Hood River Tributaries Instream Flow Study

Presented To:
Hood River County
601 State Street
Hood River, OR 97031

Submitted On:
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Executive Summary

These instream flow studies established the relationship between an index of fish habitat suitability (Area Weighted Suitability, AWS) and stream flow. The Hood River Tributaries: Neal Creek, Green Point Creek, West Fork Hood River, and East Fork Hood River are included in this report. The AWS for the species and life-stages of interest were combined with the historical and potential future changes in flow over time creating habitat time series. The habitat time series enables stakeholders to compare future climate-modified habitat time series with the historical record and make proactive decisions on managing the resource.

The Hood River County Water Planning Group (HRWPG) engaged Normandeau to conduct the instream flow studies in conjunction with a water resource model to determine the impacts of potential future climate-modified scenarios on salmonid habitat in the Hood River Tributaries. Normandeau conducted standard PHABSIM instream flow studies on one mile reaches in each of the tributaries with two reaches in the East Fork Hood River. The studies included stakeholder involvement, habitat mapping, transect selection and placement, habitat suitability criteria (HSC) development, hydraulic field measurement, simulation, and habitat modeling. The body of this report includes the methodology, summary results, and example comparisons. The detailed results are included in the Appendices. Annexes A and A1 include additional background about the HSC. There are 390 habitat time series. These are included in Annexes B1-B5 in user interactive Excel workbooks, one file for each reach. These Excel files are intended as the primary tool to compare the habitat time series.

Normandeau collaborated with Dr. Koehler of Visual Analytics on a novel method of presenting habitat time series, using raster plots for viewing and understanding the data. In addition to the standard habitat duration graphs, the final presentation (Annex C) included raster plots of the climate modified flow scenarios, and habitat time series for the East Fork Hood River. The user can toggle between raster plots in presentation mode to visually compare the historical and future scenarios enabling a detailed depiction of the impacts. This method can be useful in identifying habitat bottlenecks.

The AWS for the East Fork Hood River indicated lower flow suitability for adult and juvenile salmonids than previous studies. Annex A1 presents additional analysis of the hydraulic character of the East Fork and Annex D is a letter from the Hood River Production Program (Oregon Department of Fish and Wildlife and Confederated Tribes of the Warm Springs) detailing their concerns with the lower AWS. Habitat mapping of the entire stream sections in addition to the one mile reaches mapped for this study will indicate if the reaches are representative or if additional transects could be added to increase the accuracy of the fish habitat model.

Acronyms and Abbreviations

ADCP Acoustic Doppler Current Profiler

AWS Area Weighted Suitability (current name for WUA)

BOR Bureau of Reclamation

CTWS Confederated Tribes of the Warm Springs

HRCWPG Hood River County Water planning Group

HSC Habitat Suitability Criteria

IFG Instream Flow Group

MFID Middle Fork Irrigation District

ODFW Oregon Department of Fish and Wildlife

PHABSIM Physical Habitat Simulation model developed by the U.S. Fish and Wildlife Service

RHABSIM Riverine Habitat Simulation software conversion and enhancement of PHABSIM by TRPA, currently Normandeau Associates

SEFA System for Environmental Flow Analysis, software enhancing the capabilities of RHABSIM, RYHABSIM, and PHABSIM developed by T. Payne, I. Jowett, and B. Milhouse.

TRPA Thomas R. Payne and Associates

WDFW Washington Department of Fish and Wildlife

WSEL Water Surface Elevation

WUA Weighted Usable Area, a Habitat Index (old name for AWS)

Introduction

The Hood River County Water planning Group (HRCWPG) is developing a water resource model as a tool to assist in the long-term management of water in the Hood River Basin. Components of the water resource model account for inflows, outflows, and changes in hydrology due to climate change. In order to provide model assessment of fish habitat, Normandeau was contracted to develop an index relationship of hydraulic fish habitat to flow in various tributaries to the Hood River.

Normandeau conducted an instream flow study in each of the Hood River Tributaries: East Fork Hood River, West Fork Hood River, Neal Creek, and Green Point Creek. The objective of the instream flow study was to determine the incremental relationship between stream flow and an index to physical habitat availability, commonly called weighted usable area (WUA) and more recently called area weighted suitability (AWS, Jowett et.al. 2014), for the species and life stages of interest.

