Quality Assurance Project Plan

Leland Creek (WRIA 45) Physical HABitat SIMulation Study - 2022

July 2022

WA State Department of Ecology, Office of Columbia River IAA No. C2200146

Ecology Publication #22-12-004

Publication Information

This plan describes the objectives of the study and the procedures to be followed to achieve those objectives.

This Quality Assurance Project Plan is available via Ecology's publications database and upon request. The Ecology publication number for this Quality Assurance Project Plan is 22-12-004.

Field data collected for this project will be uploaded to Ecology's Environmental Information Management (EIM) database. This QAPP is valid through July 1, 2027.

To request an ADA accommodation, contact Ecology by phone at 509-454-4241 or email at tim.poppleton@ecy.wa.gov. For Washington Relay Service or TTY call 711 or 877-833-6341. Visit Ecology's website for more information.

Contact Information

Robert Granger
Washington Department of Fish and Wildlife
2620 N. Commercial Ave, Pasco, WA 99301
Phone: 509-492-0161

COVER PHOTO: Lower Leland Creek. PHOTO BY ROBERT GRANGER.

Quality Assurance Project Plan

Leland Creek (WRIA 45) Physical HABitat SIMulation (PHABSIM) Study - 2022

IAA No. C2200146

by Robert Granger

Published July 2022

Approved by:

Signature: Robert Granger	Date: 07/07/2022
Robert Granger, Fish and Wildlife Biologist, WDFW	
Signature:	Date: 07/08/2022
Jonathan Kohr, Environmental Planner, WDFW	
Signature: Jeffrey P. Dengel	Date: 7/08/22
Jeffrey Dengel, Environmental Planner, WDFW	
Signature: Ingrid Ekst	Date: 07/08/2022
Ingrid Ekstrom, Project Manager, Department of Ecology, Office of Columbia River	
Signature:	Date: 07/08/2022
Scott Tarbutton, Quality Assurance Coordinator, Department of Ecology, Office of Columbia River	
Signature:	Date:

1.0 Table of Contents

List of Figures

List of Tables

2.0 Abstract

Leland Creek (tributary to Icicle Creek) is a natural conveyance channel for storage water supplies originating from Square Lake intended to provide supplemental flow in lower Icicle Creek for 1) historic and current flow conditions at the Icicle-Peshastin Irrigation District's (IPID) point of diversion (POD), and 2) more recently to enhance environmental flows in lower Icicle Creek.

The Washington Department of Fish and Wildlife (WDFW) Water Science Team (WST) is tasked with conducting a Physical HABitat SIMulation (PHABSIM) study on Leland Creek with support from the Washington Department of Ecology (WDOE), the Icicle Work Group (IWG), and the Icicle Instream Flow Committee (IFC). The purpose of the PHABSIM study is to assess the amount of available habitat, quantified using Weighted Usable Area (WUA), for native salmonid species (primarily bull trout and rainbow trout) relative to the volume, timing, and duration of both natural flow conditions and during supplemental flow releases from Square Lake.

3.0 Background

3.1 Introduction and problem statement

Following site studies conducted by U.S. Fish and Wildlife Service (USFWS), Leland Creek has been identified as a drainage providing crucial habitat for ESA-listed Bull Trout. Therefore, it is imperative to understand and define both operational and baseline flow conditions, along with determining release operations at Square Lake that maintain or increase suitable habitat for this at risk species.

It is currently unknown how storage water releases from Square Lake influence the available preferred native fish habitat in Leland Creek and to what degree they may be beneficial, or conversely detrimental. This PHABSIM study will allow for an estimation of available habitat over a range of streamflows and provide a science-based approach toward recommending flow releases that are protective or enhance conditions for native fish populations.

3.2 Study area and surroundings

Leland Creek, a right bank tributary to Icicle Creek at river mile (RM) 27.9, is primarily a snow-melt driven system with its headwaters originating at around 4500 feet above sea level at Lake Leland in the Alpine Lakes Wilderness Area. However, it receives additional water from Square Lake via Prospect Creek when the IPID determines it is necessary to release storage supplies to augment flow in lower Icicle Creek to meet water supply demand. Flow from Square Lake is delivered to Leland Creek via Prospect Creek, and ultimately Icicle Creek where it is available for withdraw at the IPID's point of diversion (POD) at RM 5.7.

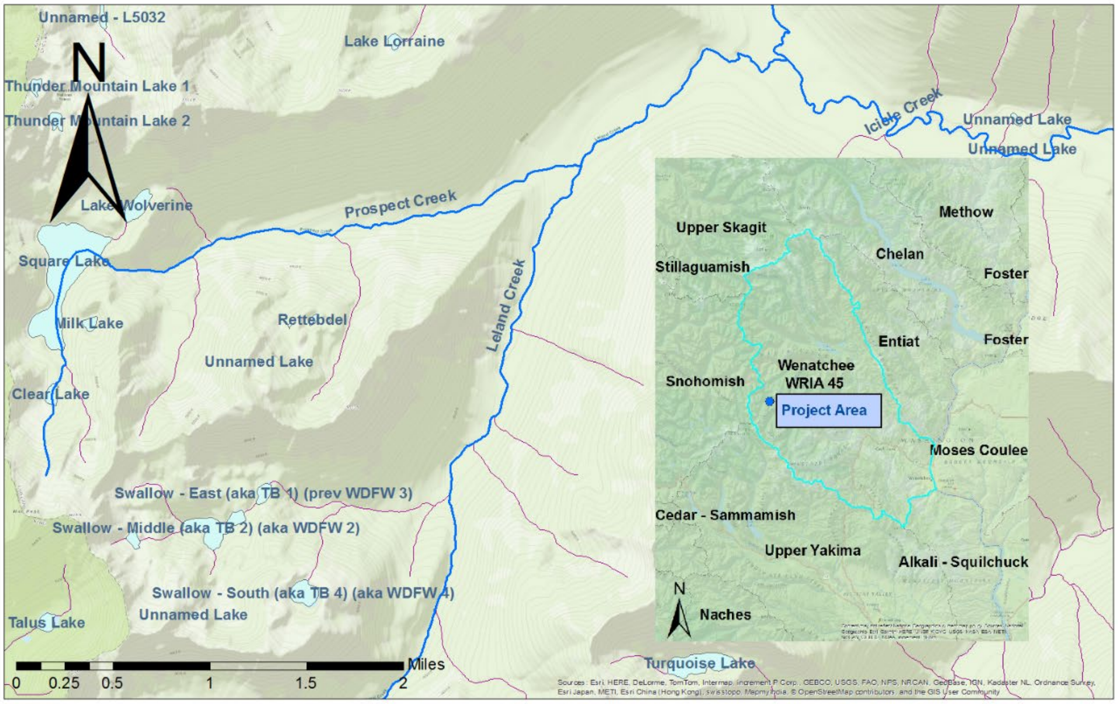

Figure 1. Map of larger study area.

3.2.1 History of study area

Between the 1920's through 50's, the IPID constructed water retention and conveyance infrastructure at Eightmile, Colchuck, Square, and Klonaqua lakes. Under the authority of their water rights, IPID manages storage water from these lakes in addition to Snow Lake, though the infrastructure at this latter location is federally owned and operated. Leland Creek serves as a natural conveyance channel for IPID storage water residing within Square Lake.

Prior to the designation of the Alpine Lakes Wilderness area in 1976, this area was predominantly owned by private entities, subjected to extensive extraction-based activities such as mining, timber extraction, and fur trapping. While machinery use and other such limitations have been imposed since the designation, the IPID has retained its ability to operate these lakes as reservoirs through easement. Currently, there is contention pertaining to the use and ongoing maintenance associated with these structures. Through the Icicle Strategy, state and federal agencies, Chelan County, IPID, and environmental organizations are forwarding a strategy that allows for the required operation, maintenance, and infrastructure upgrades at these locations, while seeking to operate within the spirit and confines of the wilderness designation.

3.2.2 Summary of previous studies and existing data

In 2016 and 2017 the IPID, in coordination with the Chelan County Natural Resources Department (CCNRD) conducted a pilot flow release study from the Alpine Lakes to enhance environmental flows and characterize the effects on lower Icicle Creek. Prior to the pilot study, questions regarding the potential effects on bull trout populations (primarily in French and Leland creeks) were raised resulting in an effort to better understand the flow and water temperature conditions in these creeks.

In 2016 WST staff began collecting flow and water temperature data in French and Leland with the ultimate goal of conducting a PHABSIM study in both. Flow data was needed to establish current conditions in the creeks and to be able to apply results of the PHABSIM studies in a meaningful way. Data collection from 2018, 2019, and 2021 was funded through the Office of Columbia River (OCR) and is available in Ecology's Environmental Information Management (EIM) database (Study ID ROBE0001). In 2020 the French Creek PHABSIM study, also funded through OCR, was completed (report available by request). Data previously collected in Leland Creek will not be used for modeling purposes, however, will inform the timing of data collection under this QAPP and allow for comparisons of known flow conditions to WUA results generated from the PHABSIM model.

3.2.3 Parameters of interest and potential sources

Data collection will occur at three separate flows; high, medium, and low with flow targets of 60.0, 30.0, and 15.0 cfs respectively. Around twelve transects (cross sections) will be established within the study area for data collection. Environmental parameters of interest that will be used in developing the PHABSIM model include:

- Depth and velocity measurements across each transect and at each of the three flows.
- Calculation of discharge for each transect and at each of the three flows (to be averaged for model input) using the mid-point method as described in EAP056.
- Wetted width measurements at each transect and at each of the three flows.
- Water surface elevations (WSELs) across each transect and at each of the three flows.
- Substrate type/size across each transect (typically collected during the low-flow survey).
- Cover type across each transect (typically collected during the low-flow survey).

3.2.4 Regulatory criteria or standards

Not applicable

3.3 Water quality impairment studies

Not applicable

3.4 Effectiveness monitoring studies

Not applicable

4.0 Project Description

4.1 Project goals

- Collection of data for input into the Riverine Habitat Simulation (RHABSIM) computer program.
- Model calibration and generate WUA curves.
- Evaluate available preferred habitat for native fish species of interest at different lifestages over a range of flows.
- Provide guidance toward flow release strategies from Square Lake that are protective of or enhance conditions for native fish species.

4.2 Project objectives

Project objectives for the PHABSIM study include:

- <u>Field data collection</u>
    - Collection of depth and velocity measurements at three flows (high, medium, and low) for model input and calculation of discharge using the mid-point method.
    - Collection of wetted width measurements at each transect at three flows (high, medium, and low).
    - Survey of WSELs at three flows (high, medium, and low).
    - Documentation of substrate and cover types withing the study reach during the low-flow survey using the generic cover and substrate codes described in the WDFW and WDOE Instream Flow Study Guidelines, 2022 and the WDFW Standard Operating Procedure for Conducting Physical HABitat SIMulation Studies in Wadable Streams and Rivers, 2022.
- <u>Modeling</u>
    - Data entry and QA/QC.
    - WSEL calibration.
    - Velocity calibration.
    - Simulate the relationship between streamflow and WUA for fish species of interest.
    - Evaluate WUA at flows for fish species and lifestages of interest for Leland Creek.

4.3 Information needed and sources

WUA results will be compared to existing seasonal time series flow data collected in 2018, 2019, and 2021 to evaluate available habitat relative to flow. This will allow for estimations of available habitat under current flow conditions, and available habitat under variable flow release scenarios from Square Lake.

4.4 Tasks required

High-flow sample

- Establish around twelve transects within the study reach that will represent each of the mesohabitat types present (pools, runs, glides, riffles, and pool-tailouts).
- Collect depth and velocity measurements along each transect at approximately 30 stations (verticals).
- Collect WSEL measurements with survey equipment at each transect. This will include three measurements across the transect; one each near the right and left banks, and one near the center of the channel.

Medium-flow sample

- Repeat depth and velocity measurements at precisely the same location as the high-flow measurement locations. Some stations will likely be dry as the flow recedes, and this will be documented in the field notes.
- Repeat WSEL survey. Although transect locations will remain the same, measurements will not likely be at the same location on the transect as the high-flow sample. However, three measurements across each transect will still be collected.

Low-flow sample

- Repeat depth and velocity measurements at precisely the same locations as the high and medium-flow sample locations (as with the medium-flow some stations will be dry).
- Repeat WSEL survey.
- Survey bed elevations along each transect between the water surface edge and the end of the transect (both right and left banks) where the stream bed will be exposed as the flow has receded.
- Collect substrate and cover type at each location where a depth and velocity measurement was collected, and at locations where the bank bed elevation measurements are collected.

PHABSIM model development

- Enter all field data into the RHABSIM program while ensuring completeness and accuracy of data entry.
- Conduct WSEL calibration.

- Conduct velocity calibration.
- Generate WUA curves for flows and fish species and lifestages of interest.

4.5 Systematic planning process

Systematic planning for this study is supported through development of this QAPP and the associated WDFW Standard Operating Procedure (SOP) for Conducting Physical HABitat SIMulation Studies on Wadable Streams and Rivers, 2022.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

Table 1 shows the responsibilities of those who will be involved in this project.

