

Quality Assurance Project Plan

Puget Sound Watershed Characterization Hydrologic Condition Index Phase 2



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Each study funded by the U.S. Environmental Protection Agency (EPA) must have an approved Quality Assurance Project Plan (QAPP). The plan describes the objectives of the study and the procedures to be followed to achieve those objectives. After completing the study, the author will post the final report of the study to the internet. This QAPP describes the Hydrologic Condition Index Development for Puget Sound – Phase 2 project being completed by Environmental Science Associates as a contractor to Ecology under CONTRACT No. C2200014.

This Quality Assurance Project Plan is available upon request from the Ecology Project Manager, Colin Hume.

This QAPP is valid through five years from the date of approval.

Contact Information

Colin Hume
Washington State Department of Ecology

Northwest Regional Office
15700 Dayton Ave. N.
Shoreline, WA. 98133
Phone: 425-395-5283
Colin.hume@ecy.wa.gov

Jonathan Ambrose
Environmental Science Associates

5309 Shilshole Ave NW
Suite 200
Seattle, WA 94107
Phone: 206.799.3687
jambrose@esaassoc.com

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Quality Assurance Project Plan

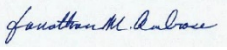

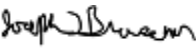



Puget Sound Watershed Characterization Phase 2

NTA 2018-0660

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By Miranda Nelson, Joe Brascher, Jonathan Ambrose, and Colin Hume

Approved by:

Signature: 	Date: 10/15/2021
Jonathan Ambrose, Project Manager, Environmental Science Associates	
Signature: 	Date: 10/13/2021
Colin Hume, Client / NTA Manager, Washington State Dept. of Ecology	
Signature: 	Date: 10/18/2021
Joe Brascher, Principal Investigator, Clear Creek Solutions	
Signature: 	Date: 10/14/2021
Margaret Clancy, Project Director, Environmental Science Associates	
Signature: 	Date: 10/12/2021
Arati Kaza, Quality Assurance Officer, Department of Ecology	
Signature: 	Date: 10/14/2021
Justin Donahue, Stormwater Strategic Initiative, Washington State Department of Ecology	

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2.0 Abstract

The goal of the Puget Sound Watershed Characterization (PSWC) Project is to provide local land use planners and resource managers with better tools for making decisions about watershed protection, restoration, and development. Over time, PSWC has evolved from a coarse-scale analytical framework for understanding watershed processes to a quantitative index for predicting how changes in land cover and land use will affect watershed health.

Entering Phase 2 of the work, the Washington State Department of Ecology (Ecology) is partnering with Environmental Science Associates (ESA) and Clear Creek Solutions, Inc. (CCS) to develop a new set of models that will evaluate hydrologic condition in watersheds where growth is planned. The project is building off methods developed by King County scientists to evaluate Critical Areas Ordinance effectiveness. The models will assess hydrologic condition using indicators such as stream flashiness based upon a combination of factors such as land cover, geology, and distance to stream and will consider climate change projections. Phase 2 will focus on the development of these Hydrologic Condition Indices (HCIs) using more regionally dispersed and rural watershed data and a more rigorous approach with greater regional depth than prior phases of work. This will make the model more relevant to the range of stakeholders the PSWC is designed to assist, specifically local governments and resource management agencies within western Washington and the Puget Sound region.

3.0 Background

3.1 Introduction and problem statement

In 2008, the EPA and King County partnered in a multiyear, comprehensive scientific study to better understand the County's new regulations and assess whether they would be effective at preventing environmental degradation from ongoing and future development (Lucchetti et al. 2014).

Initial Puget Sound watershed characterization work, pioneered by the Washington State Department of Ecology (see Stanley et al. 2005, Stanley and Grigsby 2008) and other scientists, demonstrated the need to consider watershed scale processes in planning and restoration actions (NRC 1996 and 2001, Spence et al. 1996, Dale et al. 2000).

This led to the development of the Puget Sound Watershed Characterization (PSWC), a set of water and habitat assessments described in four volumes that compare areas within a watershed for restoration and protection value as well as identifying the best location for development. It also provides a decision-support framework that helps integrate these assessments across multiple scales for use in watershed based planning at the regional, county, and city levels.

3.2 Study area and surroundings

The study area encompasses the entire Puget Sound region, including Clallam, Island, Jefferson, King, Kitsap, Lewis, Mason, Pierce, San Juan, Skagit, Snohomish, Thurston, and Whatcom counties, and 19 Water Resource Inventory Areas (WRIAs). All of the study area is located west of the Cascade Range and has mild marine-type climate typical of Western Washington. Summers are cool and relatively dry while winters are mild and wet (WRCC, 2021).

Puget Sound Wide Analysis

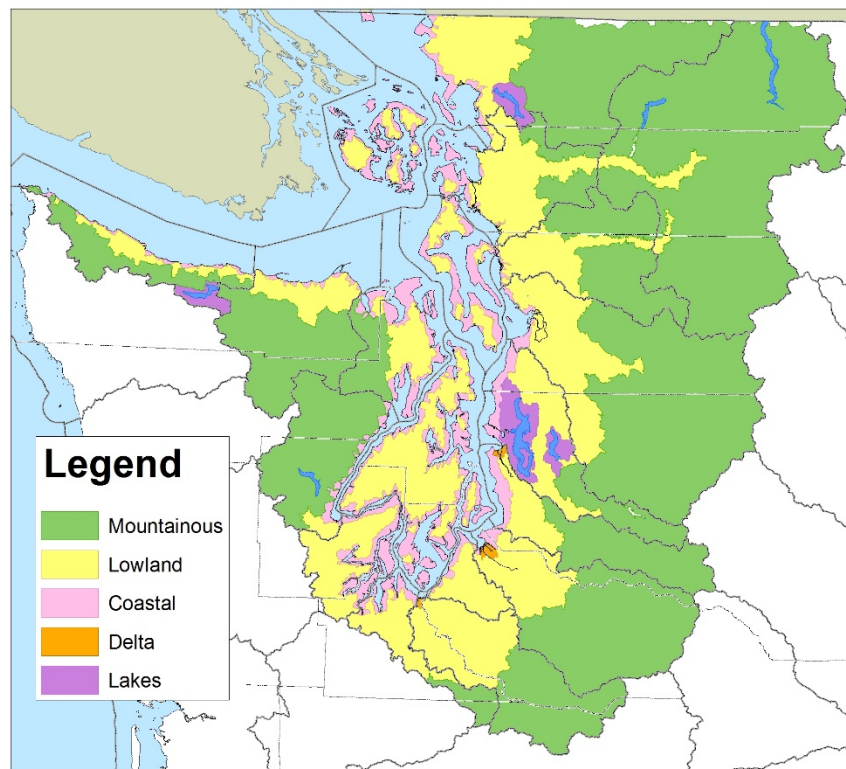


Figure 1. Map of the Puget Sound-Wide Study Area (Map produced by Ecology’s GIS Data Center).