The standard approach to instream flow analysis since 1980 has been the Instream Flow Incremental Methodology (IFIM). The IFIM is a structured habitat evaluation process initially developed by the Instream Flow Group of the U.S. Fish and Wildlife Service (USFWS) in the late 1970's to allow evaluation of alternative flow regimes for water development projects (Bovee and Milhous 1978; Bovee et al. 1998). Techniques used in the IFIM process have continued to evolve since its introduction (Bovee and Zuboy 1988; Bremm 1988; Payne 1987, 1988a, 1988b, 1992). Improvements have been made in the in the approaches to defining study reaches (Morhardt et al. 1983), in transect selection (Payne 1992), and in the techniques of PHABSIM data collection, computer modeling, and analysis (Milhous et al. 1984). The IFIM may involve multiple scientific disciplines and stakeholders, in the context of which physical habitat simulation (PHABSIM) studies are usually designed and implemented. Normandeau utilized PHABSIM for the instream flow model in each of the reaches.

Study Area

The study area was in Hood River County, Washington and included approximately one mile long reaches in the West Fork Hood River, Green Point Creek, and Neal Creek and two approximately one mile long reaches in the East Fork Hood River (Figure 1).

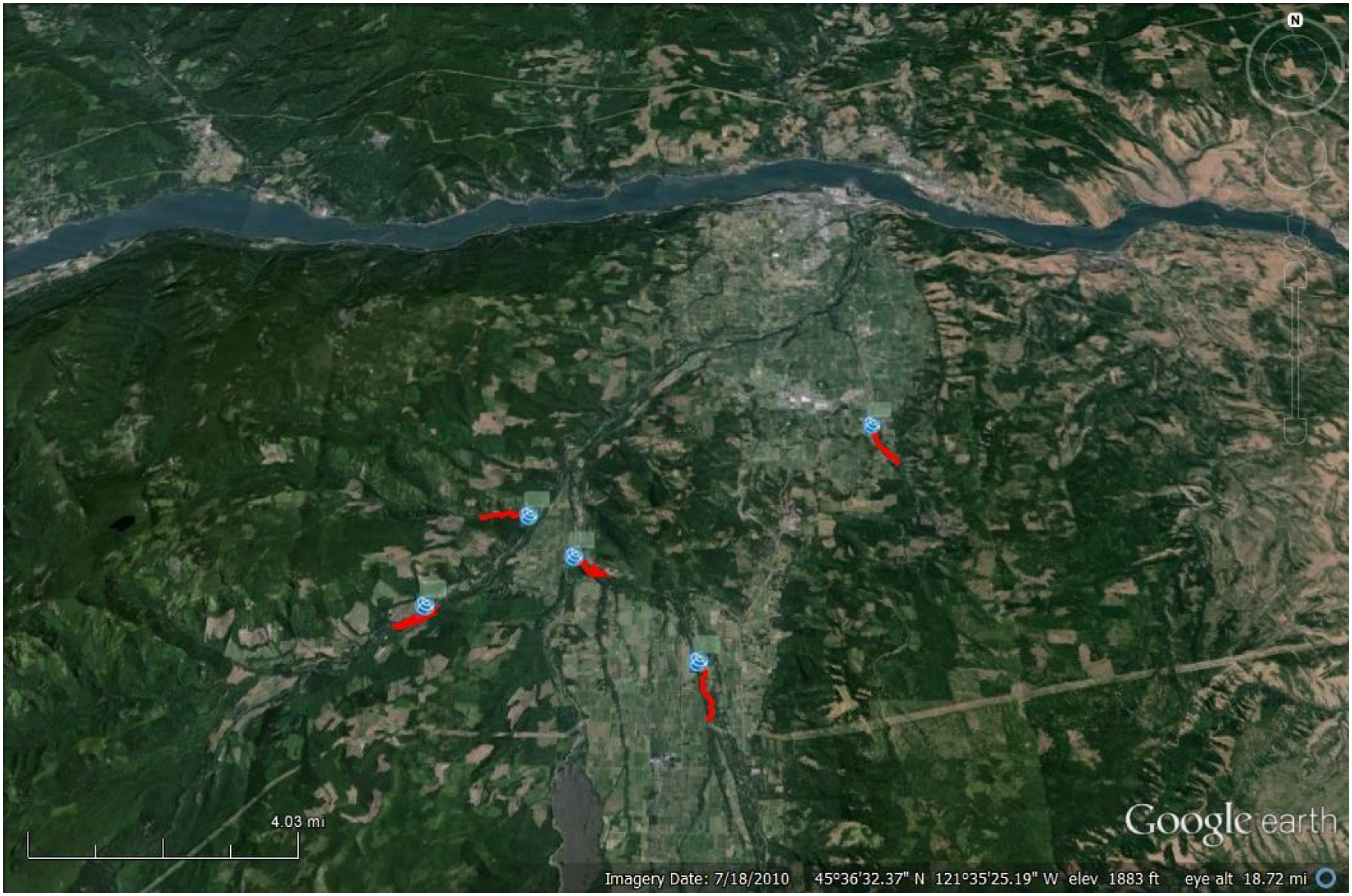


Figure 1. Locations of the Study Reaches on the East Fork and West Fork Hood River, Green Point Creek, and Neal Creek.