Table 1. Organization of project staff and responsibilities.

Staff	Title	Responsibilities
Robert Granger **WDFW** **Phone: 509-492-0161**	**Instream Flow Biologist**	**Writes the QAPP. Oversees field sampling. Conducts QA review of data, calibrates model, and analyzes model results. Writes the draft report and final report.**
Jonathan Kohr **WDFW** **Phone: 509-307-2871**	**Environmental Planner**	**Reviews the QAPP. Oversees field sampling. Conducts QA review of data, calibrates model, and analyzes model results. Writes the draft report and final report.**
Jeff Dengel **WDFW** **Phone: 509-630-9087**	**Environmental Planner**	**Provides contract support.**
David Reavill **WDFW** **Phone: 509-571-0200**	**Fish and Wildlife Biologist**	**Helps collect data and records field information.**
Emily Phillip **WDFW** **Phone: 509-314-1130**	**Fish and Wildlife Technician**	**Helps collect data and records field information.**
Ingrid Ekstrom **Department of Ecology, OCR** **Phone: 509-823-3495**	**Project Manager**	**Reviews the draft QAPP**
Scott Tarbutton **Department of Ecology, OCR** **Phone: 509-867-6534**	**Quality Assurance Coordinator**	**Reviews and approves the draft QAPP and the final QAPP.**

5.2 Special training and certifications

No special certifications are required for conducting a PHABSIM study. Field crew that do not have specific training in collecting field measurements for PHABSIM studies will be trained in the field by experienced WST staff prior to collecting any data.

Staff will have proper training in use of the Riverine HABitat SIMulation (RHABSIM) model from Thomas R. Payne and Associates (Arcata, CA) including; data input, calibration procedures, and subsequently running model outputs.

5.3 Organization chart

Not applicable.

5.4 Proposed project schedule

Table 2 list key activities, due dates, and lead staff for this project.

Table 2. Schedule for completing field and laboratory work

Task	Due date	Lead staff
Field work	August/September 2022	Robert Granger/Jonathan Kohr
Data Entry into RHABSIM	September 2022	Robert Granger/Jonathan Kohr
Model Calibration and WUA Simulation	November 2022	Robert Granger/Jonathan Kohr
Draft Report to Supervisor	December 2022	Robert Granger/Jonathan Kohr
Draft Report to Peer Reviewer	December 2022	Robert Granger/Jonathan Kohr
Final Report to OCR	January 2023	Robert Granger/Jonathan Kohr

5.5 Budget and funding

This study is funded through Task 2 of Interagency Agreement (IAA) C2200164 between the Washington Department of Ecology and the Washington Department of Fish and Wildlife.

6.0 Quality Objectives

6.1 Data quality objectives [1]

Data quality objectives (DQOs) for this study are:

- Collection of a sufficient number of depth and velocity measurements at each transect to characterize the hydraulics within the study reach at the three target flows. Approximately thirty depth and velocity measurements will be collected at each transect during the high-flow sample, with the number of measurements decreasing as the wetted width of the stream decreases at the medium-and-low flows.
- WSEL surveys at three target flows that accurately characterize the stage-discharge relationship. At each target flow, WSEL surveys will be conducted at each transect relative to the transect headpins and will use the same benchmark as a known elevation. Three measurements will be collected at each transect; one near both the right and left banks, and one near the center of the channel. The three measurements collected for each transect will be averaged for final model input.

6.2 Measurement quality objectives

Depth and velocity measurements will be collected in a manner consistent with Ecology's Environmental Assessment Program Standard Operating Procedure (EAS SOP) EAP056, Version 1.3. The exception to this is that transects will not be selected that provide the most accurate discharge measurement. Instead, transects will be selected that capture the variability in mesohabitat types within the study reach. The average discharge across all transects will be calculated for each of the three flow samples for model input.

Measurement quality will be assessed with best professional judgement and qualitative criteria based on factors observed during the measurement (calibration of equipment, transect mesohabitat type and location, hydraulics around instream structure, etc.).

During each of the sampling events one transect will be selected for a replicate discharge measurement. The two measurements will be conducted in sequence at the transect using the same flow meter to assess measurement reproducibility. Relative percent difference (RPD) will be calculated for the measurements with an acceptable threshold of 10% or less RPD.

An SOP for WSEL surveying is not available. However, the linked closed loop survey is the measure of precision. The height of the benchmark will be assigned an elevation of 100 ft at the

---

[1] DQO can also refer to ***Decision*** Quality Objectives. The need to identify Decision Quality Objectives during the planning phase of a project is less common. For projects that do lead to important decisions, DQOs are often expressed as tolerable limits on the probability or chance (risk) of the collected data leading to an erroneous decision. And for projects that intend to estimate present or future conditions, DQOs are often expressed in terms of acceptable uncertainty (e.g., width of an uncertainty band or interval) associated with a point estimate at a desired level of statistical confidence.

beginning of the survey. Transects will be surveyed in order from 1 through 12, and a final measurement at the benchmark will be collected. Our standard for measurement quality is a final benchmark measurement that is within +/- 0.05 ft. of the original assigned 100 ft. Additional guidance for conducting WSEL surveys is available in the WDFW SOP for Conducting PHABSIM Studies on Wadable Streams and Rivers, 2022.

6.2.1 Targets for precision, bias, and sensitivity

The acceptable precision and bias of measurements will be assessed at the time of measurement in the field (none of the measurements are laboratory verified because they are field specific). QC checks will be conducted in the field upon completion of data collection and again during model input as described in sections below.

Table 3. Measurement quality objectives.

MQO →	Precision	Bias
Parameter	**Duplicate Samples**	**Verification Standards (LCS,CRM,CCV)**
Discharge	10% RPD	na
Water surface elevation	±0.05 ft	na

6.2.1.1 Precision

Precision is a measure of variability among replicate measurements due to random error. Aside from the replicate discharge measurement described above, replicate measurements typically won't be collected for depth and velocity unless a measurement seems unreasonable based on professional judgement. In the event a measurement appears to be in error, it will be repeated immediately to ensure precision. WSEL measurements will be repeated as needed to ensure precision during the survey.

6.2.1.2 Bias

The HACH FH950 velocity meter will be checked for magnetic bias with a zero-velocity bucket test prior to each sampling event and calibrated per manufacturer specifications. For further assessment of measurement bias a side-by-side comparison of two velocity meters will be conducted prior to field data collection. No other equipment calibration is required.

6.2.1.3 Sensitivity

Table 4. Instrument specifications and calibration methods.

Instrument	Measured	Factory Accuracy	Calibration Methods
HACH FH950 Flow Meter	Velocity (ft/s)	±2% of reading from 0 to 10 ft/s	Bucket test prior to collection measurements

Topset Wading Rod	Water depth (tenths of ft)	Not applicable	Physical measurement
Bosch Automatic Level GOL32	Water surface elevation	1/16” at 100 ft.	Factory calibrated
Stadia Rod	Water surface elevation	Not applicable	Physical measurement
Measuring Tapes	Transect length, measurement location, and wetted width	1/100 ft.	Physical measurement

6.2.2 Targets for comparability, representativeness, and completeness

6.2.2.1 Comparability

Data collection will be conducted in a manner consistent with the following SOPs and guidelines to ensure comparability between projects:

- WDFW SOP, Standard Operating Procedure for Conducting Physical HABitat SIMulation Studies on Wadable Streams and Rivers, 2022
- Ecology EAP SOP EAP056, Measuring and Calculating Stream Discharge, Version 1.3
- WDFW and WDOE, Instream Flow Study Guidelines, 2022

6.2.2.2 Representativeness

Field staff will review the study reach to ensure transects are selected that capture the variability in mesohabitats and are representative of the reach characteristics. Sufficient depth and velocity measurements will be collected to characterize the hydraulics at each transect at each of the three sampled flows. Repeat WSEL surveys will be conducted using a common benchmark at each of the three sampled flows to ensure an accurate stage-discharge relationship over the range of modeled flows.

6.2.2.3 Completeness

A complete set of observations for each component of data collection at each flow is desired for model development. However, an insignificant loss or lack of data due to field error or inability to collect a measurement due to access (e.g., flow is too high) is possible and will not adversely affect modeling results if 5% or less of the total data set.

6.3 Acceptance criteria for quality of existing data

Time series flow data was collected in 2018, 2019, and 2021 under an Ecology approved QAPP (Publication No. 18-2-010) and associated addendums within the proposed study reach. This data is considered as good quality usable data and will be used only in evaluating final model results, and not for model development. New data collected under this QAPP will be specific to model development.

6.4 Model quality objectives

Quality objectives for calibration of the PHABSIM model are as follows (refer to WDFW Standard Operating Procedure for Conducting Physical HABitat SIMulation Studies on Wadable Streams and Rivers for further detail) :

- Simulated WSELs that are close to what was measured in the field. The model quality objective is simulated WSELs that are within 0.05 feet at the calibration (measured) flows.
- Water should flow “downhill” at all transects and at all flows.
- No fewer cells meeting the velocity criteria than in the initial model run. The criteria for how close is acceptable are 0.20 feet per second (fps) at velocities of 1.0 fps or less, and 20% at velocities greater than 1.0 fps.
- Velocity adjustment factors (VAFs) within the limits of the measured flows and to limits of extrapolation. The VAF is a ratio of two ways of calculating flow. If the two flow calculations are close the VAF will be near 1.0
- Acceptable VAFs will be within 0.80 and 1.20, and no simulated velocities will exceed 10.0 feet per second (fps) at the extrapolated flows

7.0 Study Design

7.1 Study boundaries

The proposed location for the PHABSIM study is within the 300 meters directly upstream of the confluence with Icicle Creek (Reach1). The USFWS has conducted opportunistic snorkel surveys in Leland Creek and has confirmed the presence of bull trout. However, relative abundance data is not available for much of the reach between Icicle Creek and Prospect Creek and it is not clear where bull trout spawning occurs (J. Vazquez, personal communication, August 18, 2021).

Given the available information from the USFWS, WST staff reviewed several stream reaches either through aerial imagery to the extent possible or on foot where accessible. Following is a brief description of six reaches reviewed, each of which are influenced by storage releases from Square Lake. River miles are estimated. (See Figure 2 for map of reaches):

- **Reach 1 – RM 0.00 to 0.20 – Proposed PHABSIM reach**

  In the lower section of this reach we observed good rearing habitat and potential spawning habitat from the mouth to approximately RM 0.10. The channel is braided near the confluence with Icicle Creek containing a large amount of woody debris and transitions to primarily glide and pool habitat towards the top of the reach. Relatively easy access. Documented bull trout use.

- **Reach 2 – RM 0.20 to 0.65**

  Difficult access. Steep gradient and no bull trout information available. We plan to establish two to four transects at the bottom of this reach for use in the model as it is representative of higher gradient reaches of Leland Creek.

- **Reach 3 – RM 0.65 to 1.00**

  Very difficult access and no bull trout information available.

- **Reach 4 – RM 1.00 to 1.25**

  Excellent rearing habitat. Very complex with wetlands, side channels, and large woody debris, however hazardous for high flow data collection and difficult to model. Documented bull trout use.

- **Reach 5 – RM 1.25 to 1.50**

  Presence of good rearing habitat and there appears to be some suitable spawning substrate. Relatively difficult access. Documented bull trout use. This reach was considered as an option for the study however after further review we opted for Reach 1 based on accessibility and the presence of more suitable spawning habitat.

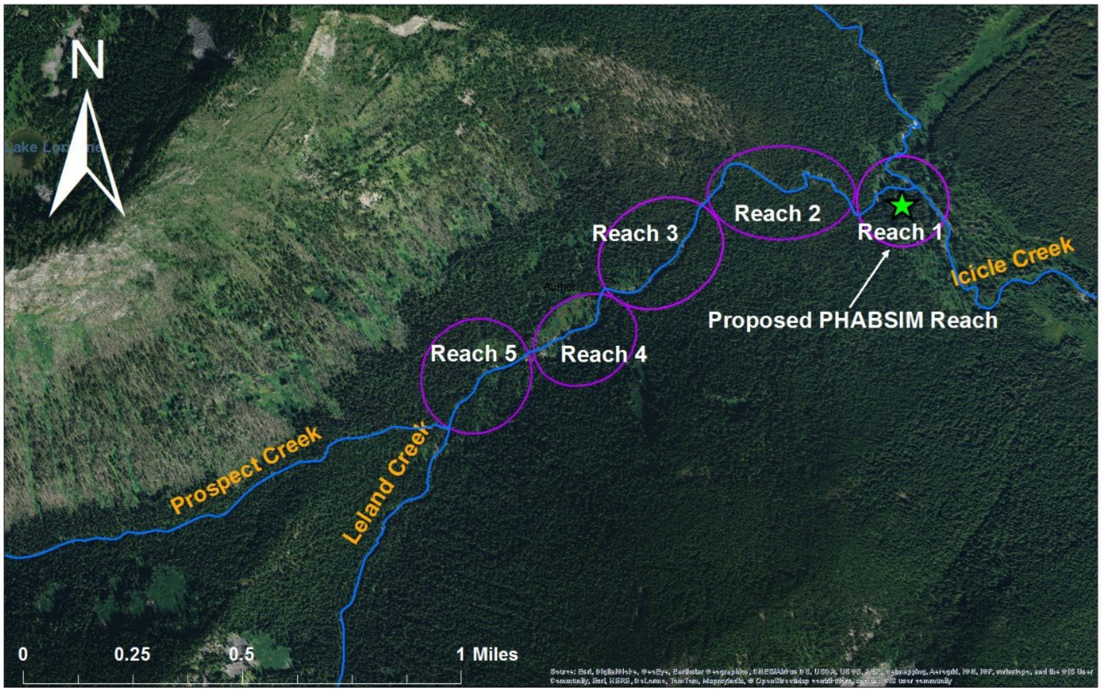

Figure 2. Map showing boundary of project study area.