3.2.1 History of study area

The project will occur in the 13 Western Washington counties listed above. Starting in the mid 1880’s until the mid-1990s, these areas have been subject to intense logging, agricultural and land development. Despite the land use change over the past 100 years, the rural areas of these two counties still have moderate to high ecological value (Stanley et al. 2019A). However, growing populations are threatening to increase the conversion of these rural lands to more

urban uses, resulting in the loss of ecological processes and biological diversity within these watersheds.

3.2.2 Summary of previous studies and existing data

The PSWC consists of four volumes published between 2012 and 2019. Volume 1, published in April 2012, briefly describes the overall conceptual decision support framework for the PSWC and details the assessment of water resources using analyses of watershed processes. It also includes Watershed Characterization Tool (WCT) 1, which assesses the relative level of importance and degradation for water flow processes, and WCT2 for assessing water quality processes.

Volume 2, published in December 2013, compares relative fish and wildlife habitat values across multiple environments and includes a series of tools (WCT3) for assessing the habitats in those environments (freshwater habitat, terrestrial habitat, and marine shorelines).

Volume 3, published in June 2013, explains how to synthesize the results of each preceding volume into an integrated decision support framework to support protection and restoration actions over multiple scales. It is intended to help users integrate and apply the assessment information in a systematic, consistent manner across multiple scales within an analytical watershed framework in order to achieve ecologically based land use and management decisions.

In Volume 4, Phase 1, published in July 2019, the Department of Ecology (Ecology) initiated development of a new “mid-scale” assessment tool (WCT4) known as the Hydrologic Condition Index (HCI) for potential further development to be applied throughout Puget Sound watersheds. Phase 2 of the project will further the development of the HCI approach based on recommendations made during Phase 1 and seek to utilize a more regionally dispersed and rural watershed dataset. Appendix A describes the basic concepts that the HCI was based upon when initially developed by King County (Luccetti et al. 2014).

3.2.3 Parameters of interest and potential sources

The project does not involve monitoring or evaluating environmental pollutants or contaminants of interest. Instead, the project team will calibrate and refine the Hydrologic Condition Index (HCI) coefficients across areas of the Puget Sound that were not part of the initial calibration. As part of the model verification, they will extract Hydrologic Pulse Counts (HPCs) and study how HPCs are impacted by major routing features within the main stem of each watershed.

3.2.4 Regulatory criteria or standards

The proposed model updates are part of a “decision support tool” designed to assist local governments making planning decisions. There are no regulatory criteria or standards directly associated with this project.

3.3 Water quality impairment studies

Not applicable.

3.4 Effectiveness monitoring studies

Not applicable.

4.0 Project Description

Local governments and resource management agencies in the Puget Sound Basin make hundreds of decisions each year that affect the health and sustainability of our terrestrial and aquatic ecosystems. Rarely are those decisions informed by a full understanding of watershed processes and actual watershed conditions or adequate data on the cumulative implications of those decisions across time and space. The goal of the Puget Sound Watershed Characterization (PSWC) Project is to remedy this problem by giving local land use planners and resource manager's better tools for making decisions about watershed protection, restoration, and development. The PSWC has been used in places such as Duvall, Birch Bay, Mukilteo, and Water Resource Inventory Area (WRIA) 7 to identify actions that improve forest cover, water quality, and wildlife habitat and that direct future development in ways that protect and restore watershed processes.

The goal of the Phase 2 portion of the work is to utilize a more regionally dispersed and rural watershed data set that will aid in making the HCI tool more relevant for the range of stakeholders that the PSWC is aimed to assist. This includes refining the HCI coefficients across areas of the Puget Sound that were not part of the initial calibration and further testing the ability of the HCI to predict the effects of zoning and land use actions on stream health through use case scenarios. The project team will work to make the HCI appealing and useful to stormwater managers and local planning agencies, elucidating ways to use the HCI information in concert with other data to guide land use planning and decision-making.

4.1 Project goals

The primary project goal is to conduct additional HSPF model verification, HSPF model expansion, and Hydrologic Pulse Count (HPC) refinement work to support the development of Phase 2 of the HCI.

4.2 Project objectives

Overarching project objectives include furthering the project's technical foundation by conducting uncertainty testing using two different areas of analysis. The project team will study the sensitivity of the Hydrological Simulation Program – FORTRAN (HSPF) calibration parameters most relevant to the Puget Sound watershed and study the impacts and sensitivity of all routing features. The team will also expand high pulse count coefficients for regional application in Puget Sound and conduct use case scenarios to demonstrate applicability to local management decisions related to land use and stormwater.

4.3 Information needed and sources

Data sources for the project include extracting information from previously developed HSPF model efforts throughout the study area. These models were developed and calibrated previously by Clear Creek Solutions for other purposes and represent a “library” of watersheds from which to draw upon. Variables from selected watershed models will be used for the purposes of sensitivity testing and development of the HCI tool. Watersheds with functional HSPF models that will be evaluated to determine inclusion in the study include those listed in Table 1 below:

Table 1. CCS Western Washington HSPF Models

COUNTY	WATERSHEDS
Whatcom	Whatcom Creek; Chuckanut Creek; Silver Beach Creek; Lincoln Creek; Hannah Creek; Fever Creek; Padden Creel; Squalicum Creek
Snohomish	North Creek; Swamp Creek; Little Bear Creek; McAleer Creek; Lyon Creek; Lunds Gulch; Big Gulch; Marshland Tributaries; Penny Creek; Tambark Creek; Martha Creek; Quilceda Creek; Pigeon Creek #1; Pigeon Creek #2; Glenhaven Creek; Powder Mill Gulch; Friar Creek; Allen Creek; Sunnyside Creek; Lake Stevens; Catherine Creek
King	North Creek; Swamp Creek; Little Bear Creek; McAleer Creek; Lyon Creek; Ronald Bog; Johnson Creek; Issaquah Creek; Densmore-Green Lake; Miller Creek; Des Moines Creek; Government Canal; Rock Creek; Venema Creek; Hylebos Creek; Snoqualmie Ridge; Hamm Creek; Issaquah Highlands; Wolfe Creek
Pierce	Clear Creek
Kitsap	Gorst Creek
Thurston	Woodland Creek; Woodard Creek; Chambers Creek; College Ditch; Yauger Park; Green Cove; Deschutes River; Indian-Moxlie; McAlister Creek
Clark	Mill Creek; Gee Creek; Whipple Creek

4.4 Tasks required

Specific project objectives broken down by task include:

Task 1.1 – Detailed Project Plan

- Complete a Detailed Project Plan (DPP)

Task 1.2 – Quality Assurance Project Plan

- Complete a Quality Assurance Project Plan (QAPP).

Task 1.3 – Project Team Meetings and Coordination

- Conduct bi-weekly project status check-in meetings between Ecology and ESA project manager from June 2021 to November 2022.
- Conduct 17 monthly technical meetings between Ecology and the ESA team from June 2021 to November 2022.

