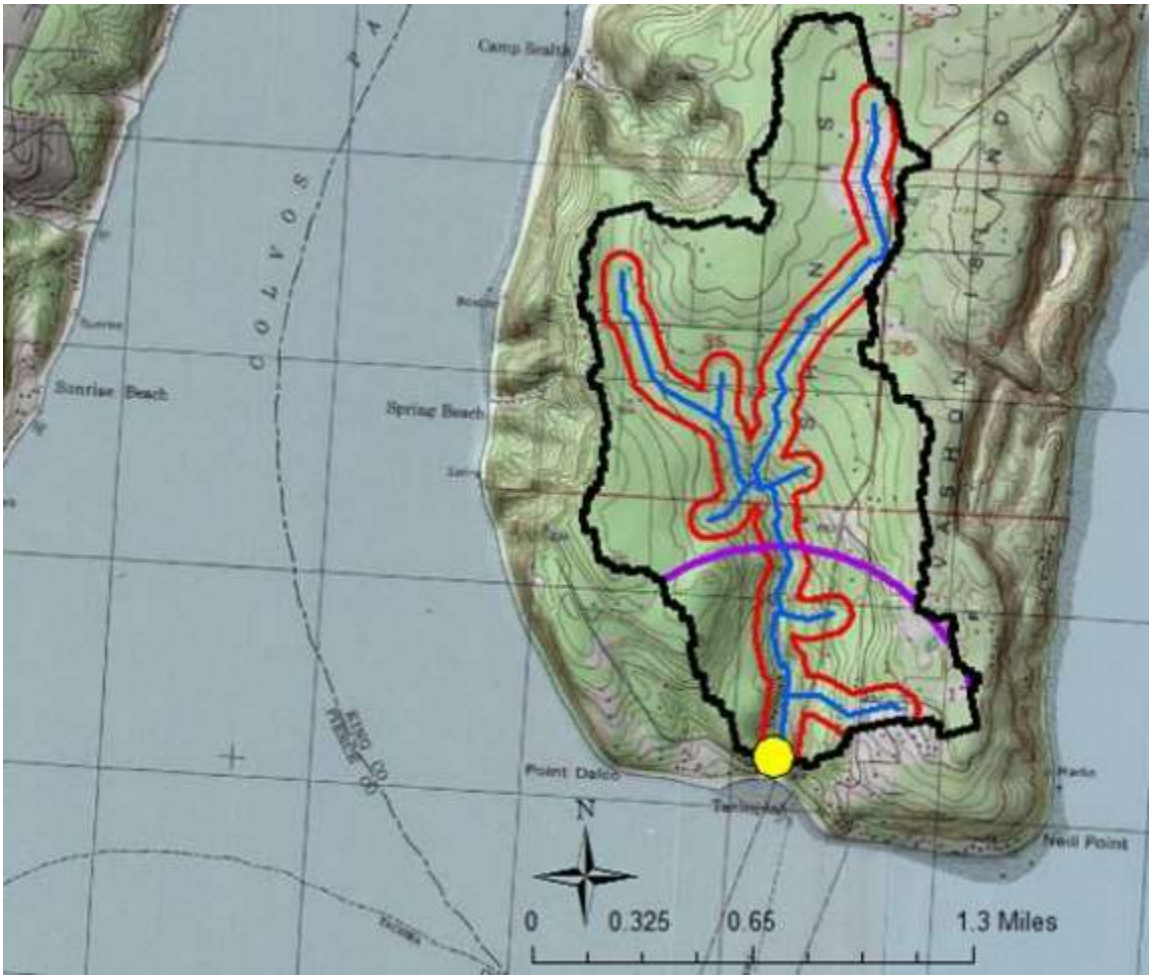

Figure 2. The basin and riparian areas that will be evaluated for each benthic macroinvertebrate sampling location, indicated by yellow dot.

The basins associated with macroinvertebrate sampling locations in the PSSB were delineated following methods developed by the EPA (2011a, 2011b) and King County (2013) based on the 30 meter National Elevation Dataset (2004) available from the National Hydrography Dataset (Figure 4). Landscape data were evaluated at up to four spatial scales: (1) within the upstream contributing watershed, (2) within a 1-km radius of the contributing watershed, (3) within a 90-m buffer in the contributing watershed, and (4) within a 90-m buffer in the 1-km contributing watershed (Figure 2) (King County 2014d). These 90-m riparian buffer calculations and "local" (1-km) contributing watersheds provide data within close proximity to the site, while the watershed data reflect conditions across the entire drainage area upstream of a site.

The processes outlined in Section 4.0 will be used to select basins. Existing macroinvertebrate data and land use data will be considered, as well as other readily available information. Once the 13 selected basins are identified, macroinvertebrate and habitat surveys will be conducted at each B-IBI site. Geospatial data will be reviewed for each of the select basins at the four scales described above (Figure 2). In addition, data from other B-IBI sites and their basins may be considered when analyzing potential stressors in the select basins. These additional data would be used to provide context and may inform the stressor identification process.

4.4 Tasks required

The primary tasks associated with this project are listed in Table 3.

Table 3. King County tasks and descriptions.

Task	Title	Description
1	QA Project Plan Development	Detailed project plan and timeline, QAPP
2	Project Administration & Management	Quarterly progress reports and invoicing, documentation, communication, FEATS reporting, Puget Sound Partnership NTA reporting, STORET data collection and reporting
3	Selection of Target Basins	Select 3 “fair” and 10 “excellent” basins from Puget Sound Stream Benthos database
4	Collection & Analysis of New and Existing Data	Conduct B-IBI surveys, physical habitat surveys, hydrologic monitoring (in 3 fair basins, install temperature and flow gages); gather geospatial data and conduct geospatial analysis; outreach to local managers
5	Stressor Identification	Identify potential stressors in each basin and evaluate all new and existing data to identify most likely stressors; build HSPF flow model for one or more basins if appropriate
6	Draft and Final Report on Restoration Basins	Prepare draft and final reports, including descriptions and maps for restoration actions
7	Draft and Final Report on Protection Basins	Prepare draft and final reports, including descriptions and maps for protection actions
8	Outreach & Dissemination	Web site, presentations, local/regional meetings

4.5 Systematic planning process used

Several systematic planning processes will be used throughout this project. The selection framework developed in Phase I of the project will be used (King County 2014a and 2014b) to select the thirteen target sites. Additional selection criteria will be used to choose the final 13 sites and described in the final reports The stressor identification analyses will follow the guidelines outlined by the EPA in their Causal Analysis/Diagnosis Decision Information System (CADDIS) conceptual model (https://www3.epa.gov/caddis/) in addition to Ecology’s Guidance for Stressor Identification of Biologically Impaired Aquatic Resources in Washington State (Ecology 2010a).

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

Table 4. Organization of project staff and responsibilities.

Staff	Title	Responsibilities
Derek Day WA Department of Ecology, Water Quality Program Phone: 360-407-7612	Stormwater Strategic Initiative Lead	Clarifies scope of the project. Provides internal review of the QAPP and approves the final QAPP.
Kate Macneale King County - WLRD Science and Tech. Section Phone: 206-477-4769	Project Manager/Principle Investigator	Writes QAPP. Oversees field sampling and transportation of samples to the laboratory. Conducts QA review of data, analyzes and interprets data, and enters data into EIM. Writes the draft report and final report.
Liora Llewellyn King County - WLRD Science and Tech. Section Phone: 206-263-0594	Investigator	Helps write the QAPP, conducts field sampling, analyzes and interprets data, creates maps and assists in writing reports.
Beth Sosik King County – WLRD Science and Tech. Section Phone: 206-263-01680594	Investigator	Assists with gathering and analyzing geospatial data, assists with field sampling
Andrew Miller King County – WLRD Science and Tech. Section Phone: 206-477-4806	Hydrologist	Install and maintain gaging equipment
Dan Lantz King County – WLRD Science and Tech. Section Phone: 206-477-4746	Investigator	Conducts field sampling
Houston Flores King County – WLRD King County Env. Lab Phone: 206-477-5192	Investigator	Conducts field sampling
Deborah Lester King County - WLRD Science and Tech. Section Phone: 206-477-4752	Unit Supervisor for the Project Manager	Provides internal review of the QAPP, approves the budget, and approves the final QAPP.
Dave White King County - WLRD Science and Tech. Section Phone:206-477-4847	Section Manager for the Project Manager	Reviews the project scope and budget, tracks progress, reviews the draft QAPP, and approves the final QAPP.
Josh Baldi King County - WLRD Phone: 206-477-9440	Director of WLRD	Approves final report
Colin Hume WA Department of Ecology SEA Program Phone: 360-319-4727	Project Manager, Puget Sound Watershed Characterization	Helps evaluates candidate basins using the Puget Sound Watershed Characterization model
Wease Bollman Rhithron Associates, Inc. Phone: 406-721-1977	President, Rhithron Associates, Inc.	Reviews macroinvertebrate sample and QC data

Staff	Title	Responsibilities
Tom Gries Department of Ecology EAP Phone: 360-407-6327	Ecology' NEP Quality Assurance Coordinator	Reviews the draft QAPP and recommends approval of the final QAPP. Reviews draft project report.
Bill Kammin Department of Ecology EAP Phone: 360-407-6946	Ecology Quality Assurance Officer	Reviews and approves the final QAPP.

EAP: Environmental Assessment Program
EIM: Environmental Information Management database
QAPP: Quality Assurance Project Plan
SEA: Shorelands and Environmental Assistance

5.2 Special training and certifications

All county field staff have extensive experience using the SOPs listed in Section 8.0, or will be trained to do so and supervised by an expert. Kate Macneale, Liora Llewellyn, and Dan Lantz attended a training led by Ecology that covered methods used for Watershed Health Monitoring (WHM). The training was held in June of 2017 and focused on the narrow protocol that will be appropriate for the selected basins. Training included the use of Ecology's e-forms. Dan Lantz has attended the training three times and has followed the SOPs listed in Section 8.0 for several projects in the last five years. Houston Flores is also familiar with the SOPs and e-forms. He took the training in 2015 and has used the SOPs for two projects within the last two years. Beth Sosik will attend the 2018 Ecology training session and assist with sampling in 2018.

King County staff are also proficient in benthic macroinvertebrate sampling. Kate Macneale has a PhD in Entomology and has been regularly conducting benthic macroinvertebrate sampling for over twenty years. Liora Llewellyn has collected hundreds of benthic macroinvertebrate samples over three years as an Environmental Aide for King County. Houston Flores and Dan Lantz have also sampled macroinvertebrates extensively using King County's and Ecology's SOPs. Additional King County staff, including Environmental Aides, hired by King County to conduct the County's ambient macroinvertebrate samples, may also help collect macroinvertebrate samples for this project. They will be trained and supervised by Kate Macneale and Liora Llewellyn.

King County staff have additional training and experience in GIS, hydrology and ecological sampling. Liora Llewellyn has a BA in Geography with a minor in GIS and over 10 years' experience with map-making and spatial analysis. Andrew Miller has a BS and Masters in Hydrology, and over 5 years of experience installing gauges, creating rating curves and analyzing hydrologic data from streams. Beth Sosik has extensive experience investigating insects as indicators of habitat quality and has conducted advanced geostatistical processing and analysis on large spatial datasets.

Rhithron taxonomists have extensive expertise identifying and counting macroinvertebrates, each having multiple certifications from the Society for Freshwater Science (http://rhithron.com/taxonomy-staff-2/).

5.3 Organization chart

See Table 4 for primary staff and their roles. As mentioned above, King County Environmental Aides may also assist with macroinvertebrate sample collections. They will be trained and supervised by Kate Macneale and Liora Llewellyn.

In addition, local jurisdictions and communities associated with each basin may provide additional information that may help characterize individual basins. If they are involved in any field work and do not already have the appropriate experience and training, they will be trained by Kate Macneale. These partners will be identified once specific basins are identified.

5.4 Proposed project schedule

The proposed project schedule is listed in Table 5.

Table 5. Proposed project schedule. Activities will be occurring during months shaded grey.

Task	Activity	2017							2018												2019							
		Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
1.1	Complete detailed project plan																											
1.2	Write and finalize QAPP																											
2.1	Submit quarterly Progress Reports																											
2.2	Maintain and organize documents for compliance																											
2.3	Communicate progress and findings with team and Ecology																											
2.4	Submit FEATS Reports																											
2.5	Submit PSP Required Status and Financial NTA Reports																											
2.6	Check that all STORET Data Collection & Reporting are complete (see Tasks 4.2.2)																											
3.1	Select 13 target basins																											
4.1.1	Collect macroinvertebrate samples at 13 sites																											
4.1.2	Enter macroinvertebrate data into PugetSoundStreamBenthos.org (PSSB)																											
4.2.1	Conduct habitat and riparian surveys at 13 target sites																											
4.2.2	Review habitat data in EIM and upload to STORET																											
4.3.1	Install gages and collect flow data at the 3 fair sites																											
4.3.2	Upload flow data to King County Hydrologic Information Center database																											
4.4.1	Gather, review, and analyze geospatial data																											
4.5	Outreach to local managers familiar with select basins																											
5.1	Conduct stressor identification analyses, focused on 3 fair basins																											
6.1	Write draft report, including maps and plans for the 3 “fair” basins																											
6.2	Write final report, including maps and plans for the 3 “fair” basins																											
7.1	Write draft report including maps and plans for the 10 “excellent” basins																											
7.2	Wrtite final report including maps and plans for the 10 “excellent” basins																											
8.1	Create web site and post QAPP (or create site within PSSB website)																											
8.2	Post presentations, geospatial data, and final reports to web site																											

5.5 Budget and funding

Funding for this project is through an EPA Water Quality National Estuary Program Stormwater Initiative Interagency Agreement, No. WQNEP-2016-KCWLRD-00016.

Cost estimates were based on estimated costs for field surveys, GIS analysis, macroinvertebrate sampling and processing, and outreach that will occur in the 13 selected basins as summarized in Tables 5 and 6. Additional costs are included for gage installation and stressor identification analyses that will be done in the three restoration basins only. Cost estimates are based on assumption that data collection, analyses and report writing will all occur within two years.