Methodology

Development of a relationship between suitable aquatic habitat and river flow for selected species and life stages within the IFIM/PHABSIM framework depends on the measurement or estimation of physical habitat parameters (depth, velocity, substrate/cover) within the study reach. Generally, the distribution of these parameters at given river flows are determined at points along transect lines across the stream channel, positioned to account for spatial and flow-related variability. A variety of hydraulic modeling techniques can be used to simulate water depth and velocity as a function of river flow; substrate and cover values are generally fixed at a given point. With physical habitat thus characterized for a range of river flows, the suitability of the habitat (for a particular species and life stage) at each point is scaled from zero to one, usually by multiplying together the corresponding suitability values for depth, velocity, and substrate from the appropriate habitat suitability criteria (HSC) curves. These point estimates of suitability are then used to weight the physical area of the study represented by each point, and the weighted areas are accumulated for the entire study reach to produce an index of useable habitat as a function of river flow for each species and life stage.

The physical area represented by each transect point depends on the design of the PHABSIM study. This study used the mesohabitat typing, or habitat mapping, approach originally described by Morhardt et al. (1983) and summarized by Bovee et al. (1998). In this design, mesohabitats (broadly defined habitat generalizations) were mapped over the entire study reach, such that each area of the waterway was characterized by a general habitat type, and the total length and proportion of the study reach assigned to each mesohabitat type was determined.

Physical habitat parameters (river flow dependent depth and velocity, substrate, and cover) representative of each mesohabitat type were measured or modeled at one or more transects placed within the mesohabitat area. The exact number and placement of transects placed in a mesohabitat type depended on the proportion of the study reach represented by each mesohabitat type, as well as practical issues such as accessibility. Generally, the total number of transects was distributed among mesohabitat types in proportion to the length of the study reach represented by each mesohabitat. The physical area represented by each transect point was then determined by both the lateral distribution of points on a transect, and the length or proportion of the study reach that each transect represented.

Stakeholder Involvement

Stakeholders, through the HRCWPG, provided input into the selection of study reaches, transect locations, species and life-stages of interest, HSC, and calibration flows, as well as reviewing the AWS curves.

Habitat Mapping

Habitat mapping consists of identifying the type (e.g. pools, runs, and riffles) and measuring the length of individual macrohabitat units over the total distance of stream courses within a project area (Morhardt et al. 1983). The method allows each transect where hydraulic data is collected to be given a weight proportional to the quantity of habitat represented by that transect. Mapping was conducted by walking the stream channel while deploying biodegradable cotton thread from a surveyor's hip chain to measure total distance. The location and length of each individual macrohabitat type was calculated by noting the distance from a downstream base reference point to upstream boundaries. Reference points were marked using surveyor's flagging every 500 feet (generally at the nearest hydraulic control) as well as GPS waypoints. These marks serve as temporary and fixed, known reference points from which to relocate specific habitat units or other features of interest during the stream studies. Other information noted during the mapping process included estimating the maximum depth for each pool habitat, and determining whether a unit could be hydraulically modeled.

Normandeau conducted habitat mapping in the five, one-mile reaches using the ODFW Aquatic Inventories Project Methods for Stream Habitat Surveys (ODFW 2010) as a guide. The basic survey included identifying habitat types, habitat unit lengths and widths, maximum depth and general substrate and riparian characteristics. Generally, for a PHABSIM study, only habitat type unit lengths and depths (pools) are used as a basis for selecting transects and weighting of the habitat model.

The mapping information was used to determine the percentages of various macrohabitats, assist with selection of study sites, and placement of transects for the hydraulic data collection. Each habitat unit was also evaluated for appropriateness for PHABSIM modeling. Such conditions that prohibit satisfactory hydraulic simulation included complex hydraulic conditions associated with strongly transverse flow conditions, plunge pools, or unique split channel configurations. Potentially dangerous and unsafe habitat units, such as those near dangerous falls or cascades, were also identified for subsequent elimination as candidates for hydraulic modeling.

The individual macrohabitat identifications and distances were entered into a database program to create a sequential map of habitat units along the entire length of stream that was surveyed. The database allowed for the computation of the percent abundance of any macrohabitat type within the entire study area or within designated reaches. The mapping data and location markers aided in the relocation of individual habitat units for subsequent inspection and transect selection.

PHABSIM: Transect Selection and Installation

Habitat mapping forms the basis for transect selection. Percent contribution of individual habitat types to total habitat is derived from the total length of a given reach. The PHABSIM habitat analysis relies upon hydraulic conditions measured along stream cross sections, or transects, placed in a variety of different macrohabitats. Habitat unit selection and transect placement was conducted by Normandeau study leads in conjunction with the HRCWPG and

ODFW. Actual habitat unit selection and transect placement was accomplished with a combination of random selection and professional judgment through the following procedure:

1. The macrohabitat type with the lowest percentage of abundance within each study segment was used as the basis for random selection (provided that the habitat type was ecologically significant and made up greater than 5% of the total study reach) and sequentially numbered. Several units were be selected by random number.