Task 2.1 – Technical Advisory Groups

- Convene the watershed advisory group (WAG) to provide input primarily on Tasks 2.2 and 2.3 three to four times over the course of the project.
- Convene a second advisory group comprised primarily of local government planners (Local Advisory Group or LAG) to advise primarily on Task 2.4 three to four times over the course of the project.

Task 2.2 – Furthering Technical Foundation

- Generate a single exceedance probability for a composite set of HPC coefficients with a known degree of uncertainty.
- Document results of the uncertainty testing and sensitivity analysis in a draft and final technical report.

Task 2.3 – Expanding High Pulse Count coefficients for Regional Application in Puget Sound

- Calculate HCI coefficients for additional regions of Puget Sound.
- Summarize Task 2.3 work in a draft technical memo and final technical report.

Task 2.4 – Alternative Future Use Cases

- Coordinate with three local governments to support the application of the HCI Soundwide.
- Prepare a technical report documenting the three pilot use cases of the HCI, methods, and results in collaboration with Ecology.
- Provide content for one story map to be hosted on Ecology’s website
- Deliver a “How to” methods manual and associated spatial tools (e.g. python/Arc Toolbox scripts) for applying HCI in alternative futures applications.

4.5 Systematic planning process

Not applicable.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

Table 2. Organization of Project Staff and Responsibilities.

Staff	Title	Responsibilities
Colin Hume Department of Ecology Phone: 425.395.5283	Client	Clarifies scope of the project. Provides internal review of the QAPP and approves the final QAPP. Coordinates and facilitates the technical advisory groups. Reviews all draft and final products produced by the consultant team.
Jonathan Ambrose ESA Phone: 206.799.3687	Project Manager	Writes the QAPP. Oversees overall work product and QA review of data. Oversees completion of the draft report and final report.
Joe Brascher Clear Creek Solutions Phone: 360.943.0304	Principal Investigator	Completes research into Puget Sound HSPF models, selection of appropriate watersheds, sensitivity analysis of model variables, evaluation of data quality, and implementation of the Hydrologic Conditions Index analysis. Lead author of draft and final reports
Margaret Clancy ESA Phone: 206.794.1548	Supervisor for the Project Manager	Provides internal review of the QAPP, approves the budget, and approves the final QAPP.
Britta Voss Department of Ecology Phone: 360-407-6070	NEP Quality Coordinator	Reviews the draft QAPP and recommends the final QAPP for approval.
Arati Kaza Department of Ecology Phone: 360-407-6964	Quality Assurance Officer	Reviews and approves the draft QAPP and the final QAPP.

QAPP: Quality Assurance Project Plan

NEP: National Estuary Program

WQX: Water Quality Exchange

5.2 Special training and certifications

Jonathan Ambrose | Project Manager, Sr. Hydrologist

Jon is senior hydrologist with 20 years of experience working within and managing interdisciplinary teams of scientists and engineers on a range of water resource and riverine projects throughout Puget Sound and the Pacific Northwest. He routinely manages large-value capital projects through all phases from data collection and analysis, alternatives development, design, and construction management. He has been the primary client point-of-contact responsible for managing contracts and ensuring adherence to project objectives and schedule, working with sub consultants to manage deliverables and budgets, and ensuring proper quality assurance/quality control (QA/QC) at all levels to deliver high-quality work products. Jon will serve as the main point-of-contact, and manage the project team to meet the schedule and milestones outlined in the scope-of-work and in the Detailed Project Plan. He will adhere to the QA/ QC protocols set forth in the QAPP to maintain high-quality data analysis, management, and work products, and assist Ecology's project manager in WAG/LAG meeting preparation, facilitation, and follow up as requested.

Margaret Clancy, PWS | Project Director

Margaret is a Professional Wetland Scientist with 30 years of experience specializing in projects that require strategic understanding of planning, design, and regulatory compliance. She has led and managed a wide range of environmental studies involving mitigation planning and implementation, watershed characterization, and the integration of resource management and land use planning. Margaret will serve as the project director providing contract management, senior oversight, and QA/QC.

Mike Leech, GISP | GIS/Web Lead

Mike has over 20 years of experience managing and supporting large geospatial, database, and web application development projects for water resources, natural resources, and conservation-focused applications. He is the firm wide lead for ESA's Geospatial and Software Development teams. Mike and his team are responsible for providing ESA's biological resources and land management teams with the technical services necessary to support major field deployments, including unmanned aerial vehicle (UAV) and mobile data collection and reporting, satellite image processing, and web-based applications and data visualizations. He has managed numerous large geospatial, database and web application development projects, including the recent launch of a comprehensive environmental compliance monitoring and management system for the Environmental Planning Group at the Los Angeles World Airports (LAWA). Mike also served as the lead for the Version 1.0 launch of the Ecology Puget Sound Watershed Characterization web application including oversight of GIS development, publishing

new map services and authoring and publishing content for the Story Maps. Mike will serve as the GIS lead for this project.

James Gregory | Hydrology & Hydraulics

James is an environmental engineer and hydrologist with a background in water quality, flood management, climate change analysis, and hydraulic and hydrologic modeling. He has extensive experience in field data collection, topographic surveying, and GIS, and has developed multiple script-based and GIS tools to process, analyze, and visualize a wide array of datasets. James' work includes collecting data to characterize physical processes in watershed, riverine, and estuarine systems, developing hydrologic and hydraulic models to simulate existing processes, evaluate restoration, and flood management alternatives.

Colin Struthers | GIS Specialist

Colin a GIS specialist with more than 10 years of experience in leading the collection of mobile data, multi-spectral satellite image and LiDAR processing, CAD integration, dynamic data visualizations, drone (Unmanned Aircraft Systems [UAS]) data capture, cartography, and web mapping. Colin has supported clients with more advanced Artificial Intelligence and machine learning techniques to automate the image classification of vegetation, wetlands, and feature extraction. He has also developed at-scale visual simulations that communicate technical project concepts with the public and help to facilitate the public visioning processes. Colin will work closely with Ecology GIS on spatial analysis, modeling, and data display for the story maps and other elements.

Mark Johnson | Land Use Planning

Mark is a senior environmental planner and land use expert with over 30 years of experience in planning, design, project management, and regulatory review. He specializes in land use and environmental policy and understands complex land use compatibility issues. He offers unique skills and a pragmatic approach that will translate into efficient use of resources supporting Ecology's project objectives. Mark will provide input and support on the alternative future scenarios analysis.