Costs for future phases are unknown and will depend primarily on the extent and type of restoration and protection actions that are planned.

Table 6. Project budget by task and subtask.

Task	Activity	Subtask Cost	Total Cost
1	**Quality Assurance Project Plan (QAPP) Development**		**$16,960**
1.1	Complete detailed project plan	$2,000	
1.2	Write and finalize QAPP	$14,960	
2	**Project Administration/Management**		**$23,800**
2.1	Submit quarterly Progress Reports	$6,000	
2.2	Maintain and organize documents for compliance	$3,000	
2.3	Communicate progress and findings with team and Ecology	$6,000	
2.4	Submit FEATS Reports	$1,200	
2.5	Submit PSP Required Status and Financial NTA Reports	$600	
2.6	Check that all STORET Data Collection & Reporting are complete (see Tasks 4.2.2)	$7,000	
3	**Select 13 target basins**		**$14,000**
4	**Collection and analysis of basin-specific data**		**$233,140**
4.1	Collect macroinvertebrate samples; enter data into PSSB database	$43,500	
4.2	Conduct habitat and riparian surveys at 13 target sites	$111,040	
4.3	Install gages, collect flow data at the 3 fair sites, and upload data to King County Hydrologic Information Center	$34,600	
4.4	Gather, review, and analyze geospatial data	$16,000	
4.5	Outreach to local managers familiar with select basins	$28,000	
5	**Conduct stressor identification analyses, focused on 3 fair basins**		**$101,000**
6	**Report for Restoring Fair Basins**		**$55,400**
6.1	Write draft report, including maps and plans for the 3 “fair” basins	$43,200	
6.2	Write final report, including maps and plans for the 3 “fair” basins	$12,200	
7	**Report for Protecting Excellent Basins**		**$55,400**
7.1	Write draft report including maps and plans for the 10 “excellent” basins	$43,200	
7.2	Wrtite final report including maps and plans for the 10 “excellent” basins	$12,200	
8	**Outreach and Dissemination of Findings**		**$11,000**
8.1	Create web site and post QAPP (or create site within PSSB website)	$1,000	
8.2	Post presentations, geospatial data, and final reports to web site	$10,000	
		Grand Total	**$510,700**

6.0 Quality Objectives

6.1 Data quality objectives

The Data Quality Objectives (DQO) for this project are for new and existing data that will be collected, reviewed and analyzed as part of the project. The DQOs for this project are that data are of high quality, representative of sample sites and their basins, and comparable across basins. Another important objective is that the data will be useful to characterize current conditions and identify potential stressors affecting the macroinvertebrate community at the selected sites. To achieve these objectives, data will be evaluated according to standard indicators of quality assurance, including:

- **Precision** is a measure of the variability in the results of replicate measurements due to random error.
- **Bias** is the difference between the population mean and the true value.
- **Sensitivity** is a measure of the capability of a method to detect what is being measured.
- **Comparability** is the ability to compare data from the current study to data from other similar studies and historical data.
- **Representativeness** is the degree to which environmental samples and other data are representative of existing conditions.
- **Completeness** is the amount of data required for your study to be a success.

Measurement quality objectives (MQOs) are criteria used to evaluate performance or acceptance of data and are based on the indicators above. Samples and data are collected with common protocols used by other regional monitoring programs. This improves data comparability and usefulness among biomonitoring colleagues. MQOs for macroinvertebrate, hydrologic, physical habitat, temperature, and geospatial data are described below.

6.2 Measurement quality objectives for Macroinvertebrate Data

Measurement quality objectives for benthic macroinvertebrate data for this study follow those from Appendix B-1 of the Quality Assurance Project Plan for Status and Trends Monitoring of Small Streams in the Puget Lowlands Ecoregion (Ecology 2014a, 2014b). Note Appendix B-1 identifies MQOs for both benthic macroinvertebrate and periphyton sampling; however, only the applicable MQOs for macroinvertebrate sampling will be used for this study.

6.2.1 Precision

Benthic macroinvertebrate samples will be composited from eight, 1-ft^2 samples spread throughout the reach. Two composite samples will be taken, one that follows a protocol that targets riffles (King County 2002) and the other that specifies samples are collected from randomly selected transects within a reach (Ecology 2016a). These two samples are not meant to be replicates, but it is expected that the B-IBI scores generated from both samples will be similar (Rehn et al 2007). A composite sample collected from 8 ft^2, using either protocol, is expected to include a sufficient number of invertebrates (at least 500 per sample) to adequately reflect the relative composition and abundance of macroinvertebrate taxa present at the site.

Field replicates will be collected using both methods from two sites in one year (i.e., at two sites in one season, there will be two composite samples collected using the riffle method and two using the transect method). Because of the large area of stream that will be disturbed in order to collect these samples, replicates will be taken at two sites with relatively large drainage areas. The relative percent difference (RPD) between replicates using the same method is expected to be <20%. In addition, data from field replicates collected for other studies using these protocols (King County ambient monitoring program, the RSMP study) will be used to compare precision found in this study to other studies using these methods.

MQOs for precision of invertebrate counts and taxonomic identification are based on the re-identification and re-enumeration of a randomly-selected 10% of samples in a blind procedure. Based on raw counts, samples must have >90% similarity (Bray-Curtis), >90% Percent Taxonomic Disagreement (PTD), >95% Percent Difference in Enumeration (PDE) (Appendix Rhithron QAPP).

6.2.2 Bias

Sampling bias will be minimized by following standard protocols for benthic macroinvertebrate collection, preservation, transportation, storage, and analysis of samples and the use of trained staff.

Analytical bias will be minimized by laboratory quality control procedures. Initial lab sample processing and subsampling will include checking sorting efficiency. These checks will be conducted on 100% of the samples by independent observers who microscopically re-examine at least 20% of sorted substrate from each sample.

6.2.3 Sensitivity

The sites will be selected based on various criteria, including prior ability to collect benthic macroinvertebrates using standard protocols. The standard methods used here, in the field and in the laboratory, are capable of collecting, counting and identifying macroinvertebrates for the use of calculating BIBI scores.

6.2.4 Comparability

Comparability is the ability to compare data from the current study to data from other similar studies and historical data. For this study, comparability is also the ability to compare data across the sites being evaluated.

Collection of benthic macroinvertebrates using standard methods will allow comparability with previous data sets. It is expected that B-IBI scores for the two samples collected using different methods will not differ significantly. However, collection of samples using both protocols will verify that assumption and ensure that new data are comparable to other data collected across the region, regardless of sampling method.

Comparability will be maintained through use of standard sampling equipment and established protocols, along with standardized data validation and reporting procedures. The sampling

protocols used in this study follow those adopted by Ecology (sections 7.2.2 and 8.2) and King County (King County 2002). The protocols were designed to produce consistent and repeatable results in each stream reach ensuring data comparability by targeting riffle or non-depositional habitat, limiting the collection window to the summer low flow period, disturbing the substrate for a standard time period (60 seconds), and using the same net mesh size (500 µm). Training in field data collection protocols for all field staff will occur prior to sample collection to ensure consistency across sampling locations. Sample collection at most sites will be led by the same field staff, further enhancing site-to-site consistency by limiting variation that can arise from use of multiple personnel. All samples will be sent to the same taxonomic laboratory (Rhithron Associates, Inc.) to ensure taxonomic identification consistency and comparability.

Standard monitoring procedures, units of measurement, and reporting conventions will be applied to meet the goal of data comparability. Standardized Operating Procedures (SOPs) for measurement and sampling are listed in sections 7.2.2 and 8.2.

6.2.5 Representativeness

Representativeness expresses the degree to which a sample accurately and precisely represents a population, parameter variations at the sampling point or an environmental condition. Representativeness of samples is ensured by adherence to standard field sampling and laboratory protocols. These sampling protocols have been widely used and are designed to produce consistent and repeatable results in each stream reach.

Macroinvertebrate samples are collected according to sampling protocols to ensure they are representative of the macroinvertebrate community present in the stream reach during low-flow periods in summer and early fall. Samples are collected from at least four riffles (King County's riffle-based method) or from eight random transects (Ecology's transect method). Most other ambient monitoring programs in the region also sample during this low-flow, summer/early fall period.

Collecting composite samples across the reach is intended to sample a sufficient area and number of invertebrates to be representative of the benthic macroinvertebrate community present at the site. Macroinvertebrate sample analyses will focus on robust metrics such as taxa richness and overall B-IBI scores. The B-IBI method has been widely used throughout the United States and has been subject to extensive regional evaluation in the Puget Sound lowlands (e.g. Booth et al. 2004, DeGasperi et al. 2009, Fore 1999, Kleindl 1995, Morely and Karr 2002, King County 2014d).

Standard sorting protocols (King County 2012, Rhithron 2016) are applied to achieve representative subsamples. Samples will be subsampled to at least 500 organisms to standardize abundance within and between sites.

The benthic macroinvertebrate data collected at 13 sites over two years will be compared to data collected at those sites in previous years. The variation found at these sites will also be compared to variation observed at other sites in the region.

6.2.6 Completeness

Completeness is defined as the total number of samples analyzed for which acceptable data are generated, compared to the total number of samples submitted for analysis. Sampling in favorable weather when flow conditions are appropriate (near summer base flow), along with adherence to standardized protocols will aid in providing a complete set of data for this project.

The loss of macroinvertebrates from a sample will be minimized by making sure the sampling cup is firmly attached to the net, washing and inspecting the net between sampling sites, carefully transferring the contents of the net to the sample bottle(s), and preserving the sample with an adequate amount of ethanol. Sample bottle and labeling information are described below in section 8. If the validity of the information from the sample is in question, the sample will be excluded from analysis. The goal for completeness of macroinvertebrate data is 100% of the total samples collected and analyzed. Completeness is defined as the total number of samples that we are confident in using for further data analysis following field collection.

6.3 Measurement quality objectives for Hydrologic Data

If available, existing hydrologic data will be used for most of the basins of interest. However, if the necessary stream gage data cannot be obtained for the three restoration basins, a water level gage will be installed for one year (October 1, 2017 – September 30, 2018, or as much of the water year as possible), and hydrologic measurements will be collected. For gages installed for this project, a data logger and pressure transducer will be installed and a rating curve will be developed (see Section 7.2). Water level measurements will be converted to discharge estimates using the rating curves developed for each gage.

MQOs for flow data include documentation that gages were installed correctly, the rating curves were comparable with hydrologic data from similar gages in the vicinity, and that gages have been maintained and calibrated regularly. Data obtained from USGS, Ecology, or King County have already been through rigorous quality control procedures before being made publicly available. Many of the protocols and MQOs related to hydrologic monitoring for this project are similar to those for the Redmond Paired Watershed Study, and thus some of the text used here is taken from that study's QAPP (Redmond 2015).

6.3.1 Precision

Existing hydrologic data will be evaluated by staff hydrologists and assessed for precision.

The MQO for precision for water level readings is that water level measured using the a depth logger (Onset Hobo Water Level 13ft data logger) should be within 5% of manually measured water level at two fixed reference points at each gage.

During site visits 8-10 times per year, staff will take multiple "tape down" measurements (stage height) from at least two fixed and established points to the water surface. The time will be recorded and gage data from that same time point will be compared to the manually measured water levels.

6.3.2 Bias

Bias in existing hydrologic data will be evaluated by referring to any notes available from depth logger calibration, replicate measurements from site visits, or field notes that document any deviations in measurements or protocols.

For hydrologic data collection, a thorough record of the site characteristics including qualitative and quantitative descriptions of the structures, equipment, instruments, channel, and hydraulic control will be kept, as well as a station log. King County will utilize trained hydrologists and standard operating procedures to eliminate sampling bias. When collecting discharge measurements, the Swoffer velocity meter will be calibrated in the field during each site visit.

Similar to precision, the bias of hydrologic monitoring data will be assessed based on comparisons of depths estimated by the loggers to manual measurements of water level that are obtained during site visits. These manual measurements will be made in conjunction with routine visits to each monitoring location (see Section 7.2).

If the monitoring equipment is not affected by drift or other operational problems, the difference between the equipment's reading and the manual measurement of water level ("instrument offset") should remain constant 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. Practically, if the instrument offset changes due to instrument "drift" three consecutive observations, a replacement or repair will be made.

6.3.3 Sensitivity

The sensitivity of each flow meter varies by the type of instrument and the accuracy of its calibration. If there are existing hydrologic data, staff hydrologists will evaluate sensitivity by reviewing data collected during summer low flow periods. New gages will be installed in locations that are conducive to measuring water depths at all stages, and from that continuous flow will be calculated. It is assumed all sites will have perennial flow and sufficient depth so that flow can be measured continuously throughout the year.

6.3.4 Comparability

Comparability will be maintained through use of standard equipment and established protocols for installing, maintaining, and calibrating flow meters. Existing hydrologic data will be compared, when available, to similar data collected at other gaging stations in the region (e.g., USGS data, King County data http://green2.kingcounty.gov/hydrology/Default.aspx). New hydrologic data will also be compared to other data collected concurrently throughout the region.

6.3.5 Representativeness

Collection of existing and new hydrologic data will follow established protocols to ensure data represent hydrologic conditions at the site and within the basin. When discharge is manually

measured at each site, staff will select a location, or cross section, that is appropriate for measuring discharge (see Section 7.2) and is representative of the site. Discharge measurements will be timed so that low and high flow extremes are captured.

6.3.6 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.

6.4 Measurement quality objectives for Physical Habitat Data

MQOs for physical habitat data will be met by having trained staff follow standard protocols (see Sections 7 and 8). MQOs for physical habitat data emphasize accuracy and precision of field measurements and data entry, which will be supported by participating in Ecology's training and following appropriate SOPs.

Existing physical data specific to each basin may also be discovered during the course of the investigation.