7.2 Field data collection

As indicated in Section 7.1 and in the above figure, the proposed study reach is between Reach 1 (RM 0.0 and 0.20), with two to four transects established at the downstream end of Reach 2 (RM 0.20 to 0.65). In the event it is not feasible to conduct the study within this reach, the alternative is to conduct the study between Reach 5 (RM 1.25 and 1.50).

7.2.1 Sampling locations and frequency

Data collection will occur at three separate flows; high, medium, and low with flow targets of 60.0, 30.0, and 15.0 cfs respectively. Around twelve transects will be established within the study reach with the goal of representing all mesohabitat types in the affected reach. Transects will be selected and marked during the initial site review.

At each of the three target flows, transects will be set up at precisely the same location to allow for measurements to capture the changes in WSELs, water depths, and velocities as the hydrograph is descending. To ensure transects are set up at the correct location, rebar stakes remain in place throughout data collection period.

Timing of data collection will be flow dependent and subject to local weather conditions. Data collection will occur when stream flows are relatively stable and not significantly changing due to rain events or rapid snow melt to ensure an accurate stage-discharge relationship. Review of previously collected discharge measurements on Leland Creek has been conducted to estimate the appropriate timing of data collection. These measurements were compared to discharge data from the USGS gage on lower Icicle Creek which indicates Leland Creek contributed approximately 10 to 15 percent of the flow in Icicle Creek during the time period of interest. From our previous observations and review of gage data we will have a rough estimate of the appropriate timing for each of the three flow samples.

7.2.2 Field parameters to be measured

- WSEL measurements along transects.
- Depth and velocity measurements along transects for model input and calculation of discharge at each transect.
- Wetted width measurements at each transect during each of the three flow samples.
- Documentation of substrate and cover types along transects.

7.3 Modeling and analysis design

Modeling and analysis design for this study will be consistent with the WDFW SOP for Conducting PHABSIM Studies on Wadable Streams and Rivers, 2022, and the RHABSIM User's Manual by Thomas R. Payne and Associates, 1998.

7.3.1 Analytical framework

The PHABSIM model takes into consideration the following components of fish habitat;

- water depth,
- water velocity,
- discharge,
- WSELs,
- substrate, and
- cover.

The computer models within the PHABSIM framework simulate the distribution of water depths and velocities with respect to substrate and overhead cover under a variety of flows. The simulated habitat parameters will be used to generate WUA at each modeled flow. The WUA habitat indexes at each flow correspond to the biological requirements of the fish species and lifestages of interest. The RHABSIM model from Thomas R. Payne and Associates (Arcata, CA) is the only computer software needed for the modeling effort.

7.3.2 Model setup and data needs

Data will be collected at a minimum of three flows (high, medium, and low) (see Section 4.3 for data needs). Target flows for data collection are 60.0, 30.0, and 15.0 cfs. This will allow simulation flows to be extrapolated out to 2.5x the high measured flow (150.0 cfs) and 0.4x the low measured flow (6.0 cfs) with associated WUA calculated for all points in between. The model can be run at any range of flows within the upper and lower limits of these values with the exception that only thirty flows may be simulated in a single model run. For Leland Creek, simulations will be run for primarily bull trout, and secondarily rainbow trout for both rearing and spawning lifestages. We will include steelhead spawning as well for the potential future presence. Although, steelhead spawning typically occurs at high flows and it is likely the 150.0 cfs upper model limit will not capture peak WUA.

PHABSIM is generally reach specific as stream habitat can significantly change longitudinally. For this model we have chosen a study reach that is known to have relatively high bull trout utilization for rearing and potential for spawning.

7.4 Assumptions of study design

The primary assumption for field data collection is that we will have the ability to capture the proposed target flows. Although it is not critical to collect data at precise flows, our goal is to be somewhat close to those targets in order to establish a reliable stage-discharge relationship and to have the ability to model (extrapolate) up or down to flows of interest.

The PHABSIM model uses the information collected at the transects and extrapolates WUA out to 1000 linear feet of stream. Because the data is limited to what is collected at the transects, the model must predict what is occurring between transects at different flows, and for the 1000 ft. modeled length of stream which is often longer than the actual surveyed reach. To account for this, we must apply transecting weighting in which we “tell” the model that a certain percentage of the study reach is the same mesohabitat as Transect 1, a certain percentage is the same as Transect 2, a certain percentage is the same as Transect 3, and so on. This is a well-known and generally accepted assumption of the PHABSIM model.

7.5 Possible challenges and contingencies

The relative remoteness of the study area poses potential challenges associated with weather or other events that may hinder access and data collection at times. It is also difficult to predict the timing of data collection in order to capture the desired range of flows. Discharge data we have collected in past when compared to the USGS gage data on lower Icicle Creek (RM 5.6) indicates Leland Creek contributed around 10 to 15 percent of the flow in Icicle Creek for the period of time of interest. If the flow targets are not achieved within reason with the three sampling events it may be necessary to conduct additional data collection.

Adaptability of field staff will be required in terms of timing and availability to ensure data collection needs are met, and to avoid conditions that put staff at risk of injury. The study is also contingent upon assurance from the IPID that it will not release flow from Square Lake during the data collection period. Alteration of streamflows during the data collection period could result in difficulty capturing the desired flow targets.

7.5.1 Logistical problems

Leland Creek lies within the Alpine Lakes Wilderness area and is accessible only by trail. Site access requires a relatively long hike of around fifteen miles (roundtrip) for each data collection effort. The project area can be subject to extreme weather events, snow, ice, high flows, fire, etc. that can inhibit access to the site. Trips to conduct field work must be well planned in order to capture the desired flow conditions while avoiding adverse conditions that could pose a risk to field staff. In addition to the relative remoteness of the stream, data collection will require occasional overnight trips by experienced staff having the proper equipment and ability to hike several miles in a day.

7.5.2 Practical constraints

Currently there are no practical constraints expected for the study. The WST is fully staffed with an experienced field crew capable of completing the required data collection. All necessary field equipment for data collection and computer software for subsequent modeling are readily available.

7.5.3 Schedule limitations

Timing of data collection is a critical component of the study. PHABSIM studies are typically based on a 3-flow regression (high, medium, and low) with the medium-flow being around half that of the high-flow, and the low-flow being around half the medium-flow. The initial (high-flow) target for data collection is around 60.0 cfs. From previous data collection efforts we have estimated that the flow in Leland Creek will likely be at that rate in mid-July. In order to successfully complete data collection, all USFS permitting requirements must be completed as well as a final approved version of this QAPP by early-July for field work planning purposes.

8.0 Field Procedures

8.1 Invasive species evaluation

All field equipment (waders, boots, meters, etc.) will be inspected and cleaned prior to, and after field work as necessary per EAP070, Version 2.2.

- Soil, debris, plants, algae, and visible vertebrates will be removed from equipment prior to leaving sample sites. Clean water and a scrub brush will be used to clean equipment when necessary.
- Wading boots and waders will be decontaminated using hot water (49° C) or an approved antibacterial all-purpose cleaner (such as Formula 409) and allowed to thoroughly dry between site visits to different locations as necessary.
- Handheld meters, wading rods, and survey equipment will be wiped dry with a clean cloth, and a non-corrosive chemical cleaner will be used to decontaminate areas where small particles cannot be removed.

8.2 Measurement and sampling procedures

Data collection will be conducted in a manner consistent with the following SOPs and guidelines to ensure comparability between projects:

- WDFW SOP, Standard Operating Procedure for Conducting Physical HABitat SIMulation Studies on Wadable Streams and Rivers, 2022
- Ecology EAP SOP EAP056, Measuring and Calculating Stream Discharge, Version 1.3
- WDFW and WDOE, Instream Flow Study Guidelines, 2022

Procedures for depth and velocity measurements

- Twelve transects will be established by extending measuring tapes perpendicular to the flow from the right to left bank and secured with rebar headpins. The right bank headpin will always be set to the zero mark on the measuring tape.
- The length of each transect between headpins will be recorded in tenths of feet for model input and for subsequent sample events.
- Twenty five to thirty depth and velocity measurements will be collected along each transect during the high-flow sample (fewer as flow declines at the medium and low flow samples).
- The location on the tape of the right and left wetted edges will be recorded in tenths of feet.
- Measurement points will be recorded with distance on the measuring tape (station) along with the associated depth and velocity observations.
- Velocity measurements will follow the six-tenths method (60% depth) unless it is necessary to use the two-point method (averaged velocities at two-tenths and eight-tenths depth) due to irregularities in the distribution of velocities.
- Measurements will be repeated at the same locations during the medium and low flow samples, with the exception of those that are no longer inundated by water.

Procedures for WSEL surveys

- Prior to conducting the survey a benchmark will be established that is easily identifiable for repeat measurements, and at a location where it will not move during the entire data collection period.
- The survey will be conducted along the same transects as the depth and velocity measurements.
- WSEL surveys will be conducted beginning at Transect 1 and continue in an upstream direction to Transect 12.
- At each transect a WSEL measurements will be collected near both right and left wetted edges of the stream, and near the center of the channel (to be averaged for model input).
- After all transect WSELs have been surveyed a final elevation measurement at the benchmark to assess the accuracy of the survey will be collected.

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

Waterproof notebooks will be used to document all data collection and contain the following information:

- Date
- Time
- Study location
- Name(s) of field staff
- General observations of weather
- Notes describing any unusual circumstances/anomalies in data collection
- Transect number
- Columns for depth and velocity readings, and substrate and cover types
- Distance on measuring tapes of right and left bank headpins and transect length
- Water surface and bed elevation measurements including:
  - Benchmark elevation (beginning and end of survey)
  - Fore sight and back sight measurements as needed
  - Turning points as needed

8.8 Other activities

Prior to any planned field work staff will be briefed on responsibilities for data collection and safety measures while in the field. All field equipment will be inspected for proper function and calibrated as needed prior to conducting field measurements.

9.0 Laboratory Procedures

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

Field staff will be instructed prior to each data collection effort on precisely what data are needed, where, and when. Data will be reviewed in the field by lead staff before leaving the site to ensure completeness and accuracy. All data will be entered into an EXCEL® spreadsheet promptly after completing each collection effort and analyzed to ensure usability, and to determine if additional needs exist. Additional review for completeness and accuracy will be conducted when data are entered into the RHABSIM program.

10.1 Field quality control

WSEL, depth, and velocity measurements will be reviewed continuously during collection. A qualitative assessment of measurements based on best professional judgement will be conducted at the time of measurement. In the event a measurement seems unreasonable, additional measurements will be collected for verification.

During subsequent site visits for repeat measurements, copies of original field notes will be provided to ensure field staff collect measurements at the correct locations. The field notes provide the location along each transect of every depth and velocity measurement collected during the previous survey(s). This will also provide a QC check to ensure WSEL and depth measurements decrease with decreased flow as expected. Velocity measurements will not necessarily decrease with decreasing flow depending on the measurement point.

10.2 Corrective action processes

Data quality assessment will be conducted during field collection, and post field collection to ensure MQOs are met. In the event data collection is found to be inconsistent with this QAPP, corrective actions may include:

- Discharge measurements not meeting the 10% or less RPD as described in Section 6.2 will be qualified as estimates and further assessed for usability.
- Discussions with field staff regarding how an error may have occurred before leaving the study site, and the necessary steps to correct it.
- Collection of additional measurements to ensure completeness and accuracy of data.
- Re-calibration of equipment if data indicate bias in measurements.
- Assessment and qualification of new data collected if necessary.

11.0 Data Management Procedures

11.1 Data recording and reporting requirements

WDFW will house all data and modeling results internally. Results of the PHABSIM model will be provided in a final report upon completion as a deliverable per IAA No. C2200146.

11.2 Laboratory data package requirements

Not applicable.

11.3 Electronic transfer requirements

Not applicable.

11.4 Data upload procedures

The following data will be submitted to the EIM (Study ID ROBE0001) following the EIM User's Manuals and data templates:

- Discharge values for each transect at each of the three flow samples.
- Wetted width measurements for each of the three transects at each of the three flow samples.
- Average depth and velocity readings at each transect at each of the three flow samples.

11.5 Model information management

Typically, the principal investigator manages these files and distributes them as necessary to appropriate personnel as WDFW does not currently have a common repository for such files.