Derek Booth, PhD, PE, PG | Strategic Advisor

Dr. Booth has integrated academic research, teaching, and private practice throughout his 30+-year career in geomorphology, hydrology, and watershed management. He is a regional leader in the study of urban stream systems, hydrologic impacts of urbanization, and the geomorphic and habitat response to those impacts. Dr. Booth has reviewed watershed assessment and management tools for Ecology for the initial watershed characterization. Now an ESA employee, Dr. Booth will serve as a strategic advisor for Phase 2 of the HCI Development. He will draw on his strong background in research, academia, and applied work in stream channel

response to urban hydrology. Dr. Booth will participate in study design, WAG meetings, and provide QA/QC at critical junctures throughout the project

Joseph Brascher | Hydrologic Modeling

Joe serves as the project manager and chief architect for the WWHM project for Ecology since its initial conception in 1999. This project involved the development of a software design tool that is based on the U.S. Environmental Protection Agency's (EPA) HSPF continuous simulation model, but incorporates Ecology's standards for development in an extremely user-friendly interface. Other relevant project experience includes Yaeger Park Regional Stormwater Modeling for the City of Olympia, and a HSPF Model for Seattle Public Utilities' Densmore-Green Lake Drainage System project. Joe will lead the HSPF model review, Phase 1 Evaluation Phase 2 Assessment, regional model evaluation, and additional analysis on the HPC's and HCI tool.

Doug Beyerlein, PhD, PE, WRE | Hydrologic Modeling

Doug has over 40 years of experience in numerous aspects of water resources planning, flood studies, and stormwater modeling. He has conducted HSPF modeling studies throughout the Puget Sound region and teaches workshops on the theory and application of HSPF to federal, state, and local agencies. Doug's project experience includes WWHM training workshops for Associated General Contractors of Washington Education Foundation, a Comprehensive Stormwater Management Plan for the City of Bellingham Department of Public Works, and HSPF modeling for Mill and Gee Watershed Calibrations for Clark County's Clean Water Program. Doug will provide QA/QC on the Phase 2 assessment, model selection, HPC development, and HCI analysis.

Colin Hume | Ecology Project Manager, Watershed Characterization & Land Use Planning Specialist

Colin Hume is a Watershed Ecologist for the Washington State Department of Ecology. Colin earned his B.S. in Biology from Western Washington University, and an M.S. in Conservation Biology and Environmental Planning from the University of Michigan School of Natural Resources and Environment where he focused on strategies for protection and restoration of watershed processes and function. Colin currently serves as manager for the Puget Sound Watershed Characterization Project and Coordinator for the Watershed Characterization Technical Assistance Team (WCTAT). He is a technical lead for the inter-agency team and has the primary responsibility for coordinating with users of the team services. Colin synthesizes information from the Characterization assessments and participates on technical advisory and review committees for watershed planning projects across Puget Sound.

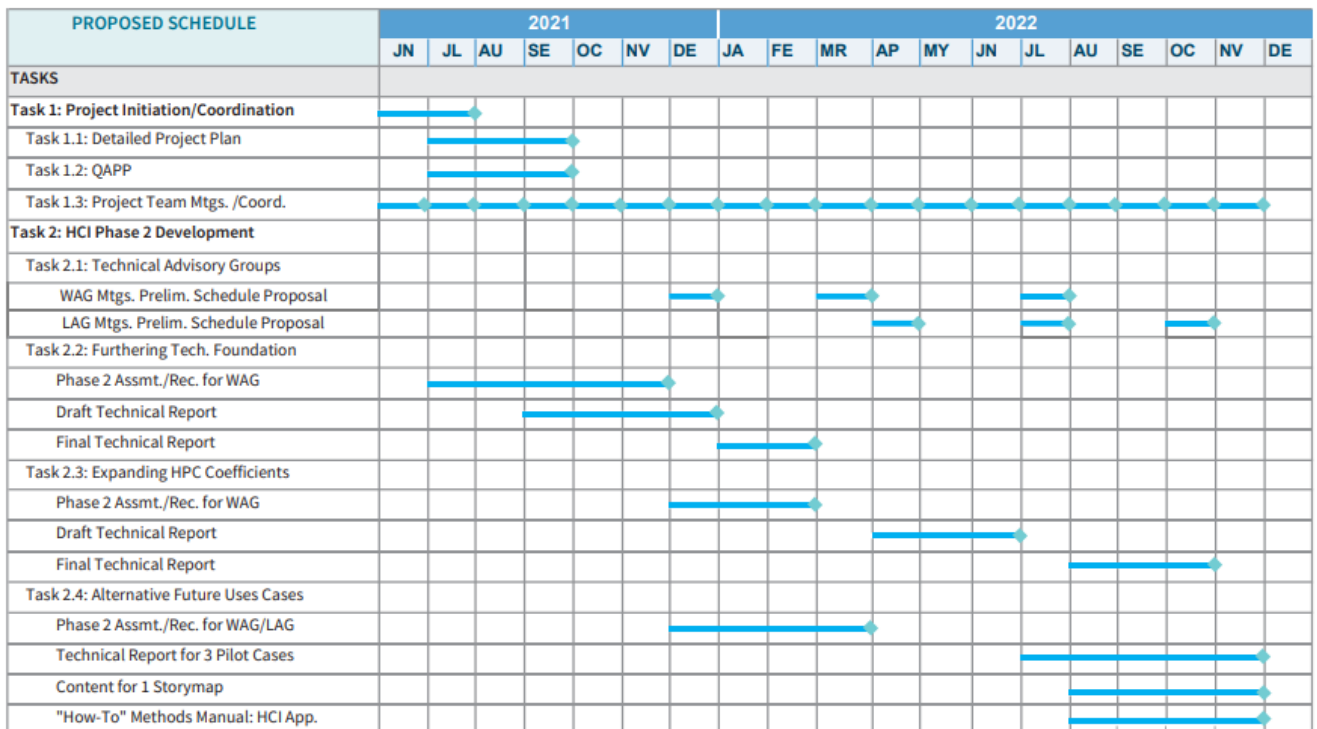
5.3 Organization chart

ORGANIZATIONAL CHART



Figure 2. Organization Chart

5.4 Proposed project schedule



◆ Deliverables

Figure 3. Proposed Project Schedule

5.5 Budget and funding

The source of funds for this Contract is the U.S. Environmental Protection Agency, National Estuary Program Stormwater Strategic Initiative grant (*CFDA# 66.123*). Total budget available for the project is \$478,968.00. Contracted services with ESA and CCS are \$206,803.00 unless additional budget is allocated from the grant total.

6.0 Quality Objectives

6.1 Data quality objectives

Not applicable, no new environmental data will be collected for this project.

6.2 Measurement quality objectives

Not applicable, no new environmental data will be collected for this project.

6.2.1 Targets for precision, bias, and sensitivity

Not applicable, no new environmental data will be collected for this project.

6.2.1.1 Precision

Not applicable, no new environmental data will be collected for this project.

6.2.1.2 Bias

Not applicable, no new environmental data will be collected for this project.

6.2.1.3 Sensitivity

Not applicable, no new environmental data will be collected for this project.