6.4.1 Precision

Precision will be assessed by evaluating variation in parameters measured in repeat visits to two sites during one season. Repeat visit variance includes the combined effects of within-season variation, measurement variation and variation in measurements collected by potentially different staff (Kaufmann et al. 2014). Estimates should be within +/- 10% (Ecology 2006). Signal to noise ratios (S:N) will be examined for habitat variables collected between the two years of sampling, and between the two repeat visits within the same year for two sites. S:N from this study will be compared to S:N values reported in other studies using these protocols (e.g., Ecology 2006, King County 2015b) or measuring similar variables (e.g., Kaufmann et al. 1999). Estimates should be within +/- 10% (Ecology 2006).

6.4.2 Bias

Sampling bias will be addressed by using trained staff and using standard procedures to measure physical habitat parameters as outlined in Ecology's SOPs (See Sections 7 and 8). If prior physical habitat data are available, metadata will be evaluated to determine if these data were collected using standard measures outlined in established protocols and meet QA/QC requirements that are reliable and transparent.

6.4.3 Sensitivity

Physical habitat SOPs were designed to facilitate the measurement of habitat parameters that are of interest in ecological studies. The sensitivity of the methods (defined as a measure of the capability of a method to detect a substance or parameter) will depend on the SOP, but in general

staff will be able to detect all parameters of interest. Ecology's habitat parameters (See Sections 7 and 8), include measurement of riparian vegetation structure and canopy cover, bank erosion vulnerability, fish cover, channel dimensions and thalweg profile, large woody debris, and human influence on the riparian area. Habitat surveys will be conducted over one to two days at each site each year, and therefore measurements will reflect conditions on those days and may not be sensitive to changes that occur at the sites throughout the year.

6.4.4 Comparability

Newly gathered physical habitat data will be collected following Ecology's WHM SOPs and therefore will be comparable to previous data collected with the same standardized methods. Existing data will be evaluated to determine if they were collected using standard measures outlined in established protocols and meets QA/QC requirements that are reliable and transparent.

6.4.5 Representativeness

Physical habitat data at each site will be collected from 11 major and 10 minor transects equally spaced along the study reach. The length of a survey reach will be 20 times the average bankfull width, but no shorter than 150 m (Ecology SOP EAP106). Data from the reach are intended to be representative of existing conditions at the site.

6.4.6 Completeness

Completeness of physical habitat data will be assessed based on entry of all data in electronic field forms. Habitat data will be collected twice (summer of 2017 and 2018) at each of the 13 sites. If existing historical habitat data are comparable, these data will also be included in the analysis.

6.5 Measurement quality objectives for Stream Temperature Data

Temperature loggers will be used to monitor in-situ water temperature at each select site. HOBO pendant temperature/light data loggers (Onset Computer Corporation) will be deployed in each study stream. Existing stream temperature data specific to each basin may also be discovered during the course of the investigation.

6.5.1 Precision

HOBO temperature loggers rely on user performed calibration to ensure maximum accuracy. Temperature loggers will be calibrated in solutions of known temperature to assess precision. The temperature MQO is 0.2 °C from the observed reading. Temperature loggers will be checked for accuracy and precision before they are deployed and once they are retrieved.

6.5.2 Bias

Bias of the continuous in-situ water temperature readings will be assessed based on comparison of data to an independently measured "true" value. The true value will be derived from manual temperature measurements obtained from an ASTM certified thermometer during calibration before deployment and after retrieval.

The difference between the HOBO reading and the manual measurement should be less than the precision specified above. If precision limits are exceeded, a replacement or repair will be made.

6.5.3 Sensitivity

Temperature loggers will record every hour. The HOBO pendant temperature logger has an accuracy of ±0.53ºC at 0 to 50ºC, an operating temperature range from -20ºC to 50ºC, a resolution of 0.14ºC at 25ºC, and drift of less than 0.1ºC/year. This sensitivity will be appropriate for the temperature range and period of measurement for this project.

6.5.4 Comparability

Temperature data will be compared to existing historical temperature data of acceptable quality or to data collected concurrently at other sites in the region (e.g., at gaging sites maintained by USGS or King County).

6.5.5 Representativeness

The temperature loggers will collect data once per hour continuously for one year (October 1, 2017 – September 30, 2018) and checked quarterly. These data will represent existing thermal conditions at each site for the year.

6.5.6 Completeness

A temperature logger will be deployed in each of the 13 study basins to continuously log hourly temperature over the study period. If the instrument performs accurately and can be retrieved quarterly, the data completeness should be 100%. If a logger is lost or fails to record data, completeness may be reduced. The target for completeness is at least 75% of possible temperature readings at each site will be collected.

Loggers will be replaced as soon as possible if lost or broken.

6.6 Measurement quality objectives for Geospatial Data

Existing geospatial data will be gathered from a variety of sources as outlined in Section 7.4 below.

Study areas (e.g., habitat survey reaches and macroinvertebrate sampling sites) were selected based on existing macroinvertebrate sampling sites (coordinates in PSSB). For each stream, the habitat survey reach (at least 150 m in length) is located such that it spans the macroinvertebrate sampling site. Unless the existing macroinvertebrate sampling site is not accessible or there is another reason to change the location, the coordinates of the new macroinvertebrate sampling site on each stream will be identical to the existing site. If identical, a hand held GPS unit will be used to navigate to and confirm the location of the new site. If not identical (e.g., the existing site is within 150 m of a tributary that will affect the habitat survey, or access was denied by property owner), a hand held GPS will be used to measure the coordinates of the new location.

As part of the habitat survey, coordinates will be measured with a hand-held a GPS (decimal degrees in NAD83) at each of the three transects: A (bottom of site), F, and K (top of site) (EAP107). The protocol calls for allowing the GPS unit time to find satellites and average readings, for greater accuracy and precision. Ideally the accuracy should be within 10 meters but sometimes topography can inhibit reception.

6.6.1 Precision

Existing geospatial data will be evaluated for precision based on the accompanying metadata provided by the data source. Data obtained from NOAA, USGS, Ecology or King County will have previously undergone QA/QC with a reliable and transparent method before being made publically available. King County will ensure that basins are correctly delineated for each select B-IBI site by following QA/QC procedures described in EPA 2011a, 2011b and King County 2013.

Target precision for new coordinate measurements taken with a hand-held GPS unit is that coordinates will be within 15 m of the true value. This will be obtained by taking measurements at each of the three target transects at each site (A, F, K) when the accuracy is within 15 m. In addition, the coordinates will be evaluated using GIS to assess if the recorded coordinates align with other geospatial data (e.g., orthophotos, topography, stream layers).

6.6.2 Bias

The metadata for each geospatial dataset will be evaluated for bias in its creation and use.

The bias of new GPS coordinates will be evaluated by looking at the position of the three measured points (at transects A, F and K) at each site and their relative position to other geospatial data (e.g., orthophotos, topography, stream layers). In addition the distance between the three points will be assessed using GIS (distance tools) and compared to field distance measurements.

6.6.3 Sensitivity

Most geospatial data used for this project will be obtained from existing sources. The accompanying metadata should provide information on the resolution, scale and extent of the data. When comparing basins, we will use geospatial data that are of the same resolution and quality across basins. If additional data are available for some basins (e.g., high-resolution data of stormwater infrastructure available for some but not all basins), those data will be used to describe conditions in those basins in more detail.

New GPS data should have accuracy to within 10 meters, as measured by the GPS unit.

6.6.4 Comparability

Existing geospatial data that follows the Federal Geographic Data Committee's guidelines for metadata should be comparable to datasets used for other projects, historically and across sites (Washington 2014).

6.6.5 Representativeness

The targeted geospatial datasets, referenced in Section 7, should represent the current and historical conditions of the basins of interest.

6.6.6 Completeness

For completeness, this project will need access to datasets encompassing all basins of interest within the Puget Sound Lowland region, as outlined in Section 7. Most of the major datasets have been utilized for past projects (King County 2014a, 2014b and 2014e, 2015a) and were found to be complete. Some more localized datasets specific to each basin may be discovered during the course of this project.

6.7 Acceptance criteria for quality of existing data

Once candidate basins have been identified, King County will assess macroinvertebrate, hydrologic, physical habitat, temperature and geospatial data from available sources as outlined in section 4.3 of this document. Data quality will be considered as outlined in a previous QAPP (B-IBI Restoration Decision Framework and Site Identification and the Strategies for Protecting and Restoring Puget Sound B-IBI Basins documents [King County, 2014a, 2014b, 2015a]). Existing data obtained from local sources needs to be consistent, obtained using comparable standard techniques and technology, and be subject to similar QA/QC standards using methods that are reliable and transparent.

Basins may be excluded from the selection process if there are extensive data gaps in data needed for characterization and stressor analysis.

6.8 Model quality objectives

If preliminary analyses suggest an HSPF model would be useful to develop restoration plans for a particular basin, a QAPP amendment will be submitted to Ecology that includes model quality objectives. But until then, this section is not applicable.

7.0 Study Design

7.1 Study boundaries and site selection

This project utilizes existing benthic macroinvertebrate monitoring data from streams throughout the Puget Lowland region (Water Resource Inventory Areas [WRIA] 1-19).The three "fair" and the 10 "excellent" sites that will be the focus of this project will be selected from over 1,200 Puget Sound sites in the PSSB database. The three "fair" sites will be referred to as the restoration sites, and the 10 "excellent" sites will be referred to as the protection sites.

Three "fair" sites will be selected using the decision framework developed in Phase I of the project (King County 2014a). The original framework specifies the inclusion of sites that:

- Have a median score of "fair", (40-60).
- Are within the Puget Lowland ecoregion (Figure 1, EPA 2013)
- Have been sampled frequently, as defined by availability of three or more years of data collected within the last five years (2012-2016), or five or more years of data (regardless of collection date)
- Have a basin area between 200 and 3000 acres
- Score among the least degraded and most important using the Puget Sound Watershed Characterization model

Development of additional criteria will be needed to reduce the number of candidate restoration sites, and will likely include a combination of the following:

- Exclude sites at or near their biologic potential[2]
- Exclude sites that cannot be accessed
- Exclude sites already being evaluated for restoration actions (e.g., streams in the Soos Creek basin that are part of the Soos Creek TMDL, or streams included in the Paired Basin Stormwater Action Monitoring [SAM] study)
- Prioritize sites that have an active stream team, local managers or elected officials that are interested in restoration
- Prioritize sites that have been prioritized in salmon recovery plans
- Prioritize sites that have been prioritized for stormwater retrofits
- Prioritize sites that have additional water quality, hydrologic, or habitat data that may inform a stressor identification analysis

Ten "excellent" sites will be selected as the "protection" sites using a modified version of the decision framework developed for "excellent" sites in Phase 1 of the project (King County 2014a). The modifications will simplify and streamline the selection process, while maintaining the intent of the original framework. The new criteria will include a combination of the following:

- Include sites that have scored excellent scored "excellent" (80 or above) at least once

[2] This refers to the expectation for a site given the extent of urbanization in its basin. If the basin is heavily urbanized, the likelihood that B-IBI scores could be restored to a high score is limited. This is described in detail in King County 2014a and Paul et al. 2009.

- Have median score of "excellent", or have scored excellent in the last three years (2014, 2015, or 2016)
- Have never scored "poor" (20-40), or "very poor" (0-20)

Additional considerations protection site selection may include:

- Exclude sites currently in protected basins (e.g., in park land, protected in conservation easements)
- Exclude sites that cannot be accessed
- Prioritize sites that have been prioritized in salmon recovery plans
- Prioritize sites that are hydrologically connected to sites with lower scores
- Prioritize sites that are in basins that are at risk of development or land conversion

Lists of candidate sites and the rationale for final site selection will be included in the final reports. Maps of each of the selected basins will also be included in the reports.

7.2 Field data collection

7.2.1 Sampling locations and frequency

Once the 13 basins have been selected, sampling sites will be established at or within 200m of the site as described in the PSSB. King County will obtain property access and determine if the site is safe and appropriate to sample. Macroinvertebrate samples and physical habitat data will be collected over one to two days at each site, and sampling will require at least two staff members per day. Timing will be concurrent with other macroinvertebrate sampling in the region, and will be completed between late July and mid October. Macroinvertebrate sampling and habitat surveys will be conducted in 2017 and 2018.

7.2.2 Field parameters to be measured

Temperature loggers will be deployed and if necessary, flow gages will be installed (in the "fair" basins) as close to the start of the water year (October 1) as possible. All equipment will be checked quarterly and will record data until October 1, 2018.

Continuous discharge will be estimate at each site using water level data from existing or new gages. If a gage is new, a rating curve will be developed by taking 8-10 velocity-area discharge measurements across a range of flow conditions (Redmond 2015). A depth logger (Onset Hobo Water Level 13ft data logger) will be placed in a PVC pipe and will record every five minutes. Water levels and discharge will be measured manually during low, medium and high-flow periods, and from these a rating curve will be generated. Water levels will be measured from at least two fixed points at the gage.

King County will follow Ecology's Watershed Health Monitoring's SOPs for physical habitat using the narrow protocol for wadeable streams. As previously described two benthic macroinvertebrate samples will be collected. One will be collected using a method that targets riffles (King County 2002) and the other will be collected using a transect-based method (EAP073, Ecology 2016a). A complete list of parameters and methods is included in Table 7.

Table 7. Field parameters and methods.

Parameters	Method	Number of samples/measurements per site
Macroinvertebrates	Targeted riffle: King County 2002	8, 1ft^2 samples collected from up to 4 riffles, composited
Macroinvertebrates	Transect-based: EAP073 (Ecology 2016a)	8, 1 ft^2 samples, collected from 8 transects, composited
Continuous temperature	Redmond 2015	Continuous, 1-hr interval
Continuous water level	Redmond 2015	at "fair" site(s), for one year, using new or established gages
Current velocity and discharge	Redmond 2015	8-10 times per site, if site has new gage
Site verification and layout	EAP106 (Ecology 2017r)	1
Reach Slope	EAP122 (Ecology 2017e)	1
Bearing	EAP123 (Ecology 2017c)	20
Thalweg Profile	EAP119 (Ecology 2017l)	10
Habitat Unit	EAP120 (Ecology 2017k)	1+
Channel Dimensions	EAP113 (Ecology 2017h)	11
Fish Cover	EAP116 (Ecology 2017i)	11
Bank Erosion	EAP112 (Ecology 2017a)	11
Substrate and Embeddedness	EAP114 (Ecology 2017j)	11
Human Influence	EAP118 (Ecology 2017f)	11
Riparian Vegetation Structure	EAP117 (Ecology 2017b)	11
Riparian Cover	EAP115 (Ecology 2017d)	11
Large Woody Debris	EAP121 (Ecology 2017n)	11
Location coordinates	EAP107 (Ecology 2017p)	3 per site

7.3 Modeling and analysis design

If preliminary analyses suggest an HSPF model would be useful to develop restoration plans for a particular basin, a QAPP amendment with a model design will be submitted to Ecology.