Raw data will be housed and managed internally by WDFW WST staff in the form of the original field notes and within EXCEL® spreadsheets. All model input and output data files will also be housed and managed internally by WDFW.

Data storage needs for associated files are minimal and typically stored on WDFW computers with backup copies stored on a common shared drive (S-drive) managed by WDFW.

Files from subsequent model runs will be given a unique naming convention that allows for easy identification of a particular model run.

12.0 Audits and Reports

12.1 Audits

Audits will be conducted internally on a regular basis to ensure data collection requirements are being met and modeling efforts and reporting are on target with deliverable dates.

12.2 Responsible personnel

Robert Granger (Instream Flow Biologist) and Jonathan Kohr (Environmental Planner), Project Leads, will conduct audits for data completeness and modeling efforts continually as the model is developed.

12.3 Frequency and distribution of reports

A draft and subsequent final report will be completed upon model calibration and generation of WUA curves. Additional reporting may occur in the form of a technical memo or addendum to the final report if further WUA analysis is requested.

12.4 Responsibility for reports

Robert Granger (Instream Flow Biologist) will be the lead author on the draft and final reports with Jonathan Kohr (Environmental Planner) as a secondary author and reviewer.

13.0 Data Verification

13.1 Field data verification, requirements, and responsibilities

Field data will be reviewed and verified as follows:

- Field staff will review data sheets prior to leaving the study site for completeness and accuracy.
- The project lead will promptly review data post-collection, and as it is transferred to EXCEL® spreadsheets.
- Further review will be conducted by the project lead and other WST staff once all data have been properly entered into spreadsheets and prepared for entry into the RHABSIM program.
- Field data will be continuously reviewed during model calibration.

13.2 Laboratory data verification

Not applicable.

13.3 Validation requirements, if necessary

Not applicable.

13.4 Model quality assessment

Refer to the WDFW Standard Operating Procedure for Conducting Physical HABitat SIMulation Studies on Wadable Streams and Rivers and the RHABSIM 2.0 User's Manual (T.R. Payne and Associates, 1998) for more detailed information on model calibration and assessment.

Documentation of model calibration efforts will be provided in the final report including; original field measured data, any changes to input data during the calibration process, and final calibration values. The final report will also include discussion and documentation of how well model quality objectives are met.

13.4.1 Calibration and validation

Model calibration is a process of adjusting inputs to the raw field data so the model predicts as accurately as possible what was measured in the field. There are different approaches to calibration available that won't be presented here, however the methodology that will be used for this study is the stage-discharge method. This method requires two calibration stages; 1) stage or depth calibration, and 2) velocity calibration.

The stage calibration relies on surveying of bed and WSEL. The goals of stage calibration are to ensure model simulation of stage falls within the field measured water surface and bed elevations, and water is flowing downhill from the most upstream to the most downstream transect at all simulated flows. Velocity calibration entails adjusting input velocities (measured velocities) so that simulated velocities are close to what is measured in the field.

13.4.1.1 Precision

Precision targets for stage calibration

Simulated WSELs should be within 0.05 feet (usually closer) of surveyed WSELs at calibration flows. Simulated WSELs should progress downhill downstream and the relationships between WSELs should be relatively consistent from flow-to-flow and transect-to-transect.

Precision targets for velocity calibration

The measured velocities are the reference velocities. The standard of a good model is that simulated velocities are close to measured velocities. The criteria for how close is acceptable are 0.20 feet per second (fps) at velocities of 1.0 fps or less, and 20% at velocities greater than 1.0 fps.

13.4.1.2 Bias

A bias assessment will use the same precision criteria as above by calculating the percent error between measured versus simulated velocities and assessing the measured WSELs relative to simulated WSELs. This is typically done during model calibration to ensure that targets for precision are being met throughout the process.

13.4.1.3 Representativeness

The measure of representativeness of the PHABSIM model is how well calibration efforts meet the above criteria for precision and bias. If the modeled values for velocities and WSELs fall within the acceptable range of measured values, we assume that the values extrapolated between and beyond measured values are reasonable. If we are confident in this, we can infer that the prediction of the distribution of depths and velocities, and the modeled flow-to-habitat relationship, are representative of the study reach.

13.4.1.4 Qualitative assessment

The end product of the PHABSIM model is a set of WUA curves generated for a range of flows, and fish species and lifestages of interest. This relationship is presented graphically representing available habitat (in ft^2 per 1000' linear feet of stream) as a function of the volume of streamflow. A qualitative assessment of the WUA curves will be made based on our confidence in the quality of data collection, model performance, and best professional knowledge (e.g., fish life requirements and personal knowledge of the study reach).

13.4.2 Analysis of sensitivity and uncertainty

Calibration of this model will use the Dual SDR (Stage-Discharge Rating) method (T.R. Payne and Associates, 1998). This method uses two separate calculations of the stage-discharge rating curve; 1) using the given (measured) data, and 2) the simulated relationship. The two are compared within the model in which a velocity adjustment factor (VAF) is produced for each transect. The VAF is a ratio between the two ways of calculating flow. If the two flow calculations are close, the VAF will be near 1.0.

This is the sensitivity test of the model. It allows for an assessment of how well the model is simulating the stage-discharge relationship relative to the measured field data. The standard for acceptable VAFs is that they fall within a range of 0.80 and 1.20. The further outside of this range of values, the more uncertainty there is in how well the model is performing. Our goal for any PHABSIM model is to stay well within this range and as near a VAF value of 1.0 as possible. The final VAF values will be provided in the final report with discussion as to how well these objectives are met.

14.0 Data Quality (Usability) Assessment

14.1 Process for determining project objectives were met

The data quality assessment will be continuous as data is collected and reviewed by the lead investigator(s). Completeness and accuracy must be evaluated at the time of collection as returning to the study site to collect additional measurements is not typically feasible. For each respective sampling event (high, medium, and low) all data must be collected the same day, and at the same flow for it to be useful in the model. A significant loss or rejection of data will require an entire sampling effort to be repeated.

As the field measurements for this study will be generally physical in nature (aside from velocity), professional judgement must be applied when reviewing the data to determine whether a particular measurement does not meet the MQOs outlined in this QAPP (e.g., a replicate discharge measurement having a RPD greater than 10%). If this should occur, the lead investigator(s) will make the determination as whether or not to use the measurement in model development.

14.2 Treatment of non-detects

Not applicable.

14.3 Data analysis and presentation methods

Not applicable.

14.4 Sampling design evaluation

Not applicable.

14.5 Documentation of assessment

Not applicable.

15.0 References

Ecology, 2019c. Quality Assurance at Ecology. Environmental Assessment Program, Washington State Department of Ecology, Olympia. https://ecology.wa.gov/About-us/How-we-operate/Scientific-services/Quality-assurance.

HACH FH950 User Manual, 2022. Edition 8. HACH Company World Headquarters. Loveland, CO.

Microsoft, 2007. Microsoft Office XP Professional, Version 10.0. Microsoft Corporation.

Parsons, J., D. Hallock, K. Seiders, W.J. Ward, C. Coffin, E. Newell, C. Deligeannis, and K. Welch, 2012. Standard Operating Procedures to Minimize the Spread of Invasive Species, Version 2.0. Washington State Department of Ecology, Olympia, WA. SOP Number EAP070. www.ecy.wa.gov/programs/eap/quality.html.

Shedd, J.R., 2017. Measuring and Calculating Stream Discharge, Version 1.3. Washington State Department of Ecology, Olympia WA. SOP Number EAP056. www.ecy.wa.gov/programs/eap/quality.html

Thomas R. Payne and Associates, 1998. User's Manual – RHABSIM (Riverine Habitat Simulation software) 2.0 for DOS and Windows, variously paged.

WDFW. 2022. Standard Operating Procedure for Conducting Physical HABitat SIMulation Studies in Wadable Streams and Rivers (Draft). Washington Department of Fish and Wildlife. Olympia, WA.

WDFW and WDOE. 2022. Instream flow study guidelines: technical and habitat suitability issues including fish preference curves (Updated, March 9,2016). Washington Department of Fish and Wildlife and Washington Department of Ecology. Olympia, WA. 84 pp. https://apps.ecology.wa.gov/publications/documents/0411007.pdf

16.0 Appendices

Appendix A. Standard Operating Procedure for Conducting Physical HABitat SIMulation Studies in Wadable Streams and Rivers (Draft)

Standard Operating Procedure for Conducting Physical HABitat SIMulation Studies on Wadable Streams and Rivers (Draft)

1.0 Purpose and Scope

This standard operating procedure (SOP) describes the techniques and methods used to conduct a Physical HABitat SIMulation (PHABSIM) study including; planning for the study, site selection, field measurement protocols, and model calibration.

2.0 Applicability

An instream flow study, such as PHABSIM, is commonly used to evaluate the relationship between rates of streamflow and available preferred habitat for different fish species and lifestages at those streamflows. It is a tool that allows water managers and streamflow practitioners to estimate the amount of preferred habitat available to fish relative to changes in the timing, magnitude, and frequency of streamflow in a particular reach of stream.

3.0 Definitions

Midsection Method – A widely used technique for calculating steam discharge, the midsection method involves the calculation of discharge in individual measurement cells in a cross section. The sum of the discharges of each cell comprise the total discharge of the stream.

Cross Section (or transect) – A vertical plane extending from either stream edge, up from the stream bottom to the surface.

Vertical – One of a series of measurement points through the cross section where depth and velocity measurements are measured (also referred to as a station for the purpose of a PHABSIM study).

Hydraulic Control – The physical features controlling the relationship between stage and discharge at a particular point in a stream.

Stage of Zero Flow – The water surface elevation at the instant the stream stops flowing in a pool; stage of zero flow (SZF) is level with the lowest point on the top of the downstream riffle-gravel bar.

Water Surface Elevation (WSEL) – The height of the water surface at a cross section as measured (or predicted). The WSEL can also be determined from the streambed elevation plus water depth. The WSEL is also called the water surface level (WSL).

Stage – The elevation, or vertical distance of the water surface above some datum (i.e., height relative to the established benchmark used during surveying of the stream geometries or as predicted from the hydraulic models) such as PHABSIM. Stage is equivalent to WSEL.

4.0 Personnel Qualifications/Responsibilities

4.1 Personnel following the procedures in this document will have the necessary training to operate the required equipment for data collection including; velocity meters and survey tools.

4.2 Staff will have proper training in use of the Riverine HABitat SIMulation (RHABSIM) model from Thomas R. Payne and Associates (Arcata, CA) including; data input, calibration procedures, and subsequently running model outputs. This model is commonly used for Washington State PHABSIM studies.

4.3 Field staff will have knowledge of safety procedures associated with the collection of streamflow and habitat information.

4.4 Users of this document typically work in the Hydrogeologist, Natural Resource Scientist, and Fisheries Biologist job classifications.

4.5 No special certifications are currently required.

5.0 Equipment, Reagents, and Supplies

5.1 A standard four-foot top-set wading rod measures vertical depths in streams shallow enough and safe for wading. A velocity meter attached to the top-set wading rod measures current speed. The design of the rod allows users to set the current meter at 0.2, 0.6, and 0.8 feet of the total stream depth.

5.2 The Hach® FH950® portable flow meter or equivalent is used for velocity measurements. The basic components of the FH950® include the velocity meter with control panel, under water velocity sensor, and sensor cable. These components attach to the wading rod, although the velocity meter may be removed and held by hand in deeper water situations to avoid being submerged.

5.3 Survey equipment: A variety of equipment is available and may be used for surveying water surface and bed elevations. The basic equipment required is an optical type or laser level, tripod, and stadia rod in English units and graduated in hundredths of feet. All survey equipment will be inspected to ensure good condition and reliability prior to field work. Refer to user's manual for the specific type of survey equipment you intend to use for maintenance and operating instructions.

5.4 Fiberglass open reel measuring tapes for establishing channel cross sections (or transects). One to three hundred foot measuring tapes are generally sufficient depending on stream channel width and should be in English units and graduated in decimal feet. Several may be required for optimal efficiency of streamflow data collection and survey efforts.

5.5 Rebar stakes (or similar) for anchoring measuring tapes between right and left stream banks when establishing transects. Typically, twelve transects are established for a PHABSIM study, however this may be more or less depending on the study site. Twelve transects will require twenty-four stakes.

5.6 As mandated by the Environmental Assessment Program's Safety Manual (EAP, 2019) staff wear an approved personal floatation device when working in areas where the danger of drowning exists, such as on the water, over the water, or alongside the water.

5.7 Following is a list of equipment to consider for field data collection:

- Auto Level
- Bucket for flow meter calibration
- Camera
- Waterproof field notebooks
- Flagging tape
- Flow meter
- GPS unit
- Hammer
- Loppers or machete
- Pencils
- Permanent marker
- Rebar (2 per transect) and safety caps
- Stadia rod (engineering grade capable of measuring 1/10 ft and 1/100 ft
- Staff gage
- Several fiberglass measuring tapes (graduated in 1/10 ft and 1/100 ft)
- Tripod
- USGS top-setting wading rod

6.0 Summary of Procedure

6.1 Technical Stages of the study include

6.1.1 Planning or scoping - develop study plan and obtain approval from interested or affected parties regarding site selection and study objectives. Parties can range from local, state, federal, tribal, and non-profit entities, and private landowners.