6.2.2 Targets for comparability, representativeness, and completeness

6.2.2.1 Comparability

Not applicable, no new environmental data will be collected for this project.

6.2.2.2 Representativeness

Not applicable, no new environmental data will be collected for this project.

6.2.2.3 Completeness

Not applicable, no new environmental data will be collected for this project.

6.3 Acceptance criteria for quality of existing data

All model input data either are obtained from reputable federal/state sources and are widely used, or have been collected by King/Snohomish Counties according to approved QAPPs. All these environmental data are assumed representative and comparable. For example, the development of the HCI mid-scale indices for this project relies upon data and modeling conducted by King County in their study of the effectiveness of land use regulations protecting stream and watershed processes (Lucchetti and Latterell 2008, Lucchetti et al. 2014). The County study sought to identify environmental response variables that had a high correlation between environmental conditions in a stream relative to conditions in the contributing watershed. For more information on data, sources see Section 3.2.2.

6.4 Model quality objectives

The primary project objective is to conduct additional model verification/model expansion/Hydrologic Pulse Count (HPC) refinement work. We will expand the study to include more regional HSPF models that will build on the prior phase of work. Using the recommendations that came from the prior work product, we will apply a more rigorous approach expanding the regional depth. We will use existing HSPF models from across the region and extract HPCs assuming no conveyance storage in the watershed. This approach will refine the quantitative measure of the hydrological condition of streams within an individual watershed.

As with the previous phase, the HCI outputs will be used to represent the stream hydrological condition. The relative accuracy of the HCI outputs can be tested against actual measurements of stream hydrological condition, known as “High Pulse Counts”. The new watersheds will be selected based on the following criteria:

- the existence of a calibrated HSPF model,
- proper watershed characteristics related to both the level and type of development,
- watershed location in the Puget Sound region, and
- Availability of existing gage data.

Similar to before, gage data for the new watersheds will be used to identify the number of High Pulse Counts during the selected study period. As a stream’s HCI, value increases, the number of observed high pulse counts should increase. Furthermore, the HCI index value should also increase for watersheds that have increasingly higher levels of development; thus, there should be a significant correlation between the actual HPC values measured at a stream gage and the calculated HCI value.

Similar to the previous work, the quality of the HCI model in predicting hydrologic condition will be tested in a series of scenarios employing different land cover resolution and flow routing methods. This is described in section 7.3.2. Additionally, the WAG will evaluate the degree of correlation (r^2) between the HCI outputs with available gage data and determine if they are useful models. A minimum r^2 value of 0.6 will be required for the models to be deemed useful. Additionally, Phase 1 of the work stated that, for testing the correlation between HCI values and gage data, an r -value of 0.88 indicates high correlation (Stanley et al. 2019B). This is equal to an r^2 value of 0.77. Phase 2 will use the same standard to evaluate usefulness of the models.

7.0 Study Design

7.1 Study boundaries

The study boundaries include the 19 WRIAs, shown below in Figure 4, that drain into the Puget Sound. The three communities chosen for the pilot study will be within the study boundary. The project does not involve any fieldwork.



Figure 4. Map showing boundary of project study area (Ecology)

7.2 Field data collection

Not applicable, as no field data will be collected.

7.2.1 Sampling locations and frequency

Not applicable.

7.2.2 Field parameters and laboratory analyses to be measured

Not applicable.

7.3 Modeling and analysis design

7.3.1 Analytical framework

This study will be based on work performed under the previous study conducted for Phase I. The purpose will be to expand the region represented by the study by including up to five previously calibrated HSPF models representing watersheds with the desirable characteristics for this study as outlined in Section 6.4. The desired watersheds have not yet been selected. These models will then be used to test and verify the current HCI and HPC calculations and will help further refine the calculations used for the estimated flow path routing as well as determine the relative importance of accurate routing estimates.

7.3.2 Model setup and data needs

The primary project objectives are to 1) expand the study area by utilizing existing, calibrated HSPF models for appropriately located watersheds in the Puget Sound basin, and 2) pilot the HCI in use case scenarios, which demonstrate a range of applications local government and natural resource planners' face.

1). Expanding the study area will require an examination of existing calibrated HSPF models to determine which models should be selected for the study. The data needs will be determined by selecting watersheds that have the best available gaged data and existing HSPF models. See Section 6.4 for more details on watershed selection. The models will be reviewed for completeness and quality of calibration and up to five new watersheds will be selected for use in the study. It will be necessary to collect the existing HSPF .uci and .wdm files as well as any existing documentation related to the calibration of these watersheds. It would be further beneficial to locate any GIS files that were used in the creation of the model files and any documentation that could describe the process for creating the Stage-Area-Storage-Discharge, or SSD tables, which are called FTABLEs in HSPF, for each of the models.

The model will investigate multiple HSPF calibration parameters, including Lower Zone Storage Nominal (LZSN), Infiltration (INFILT), Upper Zone Storage Nominal (UZSN), and Interflow (INTFW). The project team will study the sensitivity of different watersheds to each of these values across the Puget Sound region.

- LZSN controls the amount of water (soil moisture) in the lower soil zone. The lower soil zone is the soil layer between the upper soil layer (typically the top 6 inches) and the groundwater table. LZSN is used to calculate the mean infiltration capacity over a land segment in inches per time interval and to calculate inches of percolation per a time interval.
- INFILT controls the rate at which water enters the lower zone storage. The actual infiltration rate is calculated at each time step and changes based on the ratios of LZS/LZSN and UZS/UZSN, which change each time step. INFILT is used in calculating inches of percolation per time interval.
- UZSN controls the amount of water (soil moisture) in the upper soil zone. The upper soil zone is the soil layer between the surface and the lower soil zone. UZSN is used in calculating inches of percolation per a time interval.

- INTFW determines the distribution of runoff between interflow (shallow, subsurface runoff) and surface runoff.

More information on these parameters and how they are used is documented in the User Manual for Hydrological Simulation Program – FORTRAN (HSPF) (Johanson et al. 1980).

2). Piloting the HCI in use case scenarios will involve recruiting up to three “real world” planning processes related to land use planning, stormwater planning, or restoration planning. These may involve planning processes related to:

- Comprehensive Plans as a component of Growth Management Act requirements
- Land Capacity Analyses as a component of Buildable Lands Programs
- Stormwater Management Action Plan requirements related to municipal stormwater permits
- Total Maximum Daily Load Implementation Plans

The LAG will provide feedback on which use case scenarios to select and how to approach them. Each use case will have unique data needs but will share a common approach of altering current land cover to some “alternative future” condition and calculating the HCI to communicate the cumulative effect of land use decisions on hydrologic condition. Ideally, this will create a tool to facilitate discussions during planning processes whereby alternative approaches to development and restoration patterns may be considered which lower the risk of hydrologic impairment in the future. A simplistic use case scenario is presented in the phase 1 Volume 4 document (pp. 35) and illustrated with a story map on Ecology’s website:

<https://apps.ecology.wa.gov/coastalatl/wc/StoryMap.html?id=beta>.