7.4 GIS analysis and design

Geographic information system (GIS) procedures and analyses will follow methods used for Phase I of this project and outlined in the 2013 GIS Memo (King County 2013). Basin area and landscape scale metrics for the nearly 1200 benthic macroinvertebrate sampling locations in the Puget Sound Lowlands have been calculated for recent projects (King County 2013). These data will be used in the site selection process (e.g., basin area), and to develop restoration and protection plans for the selected basins. Table 8 lists the geospatial data layers that will be used in this project. Orthophotos from the National Agriculture Imagery Program (NAIP) and any Lidar data available for the basins will also be reviewed.

Table 8. Geospatial data layers that will be compiled and reviewed.

Data Layer	Source	Year	Scale	Resolution	Description/Reference
C-CAP Land Cover	Coastal Change Analysis Program	2011 and others[3]	1:100,000	30-meter	Nationally standardized database of land cover and change (1992, 1996, 2001, 2006, and 2011).
National Elevation Dataset	National Hydrography Dataset	2004	1:100,000	30-meter	Portray surface water/ drainage network (rivers, streams, lakes, ponds, coastline, etc.).
State Dept. of Natural Resources (DNR) Lands	WA Dept. of Natural Resources	2011	1:24,000	12-meter	Includes ownership parcels, disposed parcels, and easement parcels.
Major Public Lands	WA Dept. of Natural Resources	2013	1:100,000	30-meter	Contains ownership parcels for Federal, State (excluding WA DNR), County and City lands.
NLCD Land Cover	National Land Cover Dataset	2006	1:100,000	30-meter	16-class land cover classification scheme, Fry et al. 2011.
WA Zoning	WA Dept. of Commerce	2015			Draft version available in 2015; will use finalized version if available
City/UGA Areas	WA Dept. of Ecology	2011	1:24,000	12-meter	Combined incorporated City boundaries and unincorporated Urban Growth Areas (UGA).
NAIP Ortho Imagery	US Dept. of Agriculture	2011	N/A	1-meter gsd[4]	County by county mosaics of images produced for National Agricultural Imagery Program (NAIP).
Watershed Boundary Dataset	US Geologic Society	2007	1:24,000	12-meter (+/- 6m accuracy)	Defines the areal extent of surface water drainage to a point, accounting for all land and surface areas (HUC watersheds).
Surficial Geology	WA Division of Geology and Earth Resources	2010	1:100,000	30-meter	Digital Geology of Washington State.
Population	U.S. Census	2000 and 2010	1:24,000	12-meter	Census in 2000 and in 2010 determined the resident population of the U.S.
Precipitation	PRISM[5] Climate Group	1981-2010	Grid (N/A)	4-km grid cell resolution	Monthly 30-year "normal" dataset averaged over the climatological period 1981-2010.
Steelhead Distribution	StreamNet (PSMFS[6])	2005	1:100,000	30-meter	Winter steelhead distribution, Pacific Northwest compiled from WDFW data
Critical Habitat	United States Fish and Wildlife Service	2011	1:24,000	12-meter	Critical habitat for bull trout and Chinook salmon
WA State 303(d) List	WA Dept. of Ecology	2012	1:24,000	12-meter	Category 5 (impaired) listings for Washington State's 2012 Water Quality Assessment.

[3] C-CAP data for 2016 are not yet available, but if they become available by summer 2018 they will be used for this project as well.
[4] Gsd is ground sample distance.
[5] PRISM is the Parameter elevation Regression on Independent Slopes Model
[6] PSMFS is the Pacific States Marine Fisheries Commission

7.5 Assumptions in relation to objectives and study area

Based on previous studies, it is assumed that 10 basins of appropriate size with sufficient data in the "excellent" category and three in the "fair" category worthy of further study will be identified. It is assumed that prior B-IBI data have been collected using methods similar to those outlined here, and that the existing data characterize the health of the benthic macroinvertebrate community and basin conditions at the time of sampling.

7.6 Possible challenges and contingencies

A number of uncertainties will be associated with all plans developed for protection and restoration. It is assumed that most of the uncertainty will be due to an incomplete understanding of the stressors in each basin, and uncertainty about future conditions. Analyzing current conditions, using field surveys and land cover data, is fairly straightforward, but attributing B-IBI scores to specific stressors can be challenging. Most stressor identification analyses are limited by insufficient data, and this portion of the project maybe impacted by lack of data as well. For example, no water quality data are available for most basins, and collecting adequate data for this purpose would be prohibitively expensive. Consequently, plans will attempt to consider a range of possible stressors. There is also considerable uncertainty in the effectiveness of restoration actions on improving B-IBI scores. Eventually, once implemented, studying the effectiveness of these projects will help reduce the uncertainties regarding stressors, B-IBI scores, and restoration effectiveness.

7.6.1 Logistical problems

This project may encounter logistical problems associated with field sampling. Site access, suitability, safety, and timing of sampling are all typical difficulties when field sampling. However, all sites to be sampled will have been previously sampled in the past; thus, many of the concerns listed above have likely been addressed.

If necessary, landowner permission to access the site will be obtained prior to sampling. Site safety and suitability will be assessed when accessing the site, paying attention to safety concerns such as falling and drowning hazards, and hunting areas and season. Teams of two or more will wear appropriate personal protective gear, bring a field cell phone, and check in with the office before and after sampling.

Water level and temperature gages will be installed at the three basins targeted for restoration, if needed. Logistics involved in the installation, maintenance and retrieval of the gages will be accounted for, and staff will be trained by professional hydrologists before installation. Significant rain events may delay sampling, resuming a few days later when flows are stable.

7.6.2 Practical constraints

The project duration is limited to two years starting June 2017. Within this time period King County must plan, sample, analyze, and report on findings. This project is subject to review by three different agencies as well as outreach efforts to other jurisdictions and organizations interested in the project findings. King County must schedule and update relevant information on a limited timetable to ensure project success.

Rhithron Associates will conduct the taxonomic identification of the samples. They will also upload B-IBI scores to the PSSB database. Macroinvertebrate samples will be collected between July and early October each year, and will be transferred to the taxonomy lab as soon as possible. Processing can take several months and is dependent on the lab's schedule.

7.6.3 Schedule limitations

This project is subject to review internally as well as by Ecology. Sampling will cannot begin until the QAPP has been reviewed and approved. The sampling window is confined to the summer months and will involve multiple staff for a period of three to four weeks between late July and early October. If the development, review, and approval of this QAPP extends beyond the sampling window, it will not be possible to collect macroinvertebrates and physical habitat data in 2017. In addition, deployment of temperature and water level loggers may be delayed.

8.0 Field Procedures

8.1 Invasive species evaluation

King County will adhere to Ecology's methods to address the spread of invasive species as outlined in the SOP EAP070 (Ecology 2016b). At the end of every sampling day or upon moving from one waterbody to another, staff will follow a suite of decontamination procedures, including thorough cleaning, inspection, and freezing (<-10°C for > 8 hours) of all equipment possibly exposed to invasive species, aquatic or terrestrial.

8.2 Measurement and sampling procedures

Sample collection will follow Ecology's Environmental Assessment Program SOPs, the Status and Trends Monitoring for Watershed Health & Salmon Recovery: Field Data Collection Protocol for Wadeable Streams. The documents relevant to this project can be found here (https://ecology.wa.gov/About-us/How-we-operate/Scientific-services/Quality-assurance),and are listed as follows:

- EAP 011 – Instantaneous Measurements of Temperature in Water, version 1.2
- EAP 070 – Invasive Species, version 2.1
- EAP 073 – Benthic Macroinvertebrates, version 2.1
- EAP 106 – Site Verification and layout, version 1.7
- EAP 107 – Measuring Transect Coordinates with GPS, version 1.8.
- EAP 112 – Bank Erosion Vulnerability, version 1.4
- EAP 113 – Channel Dimensions, version 1.7
- EAP 114 – Substrate and Embeddedness, version 1.2
- EAP 115 – Riparian Cover, version 1.2
- EAP 116 – Fish Cover, version 1.3
- EAP 117 – Riparian Veg Structure, version 1.2
- EAP 118 – Riparian Human Influence, version 1.3
- EAP 119 – Thalweg Profile, version 1.3
- EAP 120 – Habitat Units, version 1.3
- EAP 121 – Large Woody Debris Tally, version 1.3
- EAP 122 – Narrow Slope, version 1.3
- EAP 123 – Narrow Bearing, version 1.2
- EAP 125 – Electronic Data Form, version 2.0

As previously described, a second macroinvertebrate sample will be collected using a target-riffle approach (King County 2002). Eight, $1ft^2$ samples will be collected from four riffles within the surveyed reach and composited. Sample labels will distinguish which protocol was followed. This method will serve as a duplicate sample mirroring techniques widely used in the Puget Sound area and will allow comparison between Ecology's transect-targeted and King County's riffle-targeted techniques.

King County will also conduct hydrologic monitoring if a gage does not already exist nearby. Hydrologic monitoring will follow methods described in the Redmond Paired Watershed QAPP (Redmond, 2015, Appendix E.5). Site visits will be performed quarterly to check the operational

status of the water level loggers at each monitoring location, download water level data, and make field measurements for depth and velocity (Redmond, 2015). Downloaded data files will be named with the site name plus the date as YYYY_MM_DD. Field downloaded data files and telemetered data files will be stored in directories on a King County network server managed by King County Department of Information and Technology Services. Field notes and other materials will be stored in paper files in the King County Department of Natural Resources and Parks (KCDNRP) gauging program Seattle office work area. Software applications developed by KCDNRP gauging program will be used to input data to the KCDNRP Hydrologic Information Center database. Once in the database, data are available for download from the County internet site.

8.3 Containers, preservation methods, holding times

Benthic macroinvertebrate samples will be collected in 1- and 2-liter plastic sampling jars. The samples will be preserved with 95% ethanol as indicated in Ecology's SOP (EAP073, Ecology 2016a). The containers will be stored in coolers and transferred to King County's locked storage facility until they can be batch shipped to the taxonomic laboratory (Rhithron) for processing. Samples will be held for no more than three months before shipping, and will be analyzed within four months of delivery to Rhithron. A chain-of-custody (COC) form will be filled out prior to transfer sample transfer to the taxonomic laboratory as detailed in section 8.6.

8.4 Equipment decontamination

King County will adhere to Ecology's methods to address equipment decontamination as outlined in the SOP EAP090 (Ecology 2017q).

8.5 Sample ID

Once sites are selected, site names and sample IDs will be assigned. Site names will consist of 6 characters: a two-digit WRIA number, a two-letter abbreviation for watershed or stream, and a two-digit site number. For example, if two sites are in WRIA 8, in the Cedar River or Cedar River watershed, they would be named: 08CE01 and 08CE02.

Physical habitat survey data will be entered into Ecology's WHM database and sample IDs will include a prefix and the site name. The prefix designates data are for a King County project (KCY) and the two survey events (06600, 16600). Survey data collected in 2017 and 2018 will be named with the prefixes KCY06600 and KCY16600, respectively. Therefore, for the two hypothetical sites listed above, physical habitat data would be entered in Ecology's WHM database using these site codes:

KCY06600-08CE01
KCY06600-08CE02
KCY16600-08CE01
KCY16600-08CE02

Macroinvertebrate samples collected at each site will be distinguished by sample type and year. Type will be designated by T (transect) or R (riffle). The year of the sample will be added after

the sample type. For example, for the potential site KCY06600-08CE01 described above, four samples will be collected for this project:

KCY06600_08CE01_R_17
KCY06600_08CE01_T_17
KCY06600_08CE01_R_18
KCY06600_08CE01_T_18

8.6 Chain-of-custody

To maintain the legal integrity of collected macroinvertebrate samples, a COC procedure is followed by all project staff. Before sampling begins, a blank COC form (Appendix A) is printed and placed in the sample storage area. Once sampling begins, the form is filled out daily as samples are brought in and stored. The form includes parameters for sample ID, collection date, number of containers used (larger samples with a lot of sediment sometimes require more than one container), who collected the sample, and box number for when the samples get packaged for transport. The form also includes the contact information of project managers. If a correction is required, a single line is drawn across the correction so it remains legible, and the correction written adjacent to the error, with the author's initials and date. This practice ensures the project's data are legally defensible.

When samples are ready for transport, the completed COC form is scanned and copied. A digital copy is kept for records, and a printed copy is handed to the recipient when the samples are transferred. The COC form must accompany the samples at all times. The list entered in the database will be crosschecked against the COC before the samples are transferred to the taxonomic laboratory. Upon receipt at the taxonomic laboratory the COC record will be crosschecked with each sample.

8.7 Field log requirements

King County will utilize Ecology's e-forms for physical habitat surveys as described in SOP EAP125 (Ecology 2017g). King County will also utilize waterproof field notebooks and backup rite-in-rain data collection sheets in case of equipment malfunction. The e-forms and data collection sheets include sections for sample location, descriptive notes on site conditions and field measurements. Copies of collection sheets are in Appendix A.

8.8 Other activities

When at sampling sites or driving within the basins, staff will take photos and make field notes regarding anything that may inform the stressor analysis or the development of restoration or protection plans. This may include photographs and descriptions of natural or human disturbances or other activities (e.g., landslides, roadwork).

9.0 Laboratory Procedures

9.1 Macroinvertebrate laboratory

Rhithron Associates, Inc. of Missoula, Montana is currently contracted by King County WLRD to process macroinvertebrate samples. Rhithron provides sample sorting, taxonomic identification, sample QA/QC, and data upload into the PSSB database. Samples will be processed in the same way that King County samples are typically processed. Samples are subsampled to at least 500-count, and organisms are identified according to the "fine" taxonomic effort. Laboratory procedures are based on the Rhithron protocol (King County 2012, 2014c).