6.1.2 Topographical maps.

6.1.3 Identification of areas along the stream that exhibit major morphological changes in the stream bed and/or stream banks.

6.1.4 Graph of elevation plotted against the stream's longitudinal distance.

6.1.5 Low altitude photo mosaic (preferred) or video of entire reach. Photos or videos can be used in the body of the report or in an appendix. They should be annotated with transect number and site specific information including flow, date, and names of field staff.

6.1.6 On-the-ground photos or video of all habitat types and potential barriers to fish migration (include a reference object for scale in pictures of potential barriers).

6.1.7 List of the fish species known or expected in the stream reach.

6.1.8 Available hydrological data such as the 10, 50, and 90 percent exceedance discharges by month; and information on the source of this data.

6.1.9 Locations of transects and study sites, with maps and photos or videos as documentation.

6.1.10 Range of flows to be addressed and targeted flows to be measured as calibration flows.

6.1.11 Available hydrographs to be used and any new hydrology to be collected.

6.1.12 Hydraulic model(s) to be used (e.g., IFG4, WSP/ IFG2, MANSQ).

6.1.13 Habitat preference curve verification study plan (see 8.0 below).

6.1.14 Habitat models to be used (HABSIM or similar model, plunge pool, and so on).

6.1.15 Any limiting factor analysis or time series analysis.

6.2 Field data collection

6.2.1 Discharge measurements will generally follow Ecology Standard Operating Procedure (SOP) EAP056, Measuring and Calculating Stream Discharge, with the exception that transects are not selected to provide the most accurate measurement. Instead, transects are selected to capture the variability in mesohabitats and instream structure within the study reach (e.g., large woody debris, substrate, vegetation, and undercut banks).

6.2.2 Preparation

6.2.2.1 A PHABSIM study typically requires three sampling events; at a high, medium, and low-flow in descending order as the hydrograph is receding. The range of flows sampled is determined by the questions the study is intended to answer. Ideally, the medium flow sample is fifty percent of the high flow sample, and the low flow sample is fifty percent of the medium flow. Preparation for variable conditions is extremely important in terms of equipment, and more importantly staff safety, particularly during high-flow sampling.

6.2.2.2 Complete a Field Work Plan prior to departure to the field and include; a list of all necessary equipment for data collection and staff safety.

6.2.2.3 Review equipment checklist and ensure all required equipment is in proper working condition and loaded into vehicles.

6.2.2.4 Ensure vehicles are equipped for driving conditions and are properly maintained prior to travelling to and from the study site.

6.2.2.5 Upon arriving at the study site, and prior to beginning field work, conduct a safety meeting with all field staff and discuss each person's roles and responsibilities.

6.2.3 Transect selection

6.2.3.1 The general study reach is selected and agreed upon in the planning or scoping stage (Section 6.1.1). Transect selection will occur on-site when reviewing the stream reach characteristics and mesohabitat types (pool-head, pool, pool-tailout, glide, run, and riffle) while ensuring to include available spawning habitat. This may be done prior to the first day of sampling.

6.2.3.2 Typically, twelve transects are established within the study reach and represent all mesohabitat types in the affected reach. Transects are established at each change in mesohabitat type working in an upstream direction. The overall length of the study reach is dictated by the longitudinal distance between the different mesohabitat types present. There may be more or fewer than twelve transects depending on channel characteristics and the number of different mesohabitat types present, but a minimum of twelve is recommended when possible.

6.2.3.3 Transects are established in consecutive order beginning with 1 at the most downstream extent of the study reach through 12 at the most upstream extent of the study reach.

6.2.3.4 Transect 1 is established at the most downstream hydraulic control (pool-tailout). A rebar stake (headpin) is anchored on both the right and left streambanks (looking downstream) at an elevation that is beyond the water surface elevation of the highest expected modeled flow. This is typically well beyond the transition from the stream bed to terrestrial vegetation to ensure modeling results characterize water surface elevations at the highest flow of interest. The highest modeled flow is determined by the lowest modeled flow of interest, which is typically baseflow. Once the low-flow of interest is identified, data for the medium flow is collected at 2x the low-flow, and the high-flow data is collected at 2x the medium flow. Headpins are anchored so that when a measuring tape is extended between them from the right bank to the left bank it is perpendicular to the streamflow (Figure 1).

6.2.3.5 The remaining transects are established in consecutive order by working upstream and selecting for changes in mesohabitat types. Ideally, equal numbers of mesohabitat types present in the reach are represented during transect selection. Ideally, transects should always be selected that represent available spawning habitat within the study reach. Headpins are not removed until completion of all data collection for the study.

Figure 3. Photo of lower transects with WDFW staff (Reavill and Morton) during the French Creek PHABSIM Study - 2020

6.2.4 Water depth and velocity measurements

6.2.4.1 The Hach® FH950® velocity meter is calibrated on-site using a zero-velocity bucket test and water from the study reach per model specifications prior to data collection (HACH FH950 User Manual, 01/2022, Edition 8).

6.2.4.2 Prior to collecting depth and velocity measurements, measuring tapes are secured to the right bank headpins with the zero mark of the tape centered on the headpins. The tapes are extended to the left bank headpins perpendicular to the flow and tightly secured to minimize slack and risk of detaching during field measurements. The distances on the tapes at both the right and left headpins are accurately recorded in a field notebook so they will be precisely reattached at those same points during subsequent sampling events. Note: rebar headpins must remain in place for the duration of data collection to ensure transects are set up at precisely the same location for each sampling event.

6.2.4.3 During the high-flow sample depth and velocity measurements are collected along each transect (measuring tape) starting from the right water's edge and ending at the left water's edge. Ideally, transects are divided into thirty equal segments with a depth and velocity measurement collected at each station (or vertical) along the tape. However, in some situations, it is necessary to adjust the number of stations and distance between stations to capture instream structure such as large boulders and woody material, or significant changes in velocities.

6.2.4.4 At each station a water depth measurement is collected to the nearest 0.05 foot using the top-set wading rod. The distance on the measuring tape of the right and left wetted edges are also recorded and any relevant information needed to collect subsequent measurements (during other flow samples) at that precise location are clearly and accurately recorded in a field notebook.

6.2.4.5 After the depth measurement is recorded the top-set wading rod is adjusted so the velocity sensor is set at sixty percent of the total depth from the water's surface for mean water column velocity. The velocity meter is set to twenty-five second averaging prior to collecting samples. The meter is re-set before each reading is collected, allowed to sample for twenty-five seconds, and the resulting average velocity is accurately recorded in the field notebook noting any irregularities in the measurement.

6.2.4.6 It is necessary at times to collect velocity measurements at twenty-percent and eighty-percent depths when velocities are not distributed evenly throughout the water column. This can occur for many reasons such as the transect is located downstream of instream structure or there is an object deflecting flow away from the sensor. In this case the averaged velocities between the twenty-percent and eighty-percent depths will be used in the final discharge calculations.

6.2.4.7 Upon completion of all depth and velocity measurements, field notes are checked for completeness and accuracy before leaving the study site. Upon returning to the office, they are photocopied or scanned electronically as a back-up in the event the originals are lost or destroyed.

6.2.4.8 Careful consideration of when to collect medium and low-flow samples is made in order to capture the desired range of flows for the study. When a telemetered streamflow gage is available that is representative of the study reach it is monitored regularly to determine the appropriate time to return to the study site for repeat measurements. In the event a gage is not available, it may be necessary to return to the study site and collect additional manual flow measurements between sampling events to determine the appropriate timing for the next sample.

6.2.4.9 When the flow in the study reach is approximately fifty-percent of the high-flow sampling event, field staff return to the study site and repeat the depth and velocity measurements. Copies of original high-flow field notes will be made available so field staff can accurately repeat the measurements at the correct locations. It should be noted that depths will generally decrease with decreasing flows, and definitely should not increase. If depths increase with decreasing flow it is likely that the measurement is not being taken at the correct location. It is common to have to move the wading rod slightly to the left, right, forward, or back to find the correct location. Transects are set-up precisely as they were during the high-flow sample. Note that as the flow has receded some stations will be dry and will be documented as such in the field notebook. This process is again repeated for the low-flow sample when the flow is determined to be appropriate.

6.2.4.10 All field data are entered into Excel® spreadsheets for calculation of total discharge. The discharge for each transect for each flow sampling event will be calculated using the mid-point method as described in EAP056 (see below). The average discharge is calculated for all transects for each independent sampling event, and the resulting values are used in the model.

Discharge of a given cell is calculated as:

$$q_x = v_x \left[\frac{b_{(x+1)} - b_{(x-1)}}{2}\right] d_x$$

where,

q_x = discharge through cell x,

v_x = mean velocity at vertical x,

b_x = distance from initial point to vertical x,

$b_{(x-1)}$ = distance from initial point to preceding vertical,

$b_{(x+1)}$ = distance from initial point to next vertical, and

d_x = depth of water at vertical x

The total discharge of the stream is equal to the sum of the discharges of each cell.

6.2.5 Substrate and cover data collection

6.2.5.1 Substrate and cover data are typically collected during the low-flow sample as they are more difficult to identify at higher flows. A substrate code is recorded in the field notes for each station and at all transects that a depth and velocity measurement was collected during the high-flow sample. Every station will have an associated substrate code.

Cover codes are collected at the same stations however all stations will not necessarily have cover, such as those that are mid-channel or near a stream bank lacking riparian vegetation. If cover is not present it is documented as such in the field notes. (See section 9.1 for substrate and cover codes).

6.2.5.2 Substrate and cover data are also collected between the original (high-flow) right and left wetted edge locations and the associated right or left bank headpins for each transect. The data are collected at inflection points along the transect where there are changes in substrate, elevation, and vegetation on the stream bank. The location on the transect is recorded along with the associated substrate and cover code in the field notebook.

6.2.6 Survey data collection

6.2.6.1 For each set of linked cross sections, a closed-loop survey through all headpins showing elevations and distances is required.

6.2.6.2 Set benchmark at a known location within the PHABSIM site and use 100’ as the starting elevation. This benchmark is used for each of the high, medium, and low flow surveys and should be established at a location that is easily identifiable for repeat measurements and will not move during the entire data collection period.

6.2.6.3 Establish a temporary staff gage to check fluctuations in the water surface elevations (WSEL) during each day’s discharge measurement. The water level at the staff gage should be recorded prior to the start and upon completion of data collection during each sampling event. This will allow for reconciliation of survey data in the event there are fluctuations in WSELs during data collection.

6.2.6.4 At each flow, take a survey of WSELs at each cross section, relative to the cross section headpins using that same benchmark as a known elevation.

6.2.6.5 WSELs for each transect can be sampled using the “touch” method by touching the water surface with the stadia rod and averaging at least two measurements (three is best, towards right and left banks, and one near the center).

6.2.6.6 Wading rod depths can also be taken in which the depth value is subtracted from the elevation reading. This can provide some data redundancy and an essential check on the survey technique.

6.2.6.7 A topographic survey of channel morphology (bed elevation) at each cross section (selected above), relative to the fixed cross section headpin. The investigator should ensure an adequate number of observations above the high water sampled edge are collected to accurately characterize the changes in elevation along the stream bank (inflection points). This may be only a few, or several depending on stream bank characteristics and distance from the high water sampled edge to the headpin. This is done to describe the channel cross section and note that each survey point will be used as a location for hydraulic measurement when covered by water.

6.2.7 Transect weighting

6.2.7.1 Weighting for each transect is accomplished in two steps. The first involves classification of the various habitat types present for each transect within the study reach. At each transect the habitat type is classified per Table 1. There are generally six mesohabitats types used (pool-head, pool, pool-tailout, glide, run, and riffle). These are defined by the gradient, channel shape, and substrate distribution. Two transects per mesohabitat are usually chosen, but in some cases a particular mesohabitat type may not be present or well defined. Therefore, choosing additional transects having one or a combination of the other mesohabitat types present may be necessary.

Table 5. General mesohabitat type and description used in transect selection.

Mesohabitat Type and Description	
Habitat Name	**Habitat Description**
Pool-head or hydraulic control	The downstream end of the pool generally is a hydraulic control.
Pool	Slower velocity and deeper, non-turbulent flow with a strong hydraulic control.
Pool tailout	Downstream end of a pool where spawning would more likely occur, and shallower than half the depth of the pool.
Glide	Smooth, generally unbroken surface, generally laminar flow, moderate to shallow depth, often-smaller substrates.
Run	Like a glide except faster velocities and somewhat more turbulent; surface may be broken by protruding rocks.
Riffle	Shallow with moderate velocities (less than run), lateral bottom profile is usually uniform; surface is broken but not turbulent like a run, gradient <4%.

Note: Table is derived from Bowen, 2009.