7.4 Assumptions of study design

The study design assumes that:

- HPC coefficients vary regionally and for given combinations of land use/land cover
- The HPC coefficients are representative of the land cover type and surficial geology present in the three pilot use watersheds (lowland glacial terrace)
- The HCI will be sensitive enough to help identify changes to land use development patterns at the mid-scale that will protect water flow processes

7.5 Possible challenges and contingencies

Because the study is dependent on collecting existing HSPF models and the data used to run those models the challenge will be the timely collection of these computer files and supporting documentation.

7.5.1 Logistical problems

Not applicable, as there will no fieldwork and no access issues.

7.5.2 Practical constraints

The project team will need to find local government planners to participate in the LAG. Ecology will also have to coordinate with three local Puget Sound governments to pilot use cases. Both of these actions depend on the willingness of local governments to participate in the PSWC. However, this has not been a problem in previous phases of work and is not anticipated to pose a problem in Phase 2.

7.5.3 Schedule limitations

Finding local governments and planners to participate in the PSWC, as discussed above in Section 7.5.2, in a timely manner will be key to ensuring the project stays on schedule. The project team will utilize ESA's strong relationships with planning and public works departments across the Puget Sound, including contacts in Whatcom, Kitsap and Thurston Counties, to ensure these tasks are completed in the timeframe displayed in Figure 3 Proposed Project Schedule.

8.0 Field Procedures

There will no fieldwork or data collection.

8.1 Invasive species evaluation

Not applicable.

8.2 Measurement and sampling procedures

Not applicable.

8.3 Containers, preservation methods, holding times

Not applicable.

8.4 Equipment decontamination

Not applicable.

8.5 Sample ID

Not applicable.

8.6 Chain of custody

Not applicable.

8.7 Field log requirements

Not applicable.

8.8 Other activities

Not applicable.

9.0 Laboratory Procedures

There will no fieldwork or data collection.

9.1 Lab procedures table

Not applicable.

9.2 Sample preparation method(s)

Not applicable.

9.3 Special method requirements

Not applicable.

9.4 Laboratories accredited for methods

Not applicable.

10.0 Quality Control Procedures

This project will use two Technical Advisory Groups (TAGs), consisting of one Watershed Advisory Group (WAG) and one Local Advisory Group (LAG) to track task progress, as well as review and comment on products produced. The WAG from Phase 1 will be reconvened, potentially with additional members, to provide input on Task 2.2 – Furthering Technical Foundation and 2.3 – Expanding High Pulse Count coefficients. The WAG is comprised mostly of scientists and technical experts in geology, geomorphology, hydrology, and spatial analysis. The LAG will consist of local government planners from land use and stormwater disciplines to provide input on Task 2.4 – Alternative Future Use Cases.

The project also provides quality control by employing several team members who have worked on prior phases of the project and have experience working with Ecology to ensure continuity. ESA project director, Margaret Clancy, has been involved in the Watershed Characterization project since the early 2000s, ESA hydrologist and engineer James Gregory will continue on in Phase 2 in the same role he served in during Phase 1 of the HCI development, and Derek Booth, now an ESA employee, will continue to serve in his role as a Strategic Advisor for the project.

10.1 Table of field and laboratory quality control

Not applicable, as there is no sampling or lab work associated with the project.

10.2 Corrective action processes

The TAGs will be convened to provide feedback and inform development of the HCI and associated tools. The WAG will discuss progress three to four times over the course of the project and review all interim and final products produced for Tasks 2.2 and Task 2.3. The LAG will meet three to four times over the course of the project and provide input on Task 2.4 deliverables. The WAG, TAGs, and/or LAG will identify corrective actions when progress or a deliverable does not meet the project's goals and objectives.

11.0 Data Management Procedures

11.1 Data recording and reporting requirements

Not applicable.

11.2 Laboratory data package requirements

Not applicable.

11.3 Electronic transfer requirements

Not applicable.

11.4 Data upload procedures

Not applicable.

11.5 Model information management

Modeling results will be reported in the final technical reports prepared by ESA for Task 2.2 and Task 2.3.

This will include a description of the file structure and file metadata (i.e. version control number etc.) for storing the model runs in the Ecology GIS program. All model documentation, scripts, and results will be stored on a designated Ecology GIS server and maintained for the mandatory seven-year retention period. All results will include agency standard metadata documentation that transfers with the data. The project web site (<https://apps.ecology.wa.gov/coastalatlas/wc/landingpage.html>) will provide links to all data results. These will be downloadable by the public in the form of zip files of the geodatabase, including all final data layers as well as intermediate analyses and maps.

12.0 Audits and Reports

12.1 Audits

The Ecology GIS staff, in conjunction with the PSWC, ESA, and CCS staff, will review all new model run outputs to ensure that Python scripting has been entered correctly. It is anticipated that this will occur at least twice with the HCI model. In addition, the results of audits will be shared with the WAG and LAG.

12.2 Responsible personnel

Ecology project director Colin Hume and Ecology GIS staff will conduct the review of the model runs.

12.3 Frequency and distribution of reports

ESA will prepare a draft technical report for Task 2.2 by October 2021. The draft report will be advanced to a final technical report, after WAG review, by January or February 2022. ESA will prepare a second draft technical report between April and June of 2022. It will be reviewed by the WAG and LAG councils and submitted as a final report between August and October 2022.

12.4 Responsibility for reports

Project manager, Jonathan Ambrose, ESA, and Joe Brascher, CCS, will be responsible for writing and submitting the final QAPP.

The ESA team, led by Jonathan Ambrose, will be responsible for writing and submitting the Final Technical Reports associated with Task 2.2 and 2.3. Team members include CCS hydrologic modeler, Joe Brascher, ESA GIS/Web Lead, Mike Leech, ESA environmental engineer and hydrologist, James Gregory, and ESA strategic advisor, Derek Booth, among others.

13.0 Data Verification

The EPA defines data verification as “the process of evaluating the completeness, correctness, and conformance/compliance of a specific data set against the method, procedural, or contractual requirements” (EPA, 2002).

13.1 Field data verification, requirements, and responsibilities

Not applicable, as there will be no field data collected for the project.

13.2 Laboratory data verification

Not applicable, as there is no lab work associated with the project.

13.3 Validation requirements, if necessary

Not applicable, as there is no new field or lab data that will need to be validated.

13.4 Model quality assessment

The two final technical reports for the models will assess the overall quality of the new assessment indices by evaluating the indices output against the project goals and objectives listed in Sections 4.1 and 4.2, as well as meeting the data quality objectives listed in section 6.4 of this QAPP.