Preserved samples are picked up by Rhithron staff for transport to the taxonomic laboratory. Prior to transport, samples are boxed and inventoried to verify that all samples on the COC form are accounted for.

9.2 Sample preparation method

Standard sorting protocols (King County 2012, Rhithron 2016) are applied to achieve representative subsamples. Rhithron uses Caton subsampling devices, divided into 30 grids, each approximately 5 cm by 6 cm, for all sample handling. To obtain subsamples of a minimum of 500 organisms, samples are poured into the device, grids are randomly chosen, and substrate materials lifted out into petri dishes. Using 10x-30x magnification under dissecting microscopes, technicians remove all organisms from the contents of each grid until 500 organisms are collected. The technician will then completely sort the final grid, and after the target number of organisms is obtained a large/rare search is performed. If less than 500 organisms are counted, the entire sample is sorted. Unsorted sample fractions are currently retained and stored at the Rhithron laboratory.

Once sorted, individual organisms are examined by certified technicians to their appropriate taxonomic level using 10x-80x dissecting scopes. Representatives specimens are slide mounted and examined at 200x-1000x magnification using a compound microscope. Once samples are sorted, identified, and recorded, organisms are preserved in 95% ethanol in labeled vials and archived at Rhithron. QA/QC procedures are carried out for each sample to assess sorting efficiency, identification, and data entry (Section 6).

All samples are identified to Ecology's requirements so that chironomids, Acari, and oligochaetes are all identified to lowest practical level (Table 9). This is considered the "fine" standard taxonomic effort.

Table 9. Standard taxonomic effort (STE) level for benthic sample identification.

Taxa Group	Fine STE
Oligochaeta (segmented worms)	Subfamily/genus
Acari (mites)	Genus
Gastropoda (snails)	Genus
Dytiscidae (predaceous diving beetles)	Genus (adults and larvae)
Simuliidae (blackflies)	Genus (adults and larvae)
Chironomidae (midges; larvae and pupae)	Genus/species/species group
Trichoptera (caddisflies)	Genus/species/species group
All other taxonomic groups	Lowest practical level: typically genus or species

Organisms that cannot be identified to the taxonomic targets because of immaturity, poor condition, or lack of complete current regionally applicable published keys are left at appropriate taxonomic levels that are coarser than those specified. Identified organisms are preserved in 95% ethanol in labeled vials and archived at the Rhithron laboratory.

Taxonomic data are uploaded directly into the Puget Sound Stream Benthos webpage by Rhithron. Once uploaded, data are immediately accessible by King County staff for use on the webpage or for download. Data are also stored in Rhithron's own electronic database.

9.3 Special method requirements

No special method requirements are needed for processing the macroinvertebrate samples.

9.4 Laboratories accredited for methods

Rhithron taxonomists hold multiple Society for Freshwater Science certifications for the groups of invertebrates encountered in Puget Sound samples.

10.0 Quality Control Procedures

10.1 Field and laboratory quality control

Quality control for physical habitat surveys, will consist of training and frequent discussions with field staff about data collection and the SOPs. Core field staff attended Ecology's training in June 2017. All field staff will conduct the first survey together to ensure everyone is consistent in their measurements. Staff will consult with one another in the field and consult with Ecology staff if questions arise regarding the SOPs.

Quality Control associated with macroinvertebrate collection will include a series of measures:

- All field staff will be trained in established sampling protocols.
- A core project team member will accompany and assist in sample collection to ensure consistent and common application of protocols.
- To reduce the chance of organisms being lost during sampling, nets will be visually inspected for holes and all rocks and nets will be thoroughly examined before additional samples are collected or before being discarded or stored.
- Taxonomic labs with certified taxonomists and established quality control procedures will be used for identification and census of collected taxa
- Data will be entered into a single database: the PSSB data management system

Quality control procedures for initial lab sample processing and subsampling involve checking sorting efficiency. These checks will be conducted on 100% of the samples by independent observers who microscopically re-examine at least 20% of sorted substrate from each sample. Quality control procedures for each sample will proceed as follows: the quality control technician will pour the sorted substrate from a processed sample out into a Caton tray, redistributing the substrate so that 20% of it can be accurately lifted out by removing entire grids in a random fashion. Grids will be selected, and re-examined until 20% of the substrate is re-sorted. All organisms that were missed will be counted and this number will be added to the total number obtained in the original sort. If 95% sorting efficiency is not achieved for a given sample, a failure will be recorded on the bench sheet and in the database.

Quality control for water temperature and flow monitoring will be conducted through periodic checking of the equipment. The water level and temperature loggers may need to be adjusted throughout the year to maintain a position in representative flow. During the routine site visits performed quarterly, data will be downloaded and the temperature and/or flow sensor may be repositioned if necessary.

10.2 Corrective action processes

If questions regarding field protocols are not easily resolved, staff will meet to discuss and consult with Ecology if needed. Field equipment may periodically need maintenance, battery changes and/or cleaning and calibration. If field sensors (flow and temperature) are not working properly, staff will troubleshoot the problem and replace them if necessary. Corrective actions will be noted and documented to track any interruptions in data collection.

11.0 Management Procedures

11.1 Data recording and reporting requirements

Field data will be entered into electronic forms designed for Ecology's Environmental Assessment Program and WHM physical habitat protocols. The e-forms automate data intake for the WHM database. Once checked by Ecology, King County will load the data into EIM (EAP125 SOP). Habitat data will then be transferred to EPA's STORET database.

King County will create and maintain a project page on the PSSB web site (or create a new web site) to provide access to data and reports produced for the project.

Continuous flow data will be stored on a King County network server managed by King County Department of Information and Technology Services. Field notes related to gage installation and flow issues will be stored in paper files at KC DNRP. Software applications developed by King County will be used to input data to the KCDNRP Hydrologic Information Center database. Once in the database, data are available for download from the County internet site.

Downloaded data files from field data loggers are stored in sub directories on the King county network and backed up following a schedule. Processed flow data is stored in the County hydrologic database stored on a county maintained server. Daily backups are performed.

11.2 Laboratory data package requirements

King County's contracted lab, Rhithron Associates, will upload data to the PSSB website (www.PugetSoundStreamBenthos.org) as they are available. Rhithron will also prepare a report on QA/QC results for each set of data submitted. The project manager (Kate Macneale) will review all data before they are used for the stressor identification analyses and released to the public on the PSSB.

11.3 Electronic transfer requirements

Rhithron will load macroinvertebrate data to the PSSB web site. Data available through the PSSB are downloadable in comma delimited, tabular format, sorted by location, agency, project, site code and date. The files can be easily imported into Microsoft Excel, Access or other database software.

11.4 EIM/STORET data upload procedures

Data generated as part of this project will be uploaded to EIM and to STORET.

11.5 Model information management

Not Applicable. If models are used as part of this project this information will be provided in a QAPP addendum.

12.0 Audits and Reports

12.1 Field, laboratory, and other audits

We will appreciate constructive reviews from internal staff as well as staff from Ecology and EPA, but we do not expect the data analyses and reports to be controversial. Therefore, we do not anticipate that an audit would be necessary.

12.2 Responsible personnel

Not Applicable – there will be no audit, and therefore no personnel will be responsible for the audit.

12.3 Frequency and distribution of reports

Quarterly progress reports will describe progress in data collection, analyses, and reporting throughout the project period. A draft and final report will be prepared to describe the restoration and protection plans. The draft report will be submitted to Ecology for review. Comments will be discussed with Ecology and a final report will be prepared and submitted.

12.4 Responsibility for reports

Kate Macneale, Liora Llewellyn and Beth Sosik will author the final reports.

13.0 Data Verification

13.1 Field data verification, requirements, and responsibilities

All data will be subject to verification before data analysis, distribution to an outside party (i.e., not part of the King County project team) or posting to a publicly accessible database. Prior to such use, the Project Manager will contact the appropriate project staff and field technicians responsible for collecting data to verify procedures were followed and the data were checked for errors. To provide a third-party review, at least one project team member (not project manager or technician involved in data collection) will review the data and collection procedures before data are committed to use in analysis or disseminated outside of the project team.

The project manager (Kate Macneale) will verify field data to ensure that:

- Data are consistent, correct, and complete, with no errors or omissions
- Established criteria for QC results were met
- Data specified in the Study Design were obtained
- Methods and protocols specified in this QAPP were followed.

If MQOs are not met, data will be flagged and the metrics calculated with the data will be qualified (Table 10).

Table 10. Acceptance criteria and corrective actions for data.

Parameter	Frequency	Acceptance Criteria	Corrective Action
Macroinvertebrate data	each sample	at least 500 count per sample	flag data and qualify metrics calculated from data
Hydrologic data	water level loggers checked quarterly; loggers checked for accuracy at end of study	Data record at least 90% complete; accuracy within +/- 5% of measures taken manually	flag data and qualify hydrologic metrics calculated from data
Physical habitat survey data	two streams surveyed twice in same year	measurements from replicate measurements should be within +/- 10%	Review data for reasonableness; report S:N; flag as rejected or qualified if criteria failed
Continuous temperature data	loggers checked and downloaded quarterly; loggers checked for accuracy and drift at end of study	Data record at least 75% complete; accuracy within +/- 0.53C; drift <0.1C/year	flag data

13.2 Laboratory data verification

The taxonomic laboratory project manager will verify all taxonomic results, prior to reporting. If performance objectives for sorting, counting or identification were not met, samples will be reprocessed according to the laboratory QA/QC plan (Rhithron 2016, Appendix B). Once the

taxonomic data are entered into the PSSB database, the project manager (Kate Macneale) will review the uploaded data to assure that there are no errors in the data entry.

13.3 Validation requirements, if necessary

Not Applicable.

13.4 Model quality assessment

Not Applicable.

14.0 Data Quality (Usability) Assessment

14.1 Process for determining project objectives were met

The process for evaluating whether project outcomes have met the original objectives will include several steps. New macroinvertebrate, physical habitat, hydrologic and temperature data will ultimately be deemed useful if they can help characterize conditions and stressors at the B-IBI sites and inform restoration and protection plans. To be usable and useful, data will have been collected according to the QAPP, consistent with the study design, and will have met QA/QC criteria.

Macroinvertebrate data will be usable if the MQOs for the collection and processing were met and at least 500 organisms were identified and counted per sample. Macroinvertebrate data will be useful if they are informative for stressor identification analyses. This will depend in part on whether the composition of taxa, or the relative abundance of sensitive and tolerant taxa indicate there are particular stressors affecting the stream. Potential exploratory analyses are described in section 14.3.

Physical habitat data, hydrologic data, and temperature data were collected to help characterize local conditions at the select B-IBI sites. Parameters such as substrate size, embeddedness and riparian canopy cover have been found to be correlated with B-IBI scores in regional analyses (RSMP study, draft), and inferences from those types of analyses have informed stressor identification efforts. Data will be usable if all records indicate the specified protocols were followed by experienced or trained staff and the MQOs were met.

14.2 Treatment of non-detects

If macroinvertebrate samples contain less than 500 identifiable organisms, the data will be insufficient to calculate the B-IBI. If this occurs, the data will be reported, but not used for analysis.

If the temperature loggers or hydrologic gage equipment are not functioning properly, become dislodged from the stream or are subject to significant storm events, the data may be compromised. Quality control evaluations by King County hydrologists will identify anomalies as described in Section 6.3.

14.3 Data analysis and presentation methods

Data will be uploaded and stored in several databases. Macroinvertebrate data will be uploaded and stored in the PSSB. Physical habitat data will be uploaded to the EPA's Storage and Retrieval and Water Quality Exchange (STORET) from Ecology's Environmental Information Management (EIM) and WHM databases. Flow data and temperature data will be uploaded to King County's Hydrologic Information Center database. Geospatial data will be organized in ArcGIS geodatabases. These data will all be available for public use and distribution.

Data analysis will focus on 1) generating summary statistics to characterize conditions at the select sites and 2) exploratory analyses to identify potential stressors affecting B-IBI scores.

Data exploration will be done primarily with Excel and ArcMap. Data analysis and presentation will also require R, and possibly SigmaPlot.

B-IBI scores will be used to characterize ecological integrity at each site. Additional insights and context will be gained by comparing B-IBI scores and taxonomic data from the select sites to other data from the region. The biological potential of each site (as described in King County 2014a, Paul et al. 2009) will estimated in part to assess how much B-IBI scores could be expected to increase given the current conditions.

Stressor identification analyses will use all available data to assess which potential stressors are most likely affecting the macroinvertebrate community at a site. Recent examples of this include the analysis of B-IBI scores for the Soos Creek TMDL development. Analyses may include parametric and non-parametric analyses to examine relationships among habitat and flow conditions and macroinvertebrate data. Correlation analyses, multiple regression, and multivariate analyses (using PRIMER/ PERMANOVA, or the vegan package in R) may be used to detect differences in macroinvertebrate communities and examine how environmental variables affect those patterns. Evaluating how communities differ within sites over time and among sites may inform how resilient communities are and which stressors may affect B-IBI scores over time. Distance tools in ArcMap may be used to calculate how far sensitive taxa may need to travel to recolonize "fair" sites.

Data from other studies with comparable data (e.g., WRIA 8 Status and Trends, RSMP study, Ecology WHM program) will be used to put the select basins in context. For instance, for the restoration sites, hydrologic measures (e.g., high pulse count) measured in the select basins will be compared to those measured in other drainages to assess if hydrologic conditions are likely stressors in the select basins.

14.4 Sampling design evaluation

The project sampling design was previously developed through the "B-IBI Restoration Decision Framework and Site Identification" in Phase I of this study (King County 2014a). It is anticipated that Phase II will be similar, though updated with more recent data, including field sampling using Ecology's Watershed Health Monitoring techniques, and more extensive data analyses. The usefulness and specificity of the restoration and protection plans will depend on the availability and quality of data, and on the conclusions about potential stressors that can be drawn from those data. Evaluation will also identify any remaining critical data gaps limiting stressor identification and planning.