6.2.7.2 The pool has the lowest gradient of all four mesohabitats. The pool is characterized by a hydraulic control at its downstream end. The upstream margin of the pool lies on a line containing the same absolute bed elevation as the downstream margin. Hence, if the flow from upstream is stopped, the pool would still hold water. Typically, pools have a concave channel, uniform primarily fine substrate and a tranquil water surface (Figure 2).

Figure 4. Example of pool type mesohabitat (downstream of woody debris) transect from the French Creek PHABSIM study, 2020.

6.2.7.3 The glide usually has fine sediment at the bottom. The glide is also characterized by a glassy water surface (Figure 3).

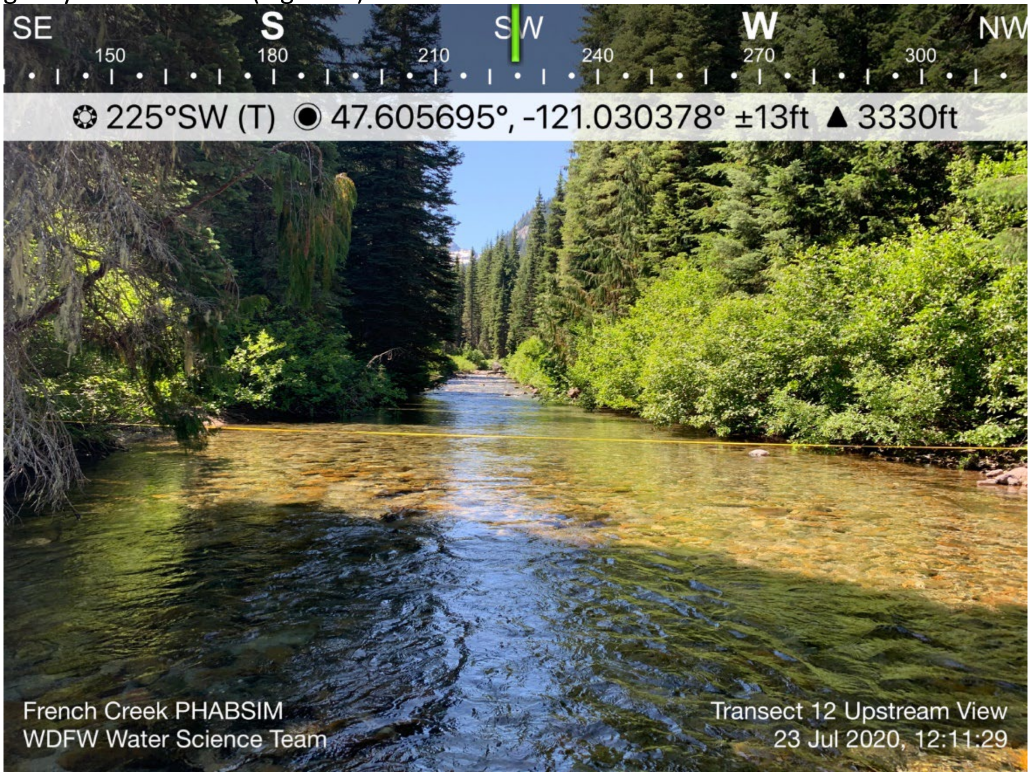

Figure 5. Photo of glide type mesohabitat transect from the French Creek PHABSIM study, 2020.

6.2.7.4 The run and the glide are characterized by intermediary gradients between the riffle and the pool, with the run having a higher gradient than the glide (Figure 4).

Figure 6. Photo of run transitioning to a glide type habitat transect from the French Creek PHABSIM study, 2020.

6.2.7.5 The riffle has the highest gradient of all four mesohabitats. For a given stream, it is shallower than the other types of mesohabitats and with higher water velocity due to its gradient (Figure 5).

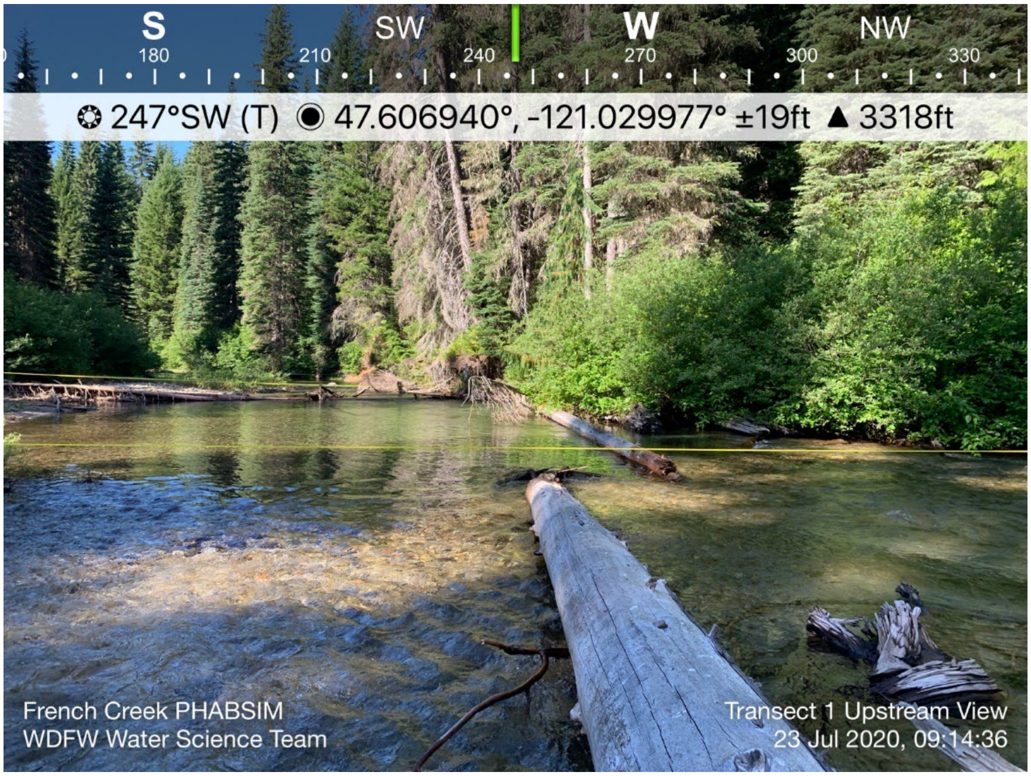

Figure 7. Photo of riffle type mesohabitat transect (also a hydraulic control) from the French Creek PHABSIM study, 2020.

6.2.7.6 Runs are moderately turbulent, with a disturbed water surface and a mix of substrate sizes (gravel, cobble, and some boulder) (Figure 6).

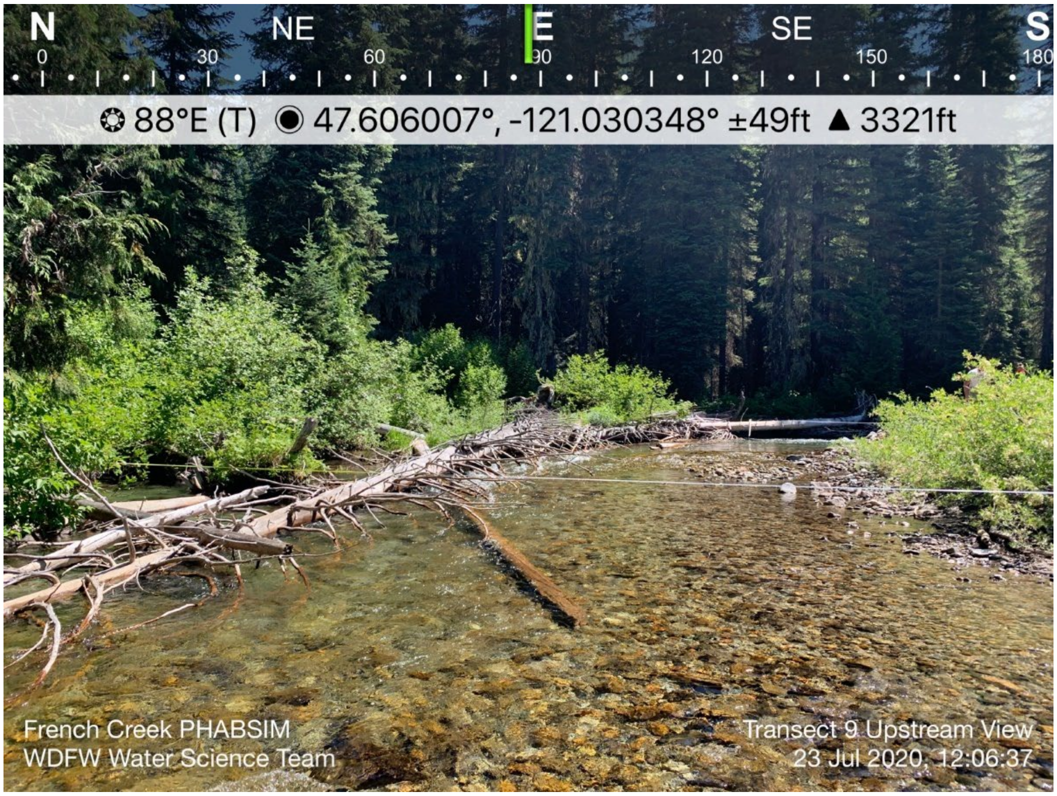

Figure 8. Figure of run type mesohabitat transect from the French Creek PHABSIM study, 2020.

6.2.7.7 The second step involves a frequency analysis to determine the proportion of each habitat type in each study reach. Transect weighting is based on the frequency (measured habitat types) in the study reach that are represented by the selected mesohabitat-type transect. For the transect weighting, and associated data entry into the RHABSIM program, each change in mesohabitat is measured and weighted throughout the study reach and assigned to the appropriate (most similar) transect.

6.2.7.8 Transects are weighted for the study reach by measuring lengths of the mesohabitat types between the adjacent transects and calculating those distances for 1000 ft of stream. The actual study reach is typically much less than 1000 ft; however the model uses the transect weighting to extrapolate the results to 1000 ft of stream.

Mesohabitat can and often does change between transects. When the length of mesohabitat is measured between transects, the resulting measured value is applied to the most comparable upstream or downstream transect. For example, if Transect 2 is identified as a pool and the pool extends 10 ft downstream towards Transect 1 and 25 ft upstream towards Transect 3, then 35 ft of pool habitat is applied to Transect 2 during weighting. Each transect is designated with a mesohabitat type. Mesohabitat length measurements are then assigned to individual transects and normalized as a percentage of the 1000 ft modeled study reach.

7.0 Hydraulic model calibration (Refer to T.R. Payne and Associates, 1998 for further detail on model calibration procedures)

7.1 The agencies request the following material for each hydraulic model run (always include a run pre-velocity calibration)

7.1.1 Input data file (bed and water surface elevations, velocities, substrate/cover, and calibration discharges for velocity regression models; bed and water surface elevations, roughness coefficients, substrate/cover, and calibration discharge for step-backwater models). Include both an unmodified and modified version of the input file along with a table of any data modifications.

7.1.2 Tables for each transect of "calibration details" with simulated velocities paired with corresponding measured velocities for each calibration flow (thus, the model needs to be run for calibration flow). If several 1-velocity models are being run, please provide tables of measured velocities with predicted velocities (e.g., measured high flow velocities with extrapolated high flow velocities from medium and low flow models, and similar treatments of medium flow and low flow velocities).

7.1.3 Tables of pre and post calibration velocity adjustment factors (VAF) for each transect and each simulated flow over the proposed range of the model.

7.1.4 Tables of "computational details" for each simulated flow, including calibration flows.

7.1.5 List of options used in the hydraulic model.

7.1.6 Site map showing placement of numbered transects in relation to pools, riffles, chutes, large boulders, large woody debris, and other channel features.

7.1.7 Table of stage (WSELs) differences between flows and between transects, such as shown below.

	Transect 1 feet	Difference feet	Transect 2 feet	Difference feet	Transect 3 feet
400 cfs:	91.20	0.10	91.30	0.15	91.45
difference	.10		.09		.10
200 cfs	91.10	0.11	91.21	0.14	91.35
difference	.05		.07		.05
100 cfs	91.05	0.09	91.14	0.16	91.30

7.2 Water Surface Elevation (WSEL) Modeling

7.2.1 The approaches available for calculation of water surface elevations are: (1) stage-discharge relationships, (2) Manning's equation, and (3) the step backwater method. The absolute minimum data set used in the application of PHABSIM requires at least one set of water surface elevations. In standard practice, at least three sets of water surface elevations are targeted for collection. Our most often used methodology is the stage-discharge method.

7.2.2 The model uses a stage-discharge relationship (rating curve) to calculate water surface elevations at each cross section (Figure 2). In the stage-discharge relationship and its simulation, each cross section is independent of all others in the data set. The procedure is conducted by performing a log-log regression between observed stage and discharge pairs at each cross section. The resulting regression equation is then used to estimate water surface elevations at all flows of interest. Figure 2 is the result of the simulated WSEL produced from the regression equation.