13.4.1 Calibration and validation

The HPC coefficients used in the HCI model were developed by King County using a calibrated HSPF model. This process is outlined in their study of nine test watersheds in King County (Lucchetti et al. 2014). Section 7.3 describes validation of the HCI model using existing hydrologic data from stream gages, including the annual number of high pulses. Calibration and validation of the model is documented and published in Appendix E, “Mid-Scale Models for Assessing Hydrologic Condition in Puget Sound Watersheds,” of Volume 4 of the PSWC (Ecology publication #11-06-016) (Stanley et al. 2019B).

13.4.1.1 Precision

Model precision will be measured using regression analysis as set forth in section 6.4 of this QAPP. Precision will be based on testing the following hypothesis: The correlation (coefficient of determination) between observed high pulse counts (independent variable) and HCI values (dependent variable) for test watersheds will exceed 0.6 (explaining 60% of the variance between the dependent and independent variables of the test).

13.4.1.2 Bias

Bias will be assessed for the HCI model by calculating the percent error (average of paired observed-modeled values divided by observed value). This will require normalizing the observed high pulse counts and obtaining a 0 to 1 value.

13.4.1.3 Representativeness

The HCI model will be representative of the conditions present in the test watersheds since the coefficients for the model were developed in watersheds, using a calibrated HSPF with similar geologic, landform, cover and precipitation characteristics.

13.4.1.4 Qualitative assessment

Regression graphs will be used to graphically display the degree of variation between the HCI values and observed high pulse counts for the three pilot cases.

13.4.2 Analysis of sensitivity and uncertainty

There is essentially one dependent variable, the high pulse count coefficient, associated with the HCI model. We will test the sensitivity of the model by identifying the threshold size of land cover change that results in no change in the HCI values during the application of the alternative futures use cases, as described in Task 2.4.

14.0 Data Quality (Usability) Assessment

14.1 Process for determining project objectives were met

Project team members, including Ecology, ESA, and CCS staff members will evaluate the results generated by the three local government pilot use cases to determine if the goals and objectives in section 4.1 and 4.2 were met and if results are deemed usable after verification (e.g., quality objectives detailed in the QAPP have been met). If the WAG, LAG, and PSWC team determine that the project goals and objectives are not met and/or the results are not deemed usable then recommendations will be made for modifying the approach.

14.2 Treatment of non-detects

Not applicable, as there is no water quality sampling associated with the project.

14.3 Data analysis and presentation methods

See section 7.3.2. In addition, ESA will work with Ecology to produce one interactive story map illustrating the application of HCI for alternative future scenarios in target watersheds in the Puget Sound that will be hosted on Ecology's Watershed Characterization website.

14.4 Sampling design evaluation

Not applicable, as there is no sampling associated with the project.

14.5 Documentation of assessment

Documentation of the data usability assessment will be included in the final technical reports generated for Task 2.2 and Task 2.3; the report will follow the format found in the existing Puget Sound Characterization document (Ecology publication #11-06-016).

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16.0 Appendices

Appendix A. Description of the original development of the Hydrologic Condition Index by King County

The Hydrologic Condition Index (HCI) predicts the cumulative downstream impacts of land cover alteration upon the movement of water across the landscape. The HCI was originally developed by King County (Lucchetti et al. 2014) and is designed to evaluate watershed condition in terms of the number of “high pulse counts” (HPCs) that occur within a stream system. High pulse counts capture a level of high flows (typically 2X mean annual flow) that is particularly damaging to stream structure (Figure A-1). Research has demonstrated that the frequency and duration of higher flows in streams and rivers is responsible for simplifying stream structure to a point where it can no longer maintain the stream’s aquatic food web that supports salmonid populations (Booth et al. 2002). DeGasperi et al. (2009) determined that, out of fifteen hydrologic metrics, high pulse count and high pulse range (HPR) (the absolute distance between mean annual flow and the peak of a high pulse count on the hydrograph) were the best in predicting the effect of land cover change upon stream flow.

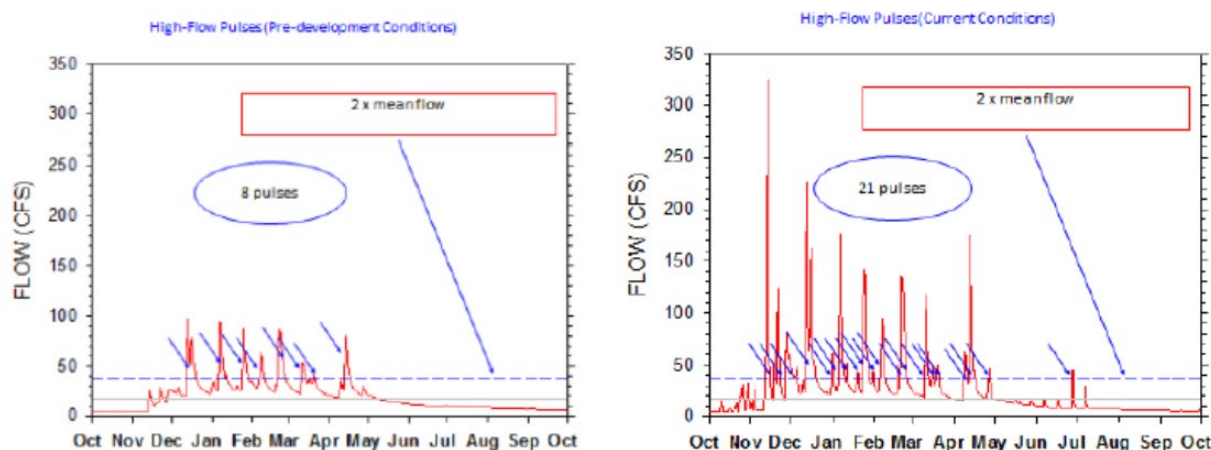
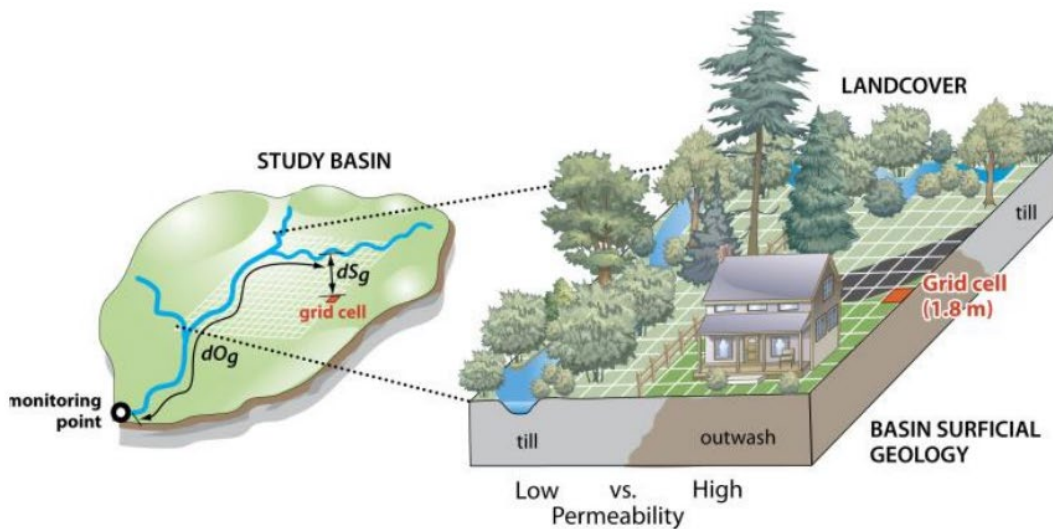


Figure A-1. High-flow pulses (High Pulse Counts) under pre-development (left) and developed (right) conditions for a King County watershed (from Horner 2013).