14.5 Documentation of assessment

The data usability assessment will be documented in the final reports.

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16.0 Appendices

Appendix A. Field Forms & Chain of Custody

Figure A-1. Chain of Custody form.

King County 2017 Macroinvertebrate Sample Inventory
KC Ambient

All data collections 8 sq ft all taxonomic identification should be taken to the "Fine" STE level matching Ecology's specifications

King County

DNRP- Water and Land Resources Division
201 South Jackson Street - MS KSC NR 0600, Seattle, WA 98119

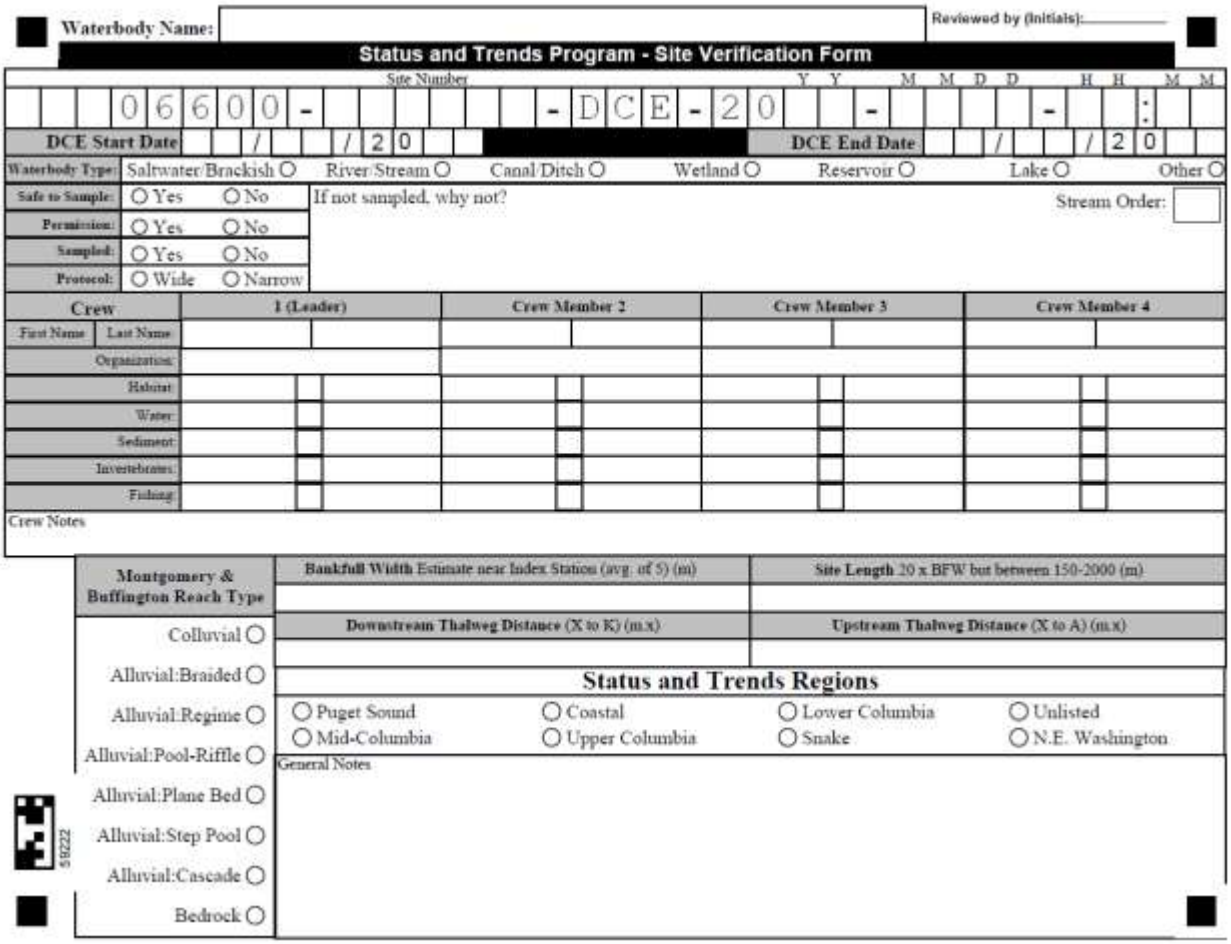
Contacts: Deb Lester - 206-477-4752
Kate Macneale - 206-477-4769

Sample ID	PSSB Project	Collect Date	Containers	QC Rep?	Collected by:	Box #	Pickup Date	Turnaround Priority

Please Note: Box numbers are not continuous from the previous pickup. This grouping begins again at box #1.

8/10/2017 1 of 2

Figure A-2. Field forms (8) in case of e-form failure



Waterbody Name:

Reviewed by (Initials):

Status and Trends Program - Site Verification Form

Site Number: 0 6 6 0 0 - - D C E - 2 0 - - : (Y Y M M D D H H M M)

DCE Start Date: / / 20

DCE End Date: / / 20

Waterbody Type:	Saltwater/Brackish ○	River/Stream ○	Canal/Ditch ○	Wetland ○	Reservoir ○	Lake ○	Other ○
Safe to Sample:	○ Yes ○ No	If not sampled, why not?				Stream Order:	
Permission:	○ Yes ○ No						
Sampled:	○ Yes ○ No						
Protocol:	○ Wide ○ Narrow						

Crew	1 (Leader)	Crew Member 2	Crew Member 3	Crew Member 4
First Name / Last Name				
Organization				
Habitat				
Water				
Sediment				
Invertebrates				
Fishing				

Crew Notes

Montgomery & Buffington Reach Type	Bankfull Width Estimate near Index Station (avg. of 5) (m)	Site Length 20 x BFW but between 150-2000 (m)
○ Colluvial ○ Alluvial:Braided ○ Alluvial:Regime ○ Alluvial:Pool-Riffle ○ Alluvial:Plane Bed ○ Alluvial:Step Pool ○ Alluvial:Cascade ○ Bedrock	Downstream Thalweg Distance (X to K) (m.x)	Upstream Thalweg Distance (X to A) (m.x)

Status and Trends Regions

○ Puget Sound ○ Coastal ○ Lower Columbia ○ Unlisted
○ Mid-Columbia ○ Upper Columbia ○ Snake ○ N.E. Washington

General Notes

59222

Reviewed by (Initials):

Status and Trends - Chemistry and Sampling Form

Site Number: 0 6 6 0 0 - _ _ _ _ _ _ - D C E - 2 0 Y Y - M M D D - H H : M M

IN SITU WATER QUALITY CALIBRATION

	Unit No.	Operator			Flag
T		Checked vs NIST	O Yes	O No	
DO		Calibrated/Checked	O Yes	O No	
pH		Calibrated/Checked	O Yes	O No	
Cond		Calibrated/Checked	O Yes	O No	
Turb		Calibrated/Checked	O Yes	O No	

IN SITU WATER QUALITY NOTES

		Transect	Time	Temp (deg C)	pH	Cond (us/cm @ 25)	DO (mg/L)	% Sat	Flag
Start Measurements			:	.	.	.	.	.	
End Measurements			:	.	.	.	.	.	

Sed:%Gravel ___ %Sand ___ %Fines ___ Field Turbidity: ___ . ___ NTU** Flag: ___

Water Sample Location ___ Work Order Number ___

Include individual comments regarding fish, benthos, sediment and water samples. Please also include a description of sample delivery method.

Sample	Primary Sample: No. of Jars	Sample ID or Fish Common Name	Flag
TPN			
TSS			
Tot P			
Cl			
Turb			
Sed PAH			
Sed Metals			
Benthos			
Fish Spp1			
Fish Spp2			
Fish Spp3			

4 3851

** If instrumentation is more accurate than field allows, please provide detailed measurement in the notes section above.

*Sediment Metals jar includes sample material to be analyzed for TOC. Note: Use standard Manchester Environmental Lab forms for tracking water and sediment samples.

Flow Location - Thalweg Station (e.g. A5) : ☐☐ Flow Meter (Model / Unit #) ☐ / ☐

Discharge Worksheet

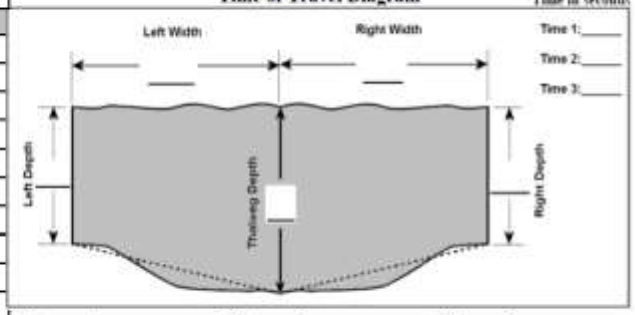
Site Number | Y Y | M M | D D | H H | M M

0 6 6 0 0 - ☐☐☐☐☐☐ - D C E - 2 0 ☐☐ - ☐☐☐☐ - ☐☐ : ☐☐

Flow Meter Zeroed Out? Y N | Wetted Width (m.x):

Cell	Tape	Depth	V 0.6	V 0.8*	V 0.2*	Notes
01						
02						
03						
04						
05						
06						
07						
08						
09						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						

Time of Travel Diagram Time in seconds



Distance1:_____ **Distance2:**_____ **Distance3:**_____

Indicate Unit of Measure for Distance measurements

Notes (discharge)

Describe Alternate Method:

Flow Method: ○ Flow Meter ○ Time of Travel ○ Bucket Flow ○ Gage

Discharge: _____ cfs

40264

* Optional velocity measurements. Only taking a 0.6 velocity is sufficient for the purposes of Status and Trends.

Reviewed by (Initials):

Status and Trends Program - GPS Positions Form

Site Number: 0 6 6 0 0 - _ _ _ _ _ - D C E - 2 0 _ _ - _ _ _ _ - _ _ : _ _

Y Y M M D D H H M M

Station	Bank	Master Lat dec deg e.g. 47.123456	Master Lon dec deg e.g. 120.123456	GPSlatDD e.g. 47.123456	GPSLonDD e.g. 120.123456	Accuracy	Accuracy Units (ft, EPE, etc)	Flag
INDEX STATION	L R							
A0	L R							
B0	L R							
C0	L R							
D0	L R							
E0	L R							
F0	L R							
G0	L R							
H0	L R							
I0	L R							
J0	L R							
K0	L R							
PUTIN	L R							
TAKEOUT	L R							

ALL COORDINATES TO BE RECORDED IN NAD83

Position comments including accuracy

Directions to access point

43161

Status & Trends - Slope and Bearing Form

Slope Measurements Started From: ○ Top of Reach ○ Bottom of Reach Reach % Slope ___.___ % Reviewed by (Initials):_____

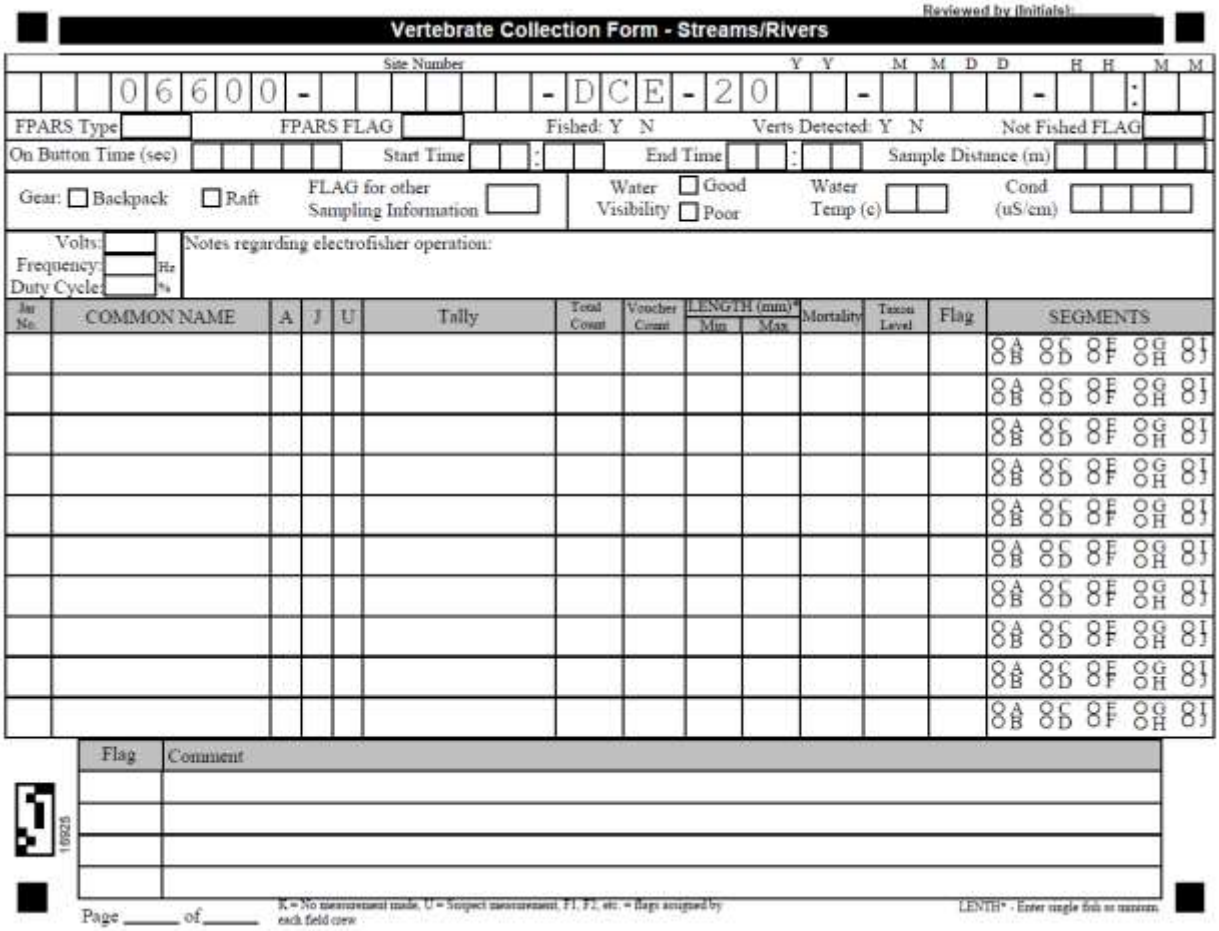
Site Number Y Y M M D D H H M M

0 6 6 0 0 - _ _ _ _ _ _ - D C E - 2 0 _ _ - _ _ _ _ - _ _ : _ _

Top Transect* LEVEL, COMPASS		Bottom Transect* ROD		Segment Length (max)	Level Wetted Depth (cm)	Eye Height on Level (cm)	Rod Wetted Depth (cm)	Level Height on Rod (cm)	Bearing (deg)	Flag	Comment

57333

*Normally sight between major and minor transects: K0 to J5, J5 to J0, J0 to I5, etc, unless there is a need for intermediate measurements. For intermediate measurements, always sight to/from a transect station 0-9 (for example K0 to J7 and J7 to J5). Bearings are magnetic north facing downstream (not adjusted).