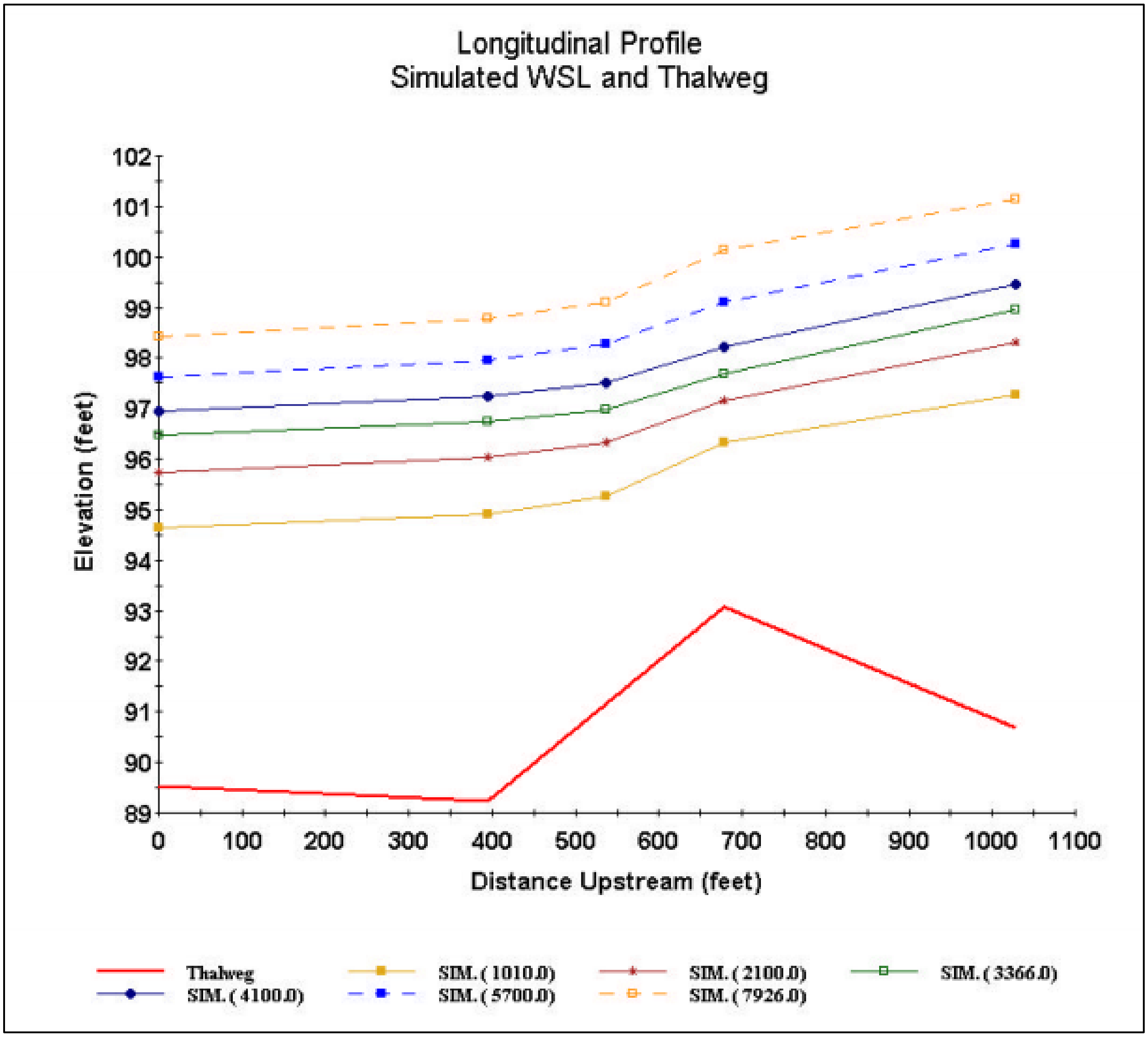

Figure 9. Longitudinal profile of simulated thalweg and water surface elevations (WSEL or WSL).

7.3 Depth or stage calibration

7.3.1 The first step of the calibration process is based on surveying of bed and water surface elevations.

7.3.2 Check for “holes” in the bed where no elevation is provided, and it goes to zero. If so, enter a measured bed elevation or an interpolated elevation. Bed elevations are usually WSEL-depth, where WSEL is water surface elevation.

7.3.3 Check thalweg elevations (deepest point on the transect). The thalweg will crest at a riffle and at each riffle going upstream the elevation should increase. The crests are hydraulic controls.

7.3.4 Elevations can be calculated in a spreadsheet, by hand, or in the model. Check for obvious errors in recording or calculations.

7.3.5 At each measured flow WSELs should increase from the most downstream transect to the most upstream transect. Although, pool transects may appear flat.

7.3.6 At extrapolated flows WSELs should increase from the most downstream to the most upstream transect. Water should not flow “uphill”.

7.3.7 Pools should be upstream of hydraulic controls and the WSEL should be lower downstream of a hydraulic control.

7.3.8 Where surveyed WSELs vary from left to right bank, any changes should be kept within the range of those measured for a particular transect.

7.3.8.1 **Example;** If Transect 1 has WSELs of 95.23 and 95.25, Transect 2 WSELs of 95.22 and 95.26, and Transect 3 WSELs of 95.25 and 95.25 as left and right elevations, the first calibration effort would be: Transect 1 = 95.24, Transect 2 = 95.24, and Transect 3 = 95.25. If this does not work use some combination of the original measured WSELs that preserve downhill flow.

7.3.9 Simulated WSELs should be within 0.05 feet (usually closer) of surveyed WSELs at calibration flows. Simulated WSELs should progress downhill downstream and the relationships between WSELs should be relatively consistent from flow-to-flow and transect-to-transect.

7.3.10 **Do not proceed to velocity calibration until stage calibration is satisfactory.**

7.4 Velocity calibration

7.4.1 Use the Centered velocity option in the model.

7.4.2 The measured velocities are the reference velocities. The standard of a good model is that simulated velocities are close to measured velocities.

7.4.2.1 The criteria for how close is acceptable are 0.20 feet per second (fps) at velocities of 1.0 fps or less, and 20% at velocities greater than 1.0 fps.

7.4.3 With the initial (measured) velocities entered, run the model. Keep track of which cells at which measured flows meet the above criteria. Attempt to adjust the regression in cells that do not meet the criteria by changing input velocities (measured velocities) to force the model to better replicate what was measured in the field Re-run the model and make additional adjustments to the input velocities as needed until simulated velocities fall within the above criteria.

7.4.3.1 If attempting to change the slope of a regression, a greater effect can often be had by a change at the low flow measurement. However, it is mostly trial and error, hence the value of tracking what worked and what didn't.

7.4.4 It is not uncommon to encounter a difficult cell, a single point on a transect in which velocity measurements were collected at the three flows, that is problematic when attempting to calibrate the velocity regression. When encountering difficult cells, a fallback approach is to set one or more input velocities to 0.0 fps, which leads to a 2-velocity regression (be aware of extreme results at extrapolated flows), or a Manning's roughness simulation of velocity (1 or no input velocities)

7.4.5 When velocities are reasonable at the measured calibration flows, evaluate Velocity Adjustment Factors (VAFs) and extrapolated velocities. The VAF is a ratio of two ways of calculating flow. If the two flow calculations are close the VAF will be near 1.0.

7.4.5.1 We recommend limiting extrapolation to flows at which all VAFs are between 0.80 and 1.20, and at which no simulated velocities exceed 10.00 feet per second. If it is necessary to model higher or lower flows, additional field work to allow calibration of an additional or extended model will be required.

7.4.6 Abrupt changes in velocities between adjacent cells should have a reasonable explanation or should be re-calibrated.

7.5 Model calibration notes

7.5.1 A well calibrated model should have the following;

7.5.1.1 WSELs and depths close to what was measured in the field,

7.5.1.2 water should flow downhill at all transects and at all flows,

7.5.1.3 no fewer cells meeting the velocity criteria than in the initial model run (distribution may change), 7.5.1.4 VAFs within the limits for measured flows and to the limits of extrapolation, and

7.5.1.5 extrapolated velocities that are reasonable.

8.0 Fish habitat suitability criteria curve verification

8.1 To complete the instream flow study, the project proponent must make a reasonable effort to determine fish habitat suitability or preference at the study site or an approved substitute site. Preference curve verification will be aimed at selected species and lifestages.

8.1.1 For information on habitat suitability study methodology and how to develop site specific curves please see the most recent version of the Instream Flow Study Guidelines: https://apps.ecology.wa.gov/publications/documents/0411007.pdf

9.0 Fish habitat preference using state default curves (recommended when site-specific habitat suitability is not available)

*Subsections 9.1 and 9.2 are excerpts from the 2016 Instream Flow Study Guidelines that describe Habitat Suitability Curve development.

9.1 Substrate and cover preference tables and coding

9.1.1 Table 2 lists codes 0.1 through 0.9, which are cover codes, and 1 through 9, which are components of the substrate code. Adjacent to each code are the recommended preference factors used to determine preference value.

9.1.2 Substrate codes use the format “ab.c” where “a” is the component code for dominant particle size (i.e. the type of substrate that covers the greatest area of bottom surface in a particular cell, not necessarily the largest diameter particle; e.g., sand may be dominant over cobble), “b” is the component code for the subdominant particle size, and “c” is tenths of cell area covered by dominant (50% or greater) substrate type. For example, the code 46.8 indicates 80% medium gravel and 20% small cobble.

9.1.3 Cover codes use the format 0.c, where “c” defines the type of cover. For example, 0.1 is an undercut bank, 0.2 is overhanging vegetation, etc.

9.1.4 Since PHABSIM can only accept 1 Cover/Substrate code, separate data decks should be developed for spawning and rearing lifestages. For biological realism, use cover for rearing and substrate for spawning in those cells where both are recorded.

9.1.5 RHABSIM can accept codes for two different attributes. This allows the user to choose one attribute (e.g. substrate) for the spawning lifestages and the other attribute (e.g. cover) for the rearing lifestages in a single data deck. But care must be taken to properly set up and assign the attributes in the HYDSIM program.

9.1.6 Recommended Preference (RP) in substrate tables 2 through 9 are calculated from generic preferences in Table 2 according to the following equation: **RP = c * Pa + (1-c) * Pb** where RP is the recommended preference, c is the percent presence of the dominant substrate, Pa is the preference factor for the dominant substrate, Pb is the preference factor for the subdominant substrate, and (1-c) is the assumed percent presence of the subdominant substrate.

9.1.7 Because there are often more than two substrate types we know the percent subdominant substrate does not usually follow the (1-c) calculation, but because we are limited to the "ab.c" format, it is an error we are willing to accept. Exceptions are noted by an asterisk.

9.1.8 **Exceptions:** There are many exceptions to the RP equation based on biological considerations. For example, if the dominant substrate was silt, clay, or organic (component code 1), or sand (component code 2), the substrate was assigned a RP of 0.00, regardless of the suitability of the subdominant component. Moreover, if the subdominant substrate was silt, clay, or organic, or sand made up 30% or more of the substrate, the RP was assigned a value of 0.00 for salmon and trout spawning, regardless of the quality of the dominant substrate, due to the smothering effect of fine substrates.

9.1.9 For salmonid spawning, the presence of bedrock (code 9) always resulted in a RP of 0.00, and in most cases, the presence of boulders (code 8) and for rainbow trout, large cobble (code 7) also resulted in an RP of 0.00 due to the inability of the fish to dig through, or move the substrate.

9.1.10 For salmonid juvenile rearing, boulders (component code 8) were found to be extremely valuable. Any presence of boulder, whether dominant or subdominant, results in a RP of 1.00 (WDFW and WDOE, 2022).

9.1.11 Another case is with redundant codes. A redundant code occurs when 100% of the substrate is of one type. If the substrate is 100% small gravel, any code between 33.5 - 33.9 could be used. By convention, redundant codes use the format aa.9.

Table 6**.** Generic Cover/Substrate Codes and Preference Value

Code	type of cover Note: Cover Codes are not used for spawning	Salmon & Trout Rearing	Whitefish Rearing	
		juvenile & resident adult	juvenile	adult
00.1	undercut bank	1.00	1.00	1.00
00.2	overhanging vegetation near or touching water[2]	1.00	1.00	1.00
00.3	rootwad (including partly undercut)	1.00	1.00	1.00
00.4	log jam/submerged brush pile	1.00	1.00	1.00
00.5	log(s) parallel to bank	0.80	0.80	0.80

---

[2] This includes low tree branches (<3 vertical ft above water surface elevation at stage of zero flow (SZF)) and bushes overhanging the bank-full water's edge.