Because the HCI method does not simulate water movement based on a water balance model (quantification of water input and output), it simplifies the calculations that are typically required in a traditional hydrologic model. King County used existing calibrated HSPF models in five watersheds, ran 61-years of climate data through the models, and artificially forced combinations of surficial geology (outwash or till) and land cover type, to calculate an average number of high pulse counts per year for each combination. By applying a grid over the watershed you are assessing, and summing the average high pulse counts in each grid cell based upon current land cover and surficial geology type along a path that water can flow to

the outlet of the watershed, one can account for a greater influence of land cover closer to a stream. HCI ultimately estimates the relative hydrologic condition of the watershed (Figure A-2). The HCI values can be compared between watersheds, because they are based on high pulse counts observed in representative watersheds for the full suite of land cover types, using calibrated hydrologic models. In essence, the HCI becomes a calibrated measure of expected impacts to stream flow that can be applied to watersheds within the Puget Sound Basin. The primary advantage of HCI, is that it would allow local governments to understand not only the impacts of existing land cover patterns within a watershed but also of future land use patterns in an alternative futures scenario building exercise.



$$HCI_s = \frac{HCV_s}{HCV_{s_worst}}$$

$$HCV_s = \sum_{g=1}^n HPC_g \left(\frac{1}{dO_g + dS_g} \right)$$

- HCI_s = the hydrological condition index for a stream site in a watershed, s, given the LULC pattern for a particular year or simulated level of development
- HCV_s = the hydrological condition value for a stream site in a watershed, s, given the LULC pattern for a particular year or simulated level of development
- g = an index from 1 to n for all the grid cells within a watershed
- HPC_g = an average high pulse count value for each grid cell type, g. There are 24 values for HPC based on the combination of 12 LULC types and 2 underlying geology types
- dO_g = overland distance (Euclidean) from the grid cell, g, to the stream channel
- dS_g = stream channel distance measured from the intersection of the overland distance to the grid cell, g, to the sampling point downstream.

File: 0308_3363L_RegMonitorMODEL.ai lpre

LULC: Land use/land cover

Figure A-2. Illustration of how King County calculated the HCI within a single watershed (Luccetti et al. 2014).

Appendix B. Glossaries, Acronyms, and Abbreviations

Glossary of General Terms

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

Anthropogenic: Human-caused.

Base flow: The component of total streamflow that originates from direct groundwater discharges to a stream.

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.

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.

Salmonid: Fish that belong to the family *Salmonidae*. Species of salmon, trout, or char.

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 snowmelt. Stormwater can also come from hard or saturated grass surfaces such as lawns, pastures, playfields, and from gravel roads and parking lots.

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

Total Maximum Daily Load (TMDL): A distribution of a substance in a 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.

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

BMP	Best management practice
e.g.	For example
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
et al.	And others
GIS	Geographic Information System software
GPS	Global Positioning System
HCI	Hydrologic Condition Index
HPC	Hydrologic Pulse Count
HSPF	Hydrologic Simulation Program-FORTRAN
i.e.	In other words
INFILT	Infiltration
INTFW	Interflow
LAG	Local Advisory Group
LZSN	Lower Zone Storage Nominal
MQO	Measurement quality objective
NAF	New Approximation Flow
NPDES	National Pollutant Discharge Elimination System
NSDZ	Near-stream disturbance zones
PSWC	Puget Sound Watershed Characterization
QA	Quality assurance

QC	Quality control
RPD	Relative percent difference
RSD	Relative standard deviation
TAG	Technical Advisory Group
TMDL	Total Maximum Daily Load
USGS	United States Geological Survey
UZSN	Upper Zone Storage Normal
WAC	Washington Administrative Code
WAG	Watershed Advisory Group
WDFW	Washington Department of Fish and Wildlife
WQA	Water Quality Assessment
WRIA	Water Resource Inventory Area

Units of Measurement

cfs	cubic feet per second
cfu	colony forming units
cms	cubic meters per second, a unit of flow
ft.	feet
km	kilometer, a unit of length equal to 1,000 meters
m	meter
μS/cm	microsiemens per centimeter, a unit of conductivity

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 (Kammin, 2010). For Ecology, it is defined according to WAC 173-50-040: “Formal recognition by [Ecology] that an environmental laboratory is capable of producing accurate and defensible analytical data.”

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* (USEPA, 2014).

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: Discrepancy between the expected value of an estimator and the population parameter being estimated (Gilbert, 1987; USEPA, 2014).

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, 2014; USEPA, 2020).

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, 2014; USEPA 2020).

Continuing Calibration Verification Standard (CCV): A quality control (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: The process of determining that the data satisfy the requirements as defined by the data user (USEPA, 2020). There are various levels of data validation (USEPA, 2009).

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, 2014).

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)/LCS duplicate: 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. Monitors a lab's performance for bias and precision (USEPA, 2014).

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

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

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

Method: A formalized group of procedures and techniques for performing an activity (e.g., sampling, chemical analysis, data analysis), systematically presented in the order in which they are to be executed (USEPA, 2001).

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): The minimum measured concentration of a substance that can be reported with 99% confidence that the measured concentration is distinguishable from method blank results (USEPA, 2016). MDL is a measure of the capability of an analytical method of distinguished samples that do not contain a specific analyte from a sample that contains a low concentration of the analyte (USEPA, 2020).

Minimum level: Either the sample concentration equivalent to the lowest calibration point in a method or a multiple of the method detection limit (MDL), whichever is higher. For the purposes of NPDES compliance monitoring, EPA considers the following terms to be synonymous: “quantitation limit,” “reporting limit,” and “minimum level” (40 CFR 136).

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:

$$RPD = [Abs (a-b)/ ((a + b)/2)] * 100\%$$

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).

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 \bar{x} is the mean of results from more than two replicate samples (Kammin, 2010).

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).

Reporting level: Unless specified otherwise by a regulatory authority or in a discharge permit, results for analytes that meet the identification criteria (i.e., rules for determining qualitative presence/absence of an analyte) are reported down to the concentration of the minimum level established by the laboratory through calibration of the instrument. EPA considers the terms “reporting limit,” “quantitation limit,” and “minimum level” to be synonymous (40 CFR 136).

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, 1992).

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, 2014).

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, 2014).

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

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

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

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

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