Reviewed by (Initials): _____

Vertebrate Collection Form - Streams/Rivers

Site Number: 0 6 6 0 0 - - - - - - D C E - 2 0 - Y Y M M D D - H H : M M

FPARS Type: ☐ FPARS FLAG: ☐ Fished: Y N Verts Detected: Y N Not Fished FLAG: ☐

On Button Time (sec): ☐☐☐☐☐☐ Start Time: ☐☐:☐☐ End Time: ☐☐:☐☐ Sample Distance (m): ☐☐☐☐☐

Gear: ☐ Backpack ☐ Raft FLAG for other Sampling Information: ☐ Water Visibility ☐ Good ☐ Poor Water Temp (c): ☐☐ Cond (uS/cm): ☐☐☐☐

Volts: ☐ Frequency: ☐ Hz Duty Cycle: ☐ % Notes regarding electrofisher operation:

Jar No.	COMMON NAME	A	J	U	Tally	Total Count	Voucher Count	LENGTH (mm)* Min	LENGTH (mm)* Max	Mortality	Taxon Level	Flag	SEGMENTS
													A B C D E F G H I J
													A B C D E F G H I J
													A B C D E F G H I J
													A B C D E F G H I J
													A B C D E F G H I J
													A B C D E F G H I J
													A B C D E F G H I J
													A B C D E F G H I J
													A B C D E F G H I J
													A B C D E F G H I J

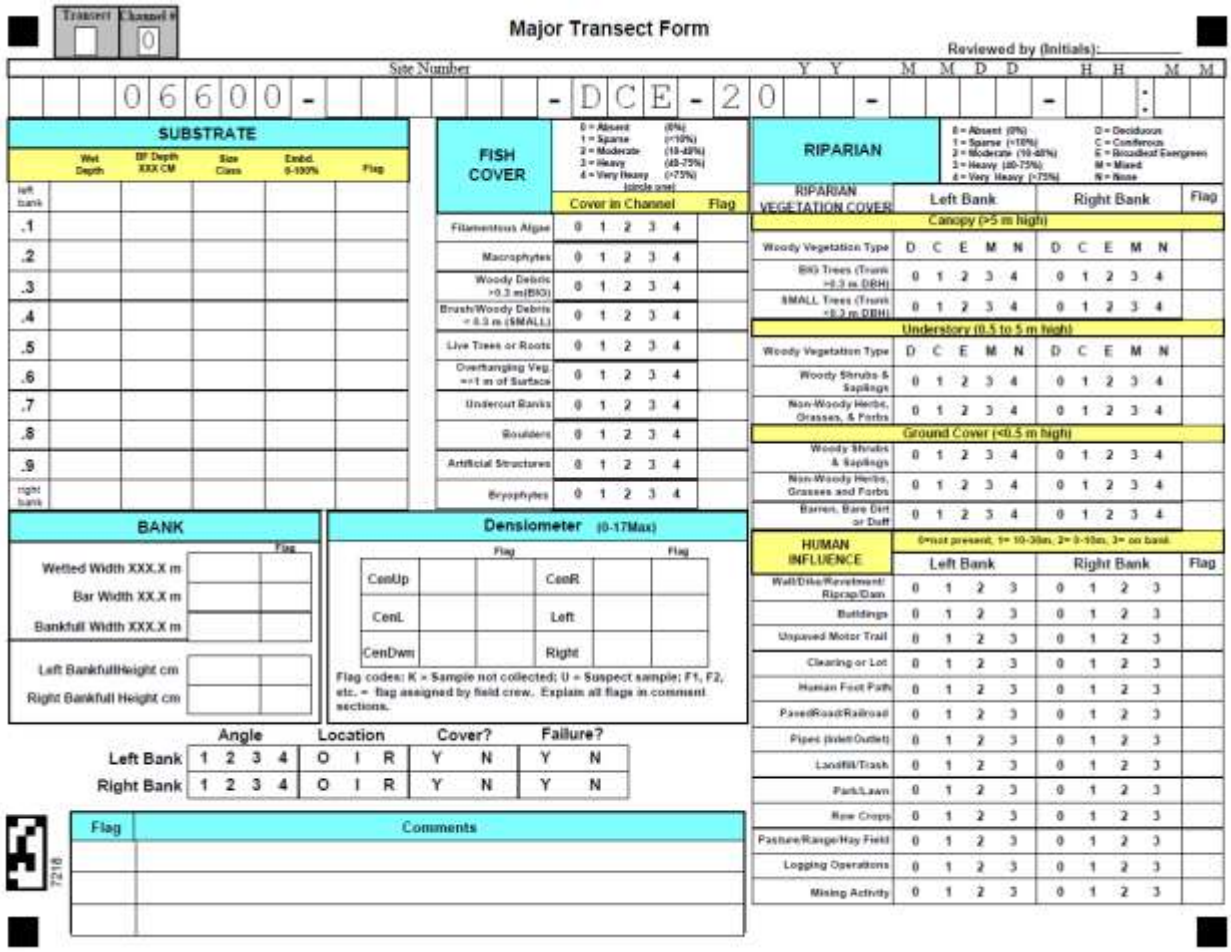
Flag	Comment

10925

Page _____ of _____

K = No measurement made, U = Suspect measurement, F1, F2, etc. = flags assigned by each field crew

LENTH* - Enter single fish or transects



Transect: | Channel #: 0

Major Transect Form

Reviewed by (Initials):_____

Site Number: 06600-__-DCE-20__-____

SUBSTRATE

	Wet Depth	BF Depth XXX CM	Size Class	Embd. 0-100%	Flag
left bank					
.1					
.2					
.3					
.4					
.5					
.6					
.7					
.8					
.9					
right bank					

FISH COVER

0 = Absent (0%); 1 = Sparse (<10%); 2 = Moderate (10-40%); 3 = Heavy (40-75%); 4 = Very Heavy (>75%) (circle one)

	Cover in Channel	Flag
Filamentous Algae	0 1 2 3 4	
Macrophytes	0 1 2 3 4	
Woody Debris >0.3 m(BIG)	0 1 2 3 4	
Brush/Woody Debris < 0.3 m (SMALL)	0 1 2 3 4	
Live Trees or Roots	0 1 2 3 4	
Overhanging Veg. <=1 m of Surface	0 1 2 3 4	
Undercut Banks	0 1 2 3 4	
Boulders	0 1 2 3 4	
Artificial Structures	0 1 2 3 4	
Bryophytes	0 1 2 3 4	

RIPARIAN

0 = Absent (0%); 1 = Sparse (<10%); 2 = Moderate (10-40%); 3 = Heavy (40-75%); 4 = Very Heavy (>75%)

D = Deciduous; C = Coniferous; E = Broadleaf Evergreen; M = Mixed; N = None

RIPARIAN VEGETATION COVER	Left Bank	Right Bank	Flag
Canopy (>5 m high)			
Woody Vegetation Type	D C E M N	D C E M N	
BIG Trees (Trunk >0.3 m DBH)	0 1 2 3 4	0 1 2 3 4	
SMALL Trees (Trunk <0.3 m DBH)	0 1 2 3 4	0 1 2 3 4	
Understory (0.5 to 5 m high)			
Woody Vegetation Type	D C E M N	D C E M N	
Woody Shrubs & Saplings	0 1 2 3 4	0 1 2 3 4	
Non-Woody Herbs, Grasses, & Forbs	0 1 2 3 4	0 1 2 3 4	
Ground Cover (<0.5 m high)			
Woody Shrubs & Saplings	0 1 2 3 4	0 1 2 3 4	
Non-Woody Herbs, Grasses and Forbs	0 1 2 3 4	0 1 2 3 4	
Barren, Bare Dirt or Duff	0 1 2 3 4	0 1 2 3 4	

BANK

		Flag
Wetted Width XXX.X m		
Bar Width XX.X m		
Bankfull Width XXX.X m		
Left BankfullHeight cm		
Right Bankfull Height cm		

Densiometer (0-17Max)

	Flag		Flag
CenUp		CenR	
CenL		Left	
CenDwn		Right	

Flag codes: K = Sample not collected; U = Suspect sample; F1, F2, etc. = flag assigned by field crew. Explain all flags in comment sections.

	Angle	Location	Cover?	Failure?
Left Bank	1 2 3 4	O I R	Y N	Y N
Right Bank	1 2 3 4	O I R	Y N	Y N

HUMAN INFLUENCE

0=not present, 1= 10-30m, 2= 3-10m, 3= on bank

	Left Bank	Right Bank	Flag
Wall/Dike/Revetment/ Riprap/Dam	0 1 2 3	0 1 2 3	
Buildings	0 1 2 3	0 1 2 3	
Unpaved Motor Trail	0 1 2 3	0 1 2 3	
Clearing or Lot	0 1 2 3	0 1 2 3	
Human Foot Path	0 1 2 3	0 1 2 3	
Paved/Road/Railroad	0 1 2 3	0 1 2 3	
Pipes (Inlet/Outlet)	0 1 2 3	0 1 2 3	
Landfill/Trash	0 1 2 3	0 1 2 3	
Park/Lawn	0 1 2 3	0 1 2 3	
Row Crops	0 1 2 3	0 1 2 3	
Pasture/Range/Hay Field	0 1 2 3	0 1 2 3	
Logging Operations	0 1 2 3	0 1 2 3	
Mining Activity	0 1 2 3	0 1 2 3	

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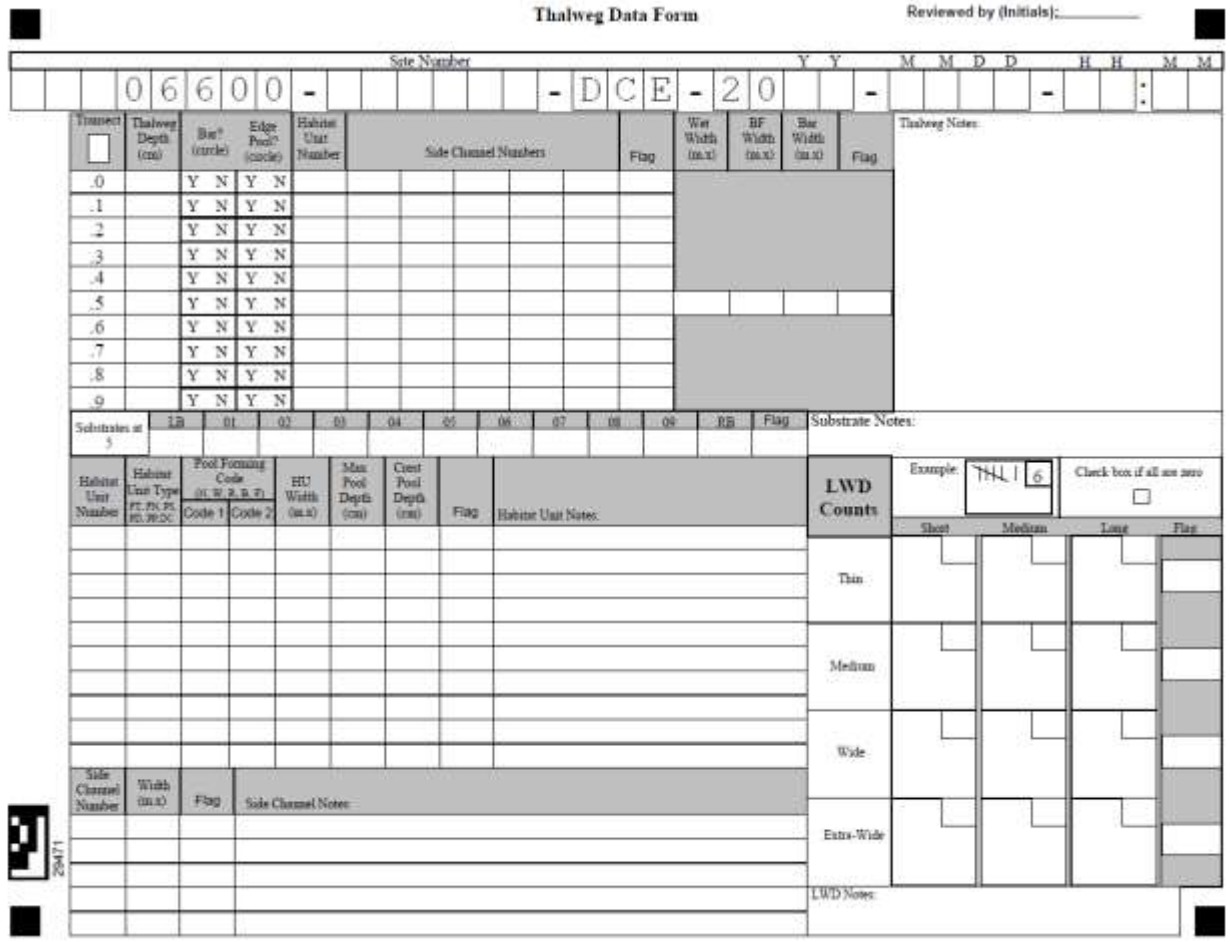
Flag	Comments



Thalweg Data Form

Reviewed by (Initials):_____

Site Number: 0 6 6 0 0 - - - - - - - D C E - 2 0 - - - - - - - - : - -

Y Y M M D D H H M M

Transect	Thalweg Depth (cm)	Bar* (circle)	Edge Pool* (circle)	Habitat Unit Number	Side Channel Numbers	Flag	Wet Width (m.x)	BF Width (m.x)	Bar Width (m.x)	Flag
.0		Y N	Y N							
.1		Y N	Y N							
.2		Y N	Y N							
.3		Y N	Y N							
.4		Y N	Y N							
.5		Y N	Y N							
.6		Y N	Y N							
.7		Y N	Y N							
.8		Y N	Y N							
.9		Y N	Y N							

Thalweg Notes:

Substrates at 5	LB	01	02	03	04	05	06	07	08	09	RB	Flag

Substrate Notes:

Habitat Unit Number	Habitat Unit Type (FT, FN, FS, RT, RF, SC)	Pool Forming Code (0, W, 2, 3, 4) Code 1	Code 2	HU Width (m.x)	Max Pool Depth (cm)	Crest Pool Depth (cm)	Flag	Habitat Unit Notes:

LWD Counts

Example: THL | 6

Check box if all are zero ☐

	Short	Medium	Long	Flag
Thin				
Medium				
Wide				
Extra-Wide				

LWD Notes:

Side Channel Number	Width (m.x)	Flag	Side Channel Notes:

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Appendix B. Glossaries, Acronyms, and Abbreviations

Glossary of General Terms

Ambient: Background or away from point sources of contamination. Surrounding environmental condition.