00.6	aquatic vegetation						0.80	0.80	0.80
00.7	short (<1’) terrestrial grass						0.10	0.10	0.10
00.8	tall (>3’) dense grass[3]						0.70	0.70	0.10
00.9	vegetation > 3 vertical ft above SZF						0.20	0.20	0.20
Code	type of substrate	Spawning					Salmon & Trout Rearing	Whitefish Rearing	
		salmon	steelhead[4]	resident trout	native char5[5]	whitefish	juvenile & resident adult	juvenile	adult
1	silt, clay, or organic	0.00	0.00	0.00	0.00	00	0.10	0.38	0.15
2	sand	0.00	0.00	0.00	0.00	0.00	0.10	0.38	0.15
3	sm gravel (.1-.5")	0.30	0.50	0.80	1.00	1.00	0.10	0.74	0.76
4	med gravel (.5-1.5")	1.00	1.00	1.00	1.00	1.00	0.30	0.88	0.91
5	lrg gravel (1.5-3")	1.00	1.00	0.80	1.00	1.00	0.30	0.88	0.91
6	sm cobble (3-6")	1.00	1.00	0.50	0.70	1.00	0.50	1.00	1.00
7	lrg cobble (6-12")	0.50	0.30	0.00	0.70	0.50	0.70	1.00	1.00
8	boulder (>12")	0.00	0.00	0.00	0.0	0.0	1.00	1.00	1.00
9	bedrock	0.00	0.00	0.00	0.00	0.00	0.30	0.50	0.30

9.2 Depth and velocity preference curves

---

[3] This category refers to stout, almost bushy type grasses such as reed canary grass up to the bank-full water’s edge.

[4] This category includes intermountain and coastal cutthroat (*Oncorhynchus clarki*).

[5] This category includes Bull Trout (*Salvelinus confluentus*) and Dolly Varden (*S. malma*).

9.2.1 There are various recommended preference curves along with the coordinates used to make the curves. Recommended preference curves represent smoothed versions of the calculated preference curves. Smoothing of preference coordinates is based on professional judgment and observations from studies of wild fish. Such smoothing removes stair-stepped patterns at the upper and lower ends of the hydraulic distributions. Figures 3 and 4 provide examples of calculated and smoothed velocity preference curves for a specific fish species and life stage.

9.2.2 Some of the "Calculated depth preference curves" show habitat value in a depth interval that includes 0.00 ft. This is a consequence of grouped observations and weighted calculations. Recommended Preferences begin with calculated suitabilities that are then adjusted based on actual observations and professional judgment.

9.2.3 Depth and velocity preference curves are being revised continually as new data are obtained and analyzed. **Please contact the Department of Ecology or WDFW for the most recent preference curves for salmon, trout, and other game fishes**.

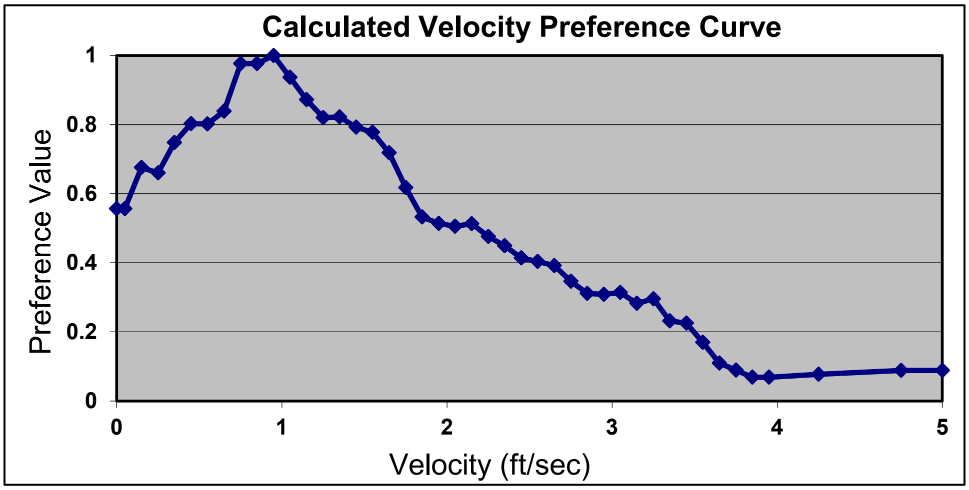

Figure 10. Example of calculated velocity preference curve with coordinates.

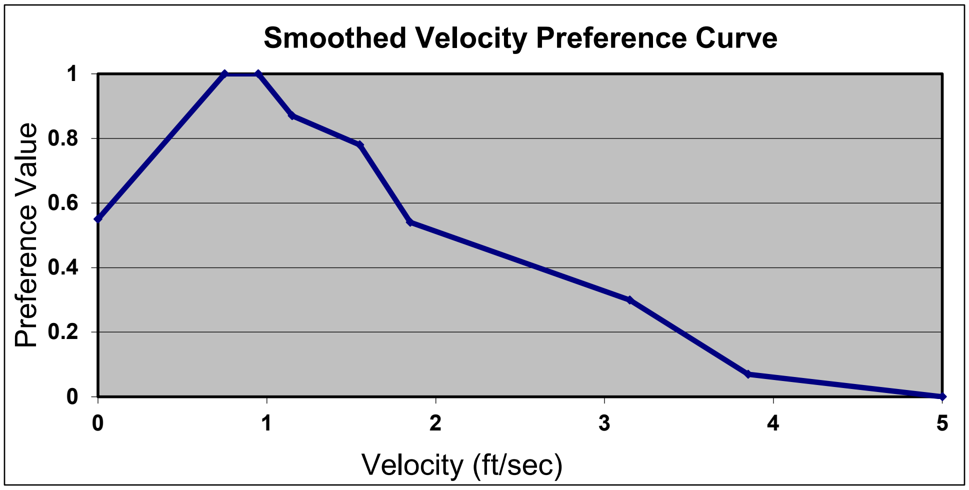

Figure 11. Preference curve in Figure 3 above after smoothing to remove stair-stepped pattern.

10.0 Habitat model runs (Refer to T.R. Payne and Associates, 1998 for further detail on habitat model runs)

10.1 A major product of an instream flow study is a set of tables and graphs showing the habitat to stream flow relationship. In PHABSIM and RHABSIM, this is produced by the HABTAT or HABSIM program and uses weighted usable area (WUA) as a measure of fish habitat.

10.2 PHABSIM accepts 1 Substrate/Cover code in the input file. Separate runs of HABTAT should be run for spawning and rearing lifestages. For biological realism, use cover for rearing and substrate for spawning in those cells where both are recorded.

10.3 In contrast, RHABSIM accepts coded for two different attributes. This allows the HABSIM to use substrate for spawning lifestages and cover for rearing lifestages in a single run.

10.4 In studies with multiple sites, the tables discussed above should be provided for each site individually and for all sites combined. The combined or composite tables should have results at each site weighted according to the total stream area (including unsampled areas) that it represents.

10.5 The final report, in which these tables are presented, should also include:

10.5.1 The preference curves used with documentation of agency approval, and

10.5.2 The list of options used in the habitat model.

11.0 Records management

11.1 Field notes

11.1.1 The primary investigator for the study typically retains the original field notes while creating electronic copies for distribution to other staff involved in the modeling effort, and as backup in the event originals are lost or destroyed.

11.2 RHABSIM/PHABSIM files

11.2.1 A designated WDFW or Ecology staff member will store and maintain all PHABSIM/RHABSIM files, as well as any associated electronic data associated with the model(s).

12.0 Safety

12.1 Field staff will follow all EAP safety policies and consider safety the top priority when conducting field measurements. Refer to the EAP Safety Manual, (EAP, 2019) for further information about working in and around streams.

12.2 Never attempt field data collection that may result in injury to staff or damage to equipment.

12.3 Take appropriate action if conditions are deemed unsafe for field data collection. Suspend or re-schedule data collection if necessary.

12.4 Safely cross streams in accordance with the guidelines for working in and around streams established in the EAP Safety Manual (EAP, 2019).

13.0 References

13.1 HACH FH950 User Manual, 2022. Edition 8. HACH Company World Headquarters. Loveland, CO.

13.2 https://www.usbr.gov/mp/bdo/docs/coordinated-long-term/Appendix-A-Mesohabitat-Types-Bowen-2009.pdf

13.3 Environmental Assessment Program, 2019. Environmental Assessment Program Safety Manual, March 2019. Washington Department of Ecology, Olympia, WA.

13.4 Shedd, J.R., 2017. Measuring and Calculating Stream Discharge, Version 1.3. Washington State Department of Ecology, Olympia WA. SOP Number EAP056. www.ecy.wa.gov/programs/eap/quality.html

13.5 Thomas R. Payne and Associates, 1998. User’s Manual – RHABSIM (Riverine Habitat Simulation software) 2.0 for DOS and Windows, variously paged.

13.6 WDFW and WDOE. 2022. Instream flow study guidelines: technical and habitat suitability issues including fish preference curves (Updated, March 9,2022). Washington Department of Fish and Wildlife and Washington Department of Ecology. Olympia, WA. 84 pp. https://apps.ecology.wa.gov/publications/documents/0411007.pdf

Appendix B. Glossaries, Acronyms, and Abbreviations

Glossary of General Terms

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

Char: Fish of genus *Salvelinus* distinguished from trout and salmon by the absence of teeth in the roof of the mouth, presence of light-colored spots on a dark background, absence of spots on the dorsal fin, small scales, and differences in the structure of their skeleton. (Trout and salmon have dark spots on a lighter background.)

Reach: A specific portion or segment of a stream.

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

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

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.

Acronyms and Abbreviations

e.g.	For example
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
i.e.	In other words
QA	Quality assurance
QC	Quality control
RM	River mile
SOP	Standard operating procedures
TSS	Total suspended solids
USFS	United States Forest Service
WDFW	Washington Department of Fish and Wildlife
WRIA	Water Resource Inventory Area
PHABSIM	Physical HABitat SIMulation
RHABSIM	Riverine Habitat Simulation

Units of Measurement

cfs	cubic feet per second
ft	feet
m	meter
WSEL	water surface elevation
WUA	weighted usable area

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 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).

References for QA Glossary

40 CFR 136. Title 40 Code of Federal Regulations, Part 136: Guidelines Establishing Test Procedures for the Analysis of Pollutants. Available at: https://www.ecfr.gov/cgi-bin/text-idx?SID=3cf9acace214b7af340ea8f6919a7c39&mc=true&node=pt40.25.136&rgn=div5 (accessed 26 Feb. 2020).

Ecology, 2004. Guidance for the Preparation of Quality Assurance Project Plans for Environmental Studies. Washington State Department of Ecology, Olympia, WA. Available at: https://fortress.wa.gov/ecy/publications/SummaryPages/0403030.html (accessed 6 Mar. 2020).

Gilbert, R.O., 1987. Statistical Methods for Environmental Pollution Monitoring. Van Nostrand Reinhold, New York, NY.

Kammin, W., 2010. Definition developed or extensively edited by William Kammin, 2010. Washington State Department of Ecology, Olympia, WA.

USEPA, 1992. Guidelines for exposure assessment. U.S. Environmental Protection Agency, Risk Assessment Forum, Washington, D.C. EPA/600/Z-92/001. Available at:

https://www.epa.gov/sites/production/files/2014-11/documents/guidelines_exp_assessment.pdf (accessed 26 Feb. 2020).

USEPA, 2001. EPA Requirements for Quality Assurance Project Plans, EPA QA/R-5. U.S. Environmental Protection Agency, Washington, DC. EPA/240/B-01/003. Available at: https://www.epa.gov/quality/epa-qar-5-epa-requirements-quality-assurance-project-plans (accessed 26 Feb. 2020).

USEPA, 2006. Guidance on Systematic Planning Using the Data Quality Objectives Process EPA QA/G-4. U.S. Environmental Protection Agency, Washington, DC. Available at: https://www.epa.gov/sites/production/files/2015-06/documents/g4-final.pdf (accessed 26 Feb. 2020).

USEPA, 2009. Guidance for Labeling Externally Validated Laboratory Analytical Data for Superfund Use, OSWER No. 9200.1-85, EPA 540-R-08-005. U.S. Environmental Protection Agency, Washington, DC. Available at: https://www.epa.gov/nscep.

USEPA, 2014. Compendium: Project Quality Assurance and Quality Control: Chapter 1. U.S. Environmental Protection Agency, Washington, DC. SW-846 Update V. Available at: https://www.epa.gov/sites/production/files/2015-10/documents/chap1_1.pdf (accessed 26 Feb. 2020).

USEPA, 2016. Definition and Procedure for the Determination of the Method Detection Limit, Revision 2. EPA 821-R-16-006. U.S. Environmental Protection Agency, Washington, DC. Available at: https://www.epa.gov/sites/production/files/2016-12/documents/mdl-procedure_rev2_12-13-2016.pdf (accessed 6 Mar. 2020).

USEPA, 2020. Glossary: Environmental Sampling and Analytical Methods (ESAM) Program. U.S. Environmental Protection Agency, Washington, DC. Available at: https://www.epa.gov/esam/glossary (accessed 26 Feb. 2020).

USGS, 1998. Principles and Practices for Quality Assurance and Quality Control. Open-File Report 98-636. U.S. Geological Survey, Reston, VA. Available at: https://pubs.usgs.gov/of/1998/ofr98-636/ (accessed 26 Feb. 2020).

WAC 173-50-040. Title 173 Washington Administrative Code. Accreditation of Environmental Laboratories: Definitions. Available at: https://apps.leg.wa.gov/WAC/default.aspx?cite=173-50-040 (accessed 26 Feb. 2020).