Bankfull stage: Formally defined as the stream level that "corresponds to the discharge at which channel maintenance is most effective, that is, the discharge at which moving sediment, forming or removing bars, forming or changing bends and meanders, and generally doing work that results in the average morphologic characteristics of channels (Dunne and Leopold, 1978).

Benthic Index of Biotic Integrity (B-IBI): A standardized scoring system which can be used to compare and rank the health of different streams using the relative diversity and abundance of species of benthic macroinvertebrates in freshwater streams and rivers.

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.

National Pollutant Discharge Elimination System (NPDES): National program for issuing, modifying, revoking and reissuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements under the Clean Water Act. The NPDES program regulates discharges from wastewater treatment plants, large factories, and other facilities that use, process, and discharge water back into lakes, streams, rivers, bays, and oceans.

Nonpoint source: Pollution that enters any waters of the state from any dispersed land-based or water-based activities, including but not limited to atmospheric deposition, surface-water runoff from agricultural lands, urban areas, or forest lands, subsurface or underground sources, or discharges from boats or marine vessels not otherwise regulated under the NPDES program. Generally, any unconfined and diffuse source of contamination. Legally, any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act.

Point source: Source of pollution that discharges at a specific location from pipes, outfalls, and conveyance channels to a surface water. Examples of point source discharges include municipal wastewater treatment plants, municipal stormwater systems, industrial waste treatment facilities, and construction sites where more than 5 acres of land have been cleared.

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

recreational, or other legitimate beneficial uses, or (3) livestock, wild animals, birds, fish, or other aquatic life.

Reach: A specific portion or segment of a stream.

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

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

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).

Surface waters of the state: Lakes, rivers, ponds, streams, inland waters, salt waters, wetlands and all other surface waters and water courses within the jurisdiction of Washington State.

Thalweg: The deepest and fastest moving portion of a stream.

Total Maximum Daily Load (TMDL): A distribution of a substance in a water body 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 waste load 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 waste load determination. A reserve for future growth is also generally provided.

Turbidity: A measure of water clarity. High levels of turbidity can have a negative impact on aquatic life.

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, requiring 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 standards and are not expected to improve within the next two years.

Acronyms and Abbreviations

B-IBI	(See Glossary above)
BMP	Best management practice
e.g.	For example
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
et al.	And others
GIS	Geographic Information System software
GPS	Global Positioning System
i.e.	In other words
PSP	Puget Sound Partnership
PSSB	Puget Sound Stream Benthos website database
QA	Quality assurance
QC	Quality control
RPD	Relative percent difference
RSD	Relative standard deviation
SOP	Standard operating procedures
TMDL	(See Glossary above)
USGS	United States Geological Survey
WDFW	Washington Department of Fish and Wildlife
WRIA	Water Resource Inventory Area

Units of Measurement

°C	degrees centigrade
cfs	cubic feet per second
ft	feet
gsd	ground sample distance
km	kilometer, a unit of length equal to 1,000 meters
m	meter

Quality Assurance Glossary

Accreditation: A certification process for laboratories, designed to evaluate and document a lab's ability to perform analytical methods and produce acceptable data. For Ecology, it is "Formal recognition by (Ecology)…that an environmental laboratory is capable of producing accurate analytical data." [WAC 173-50-040] (Kammin, 2010)

Accuracy: The degree to which a measured value agrees with the true value of the measured property. USEPA recommends that this term not be used, and that the terms precision and bias be used to convey the information associated with the term accuracy. (USGS, 1998)

Analyte: An element, ion, compound, or chemical moiety (pH, alkalinity) which is to be determined. The definition can be expanded to include organisms, e.g., fecal coliform, Klebsiella. (Kammin, 2010)

Bias: The difference between the population mean and the true value. Bias usually describes a systematic difference reproducible over time, and is characteristic of both the measurement system, and the analyte(s) being measured. Bias is a commonly used data quality indicator (DQI). (Kammin, 2010; Ecology, 2004)

Blank: A synthetic sample, free of the analyte(s) of interest. For example, in water analysis, pure water is used for the blank. In chemical analysis, a blank is used to estimate the analytical response to all factors other than the analyte in the sample. In general, blanks are used to assess possible contamination or inadvertent introduction of analyte during various stages of the sampling and analytical process. (USGS, 1998)

Calibration: The process of establishing the relationship between the response of a measurement system and the concentration of the parameter being measured. (Ecology, 2004)

Check standard: A substance or reference material obtained from a source independent from the source of the calibration standard; used to assess bias for an analytical method. This is an obsolete term, and its use is highly discouraged. See Calibration Verification Standards, Lab Control Samples (LCS), Certified Reference Materials (CRM), and/or spiked blanks. These are all check standards, but should be referred to by their actual designator, e.g., CRM, LCS. (Kammin, 2010; Ecology, 2004)

Comparability: The degree to which different methods, data sets and/or decisions agree or can be represented as similar; a data quality indicator. (USEPA, 1997)

Completeness: The amount of valid data obtained from a project compared to the planned amount. Usually expressed as a percentage. A data quality indicator. (USEPA, 1997)

Continuing Calibration Verification Standard (CCV): A QC sample analyzed with samples to check for acceptable bias in the measurement system. The CCV is usually a midpoint calibration standard that is re-run at an established frequency during the course of an analytical run. (Kammin, 2010)

Control chart: A graphical representation of quality control results demonstrating the performance of an aspect of a measurement system. (Kammin, 2010; Ecology 2004)

Control limits: Statistical warning and action limits calculated based on control charts. Warning limits are generally set at +/- 2 standard deviations from the mean, action limits at +/- 3 standard deviations from the mean. (Kammin, 2010)

Data integrity: A qualitative DQI that evaluates the extent to which a data set contains data that is misrepresented, falsified, or deliberately misleading. (Kammin, 2010)

Data Quality Indicators (DQI): Commonly used measures of acceptability for environmental data. The principal DQIs are precision, bias, representativeness, comparability, completeness, sensitivity, and integrity. (USEPA, 2006)

Data Quality Objectives (DQO): Qualitative and quantitative statements derived from systematic planning processes that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions.
(USEPA, 2006)

Data set: A grouping of samples organized by date, time, analyte, etc. (Kammin, 2010)

Data validation: An analyte-specific and sample-specific process that extends the evaluation of data beyond data verification to determine the usability of a specific data set. It involves a detailed examination of the data package, using both professional judgment, and objective criteria, to determine whether the MQOs for precision, bias, and sensitivity have been met. It may also include an assessment of completeness, representativeness, comparability and integrity, as these criteria relate to the usability of the data set. Ecology considers four key criteria to determine if data validation has actually occurred. These are:

- Use of raw or instrument data for evaluation.
- Use of third-party assessors.
- Data set is complex.
- Use of EPA Functional Guidelines or equivalent for review.

Examples of data types commonly validated would be:

- Gas Chromatography (GC).
- Gas Chromatography-Mass Spectrometry (GC-MS).
- Inductively Coupled Plasma (ICP).

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

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

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

Detection limit (limit of detection)**:** The concentration or amount of an analyte which can be determined to a specified level of certainty to be greater than zero. (Ecology, 2004)

Duplicate samples: Two samples taken from and representative of the same population, and carried through and steps of the sampling and analytical procedures in an identical manner. Duplicate samples are used to assess variability of all method activities including sampling and analysis. (USEPA, 1997)

Field blank: A blank used to obtain information on contamination introduced during sample collection, storage, and transport. (Ecology, 2004)

Initial Calibration Verification Standard (ICV): A QC sample prepared independently of calibration standards and analyzed along with the samples to check for acceptable bias in the measurement system. The ICV is analyzed prior to the analysis of any samples. (Kammin, 2010)

Laboratory Control Sample (LCS): A sample of known composition prepared using contaminant-free water or an inert solid that is spiked with analytes of interest at the midpoint of the calibration curve or at the level of concern. It is prepared and analyzed in the same batch of regular samples using the same sample preparation method, reagents, and analytical methods employed for regular samples. (USEPA, 1997)

Matrix spike: A QC sample prepared by adding a known amount of the target analyte(s) to an aliquot of a sample to check for bias due to interference or matrix effects. (Ecology, 2004)

Measurement Quality Objectives (MQOs)**:** Performance or acceptance criteria for individual data quality indicators, usually including precision, bias, sensitivity, completeness, comparability, and representativeness. (USEPA, 2006)

Measurement result: A value obtained by performing the procedure described in a method. (Ecology, 2004)

Method: A formalized group of procedures and techniques for performing an activity (e.g., sampling, chemical analysis, data analysis), systematically presented in the order in which they are to be executed. (EPA, 1997)

Method blank: A blank prepared to represent the sample matrix, prepared and analyzed with a batch of samples. A method blank will contain all reagents used in the preparation of a sample, and the same preparation process is used for the method blank and samples. (Ecology, 2004; Kammin, 2010)

Method Detection Limit (MDL): This definition for detection was first formally advanced in 40CFR 136, October 26, 1984 edition. MDL is defined there as the minimum concentration of an analyte that, in a given matrix and with a specific method, has a 99% probability of being identified, and reported to be greater than zero. (Federal Register, October 26, 1984)

Percent Relative Standard Deviation (%RSD): A statistic used to evaluate precision in environmental analysis. It is determined in the following manner:

$$\%RSD = (100 * s)/x$$

where s is the sample standard deviation and x is the mean of results from more than two replicate samples. (Kammin, 2010)

Parameter: A specified characteristic of a population or sample. Also, an analyte or grouping of analytes. Benzene and nitrate + nitrite are all "parameters." (Kammin, 2010; Ecology, 2004)

Population: The hypothetical set of all possible observations of the type being investigated. (Ecology, 2004)

Precision: The extent of random variability among replicate measurements of the same property; a data quality indicator. (USGS, 1998)

Quality assurance (QA): A set of activities designed to establish and document the reliability and usability of measurement data. (Kammin, 2010)

Quality Assurance Project Plan (QAPP): A document that describes the objectives of a project, and the processes and activities necessary to develop data that will support those objectives. (Kammin, 2010; Ecology, 2004)

Quality control (QC): The routine application of measurement and statistical procedures to assess the accuracy of measurement data. (Ecology, 2004)

Relative Percent Difference (RPD): RPD is commonly used to evaluate precision. The following formula is used:

$$[Abs(a-b)/((a + b)/2)] * 100$$

where "Abs()" is absolute value and a and b are results for the two replicate samples. RPD can be used only with 2 values. Percent Relative Standard Deviation is (%RSD) is used if there are results for more than 2 replicate samples (Ecology, 2004).

Replicate samples: Two or more samples taken from the environment at the same time and place, using the same protocols. Replicates are used to estimate the random variability of the material sampled. (USGS, 1998)

Representativeness: The degree to which a sample reflects the population from which it is taken; a data quality indicator. (USGS, 1998)

Sample (field): A portion of a population (environmental entity) that is measured and assumed to represent the entire population. (USGS, 1998)
Sample (statistical): A finite part or subset of a statistical population. (USEPA, 1997)

Sensitivity: In general, denotes the rate at which the analytical response (e.g., absorbance, volume, meter reading) varies with the concentration of the parameter being determined. In a specialized sense, it has the same meaning as the detection limit. (Ecology, 2004)

Spiked blank: A specified amount of reagent blank fortified with a known mass of the target analyte(s); usually used to assess the recovery efficiency of the method. (USEPA, 1997)

Spiked sample: A sample prepared by adding a known mass of target analyte(s) to a specified amount of matrix sample for which an independent estimate of target analyte(s) concentration is available. Spiked samples can be used to determine the effect of the matrix on a method's recovery efficiency. (USEPA, 1997)

Split sample: A discrete sample subdivided into portions, usually duplicates (Kammin, 2010)

Standard Operating Procedure (SOP): A document which describes in detail a reproducible and repeatable organized activity. (Kammin, 2010)

Surrogate: For environmental chemistry, a surrogate is a substance with properties similar to those of the target analyte(s). Surrogates are unlikely to be native to environmental samples. They are added to environmental samples for quality control purposes, to track extraction efficiency and/or measure analyte recovery. Deuterated organic compounds are examples of surrogates commonly used in organic compound analysis. (Kammin, 2010)

Systematic planning: A step-wise process which develops a clear description of the goals and objectives of a project, and produces decisions on the type, quantity, and quality of data that will be needed to meet those goals and objectives. The DQO process is a specialized type of systematic planning. (USEPA, 2006)

References for QA Glossary

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Appendix C. Laboratory Quality Assurance Plan