2. In the field, the first selected unit was relocated and, if it was modelable, reasonably typical, and it appeared safe to collect hydraulic data during high flows, a transect was placed that would best represent the habitat type. The second or higher randomly selected units were used only if initial units were rejected.

3. At least one example of each remaining more-abundant habitat type was then located in the immediate vicinity of the random transect (upstream or downstream) until the additional study transects were placed in other macrohabitat units. This created a study site and transect "cluster", which reduced data collection travel time.

Calibration Flows

Calibration flows are the flows at which water surface elevations and velocities are measured and from which the model simulations are built. A total of three sets of calibration flow measurements, high, middle and low were made at each transect. Generally the simulations will be valid for a range of flows from forty percent of the low calibration flow to 250 percent of the high calibration flow. Velocities at each transect station were measured at the highest safe calibration flow. In the case of unregulated rivers, such as the streams in this study, calibration flow targets were identified, but the measurements were opportunistic depending on the weather during the sampling period.

Field Data Collection

Water Surface Elevation and Velocity Measurements

One complete set of depths and velocity measurements was collected at each transect at the middle flow or the flow level that could be effectively and safely measured. Data was collected using wading/velocity measurement techniques at shallow habitats, and an acoustic Doppler current profiler (ADCP) mounted on a rigid trimaran in deep pool habitats. The TRDI Rio Grande 1200kHz ADCP sends and receives acoustic pulses in order to measure the Doppler shift and phase change of the echoes to calculate depth and velocity patterns. Additional measurements of water surface elevation for each transect and a single discharge measurement (per transect cluster) were made at the middle and low flow levels.

The amount and type of data collected is suitable for use in a hydraulic simulation with the PHABSIM computer model in the one-velocity mode for the entire range of flows (Payne 1987). The one-flow model of PHABSIM has been shown to calculate habitat values very close to those obtained with three full sets of depth and velocity data (Payne 1988b).

Field data collection and the form of data recording basically followed the guidelines established in the IFG field techniques manuals (Trihey and Wegner 1981; Milhous et al. 1984; Bovee 1997). Additional quality control checks that have been found valuable during previous applications of the simulation models were employed. The techniques for measuring discharge generally followed the guidelines outlined by Rantz (1982). A minimum of 20 wetted stations per stream transect were be established, with a goal of no less than 15 wetted stations at the lowest measured flow. The boundaries of each station along each transect were normally at consistent increments, but significant changes in velocity, substrate, depth, or other important stream habitat features sometimes required additional stationing.

Substrate and Cover Characterization

Substrate and cover attributes and codes used in this study are described in Tables 1 and 2.

Table 1. Substrate size and codes.

Substrate Type	Size	Code
Silt, clay, organic		1
Sand		2
Small gravel	0.1 – 0.5 “	3
Medium gravel	0.5 – 1.5 “	4
Large gravel	1.3 – 3 ”	5
Small cobble	3 – 6 “	6
Large cobble	6 – 12 “	7
Boulder	> 12”	8
Bedrock		9

Table 2. Cover types and codes.

Cover Type	Code
Boulder	1
Cobble	2
Cobble + Log	3
Boulder + Log	4
Boulder + Rootwad	5
Log	6
Logs	7
Log + Rootwad or Logjam	8
None (Depth <6.5 ft.)	9
None (Depth ≥6.5 ft.)	9.65
Undercut bank	10
Overhanging Vegetation	11
Terrestrial Vegetation	12
Roots	13
Woody Debris	14

Quality Assurance/Quality Control

To assure quality control in the collection of field data, the following data collection procedures and protocols were utilized:

Staff gauges were established and continually monitored throughout the course of collecting data. If significant changes occurred, water surface elevations were re-measured following collection of transect water velocity data.

Independent benchmarks were established for each set of transects. The benchmark was an immovable tree, boulder, or other naturally occurring object not subject to tampering. Upon establishment of headpin and tailpin elevations, a level loop was shot to check the auto-level instrument for accuracy. Acceptable error tolerances on level loop measurements were set at 0.02 feet. This tolerance was also applicable to both headpin and tailpin measurements, unless extenuating circumstances (e.g., pins under sloped banks, shots through dense foliage) accounted for the discrepancies, and the accompanying headpin or tailpin met the tolerance criteria.

Water surface elevations were measured on both banks on each transect. If possible, on more complex and uneven transects, such as riffles, water surface elevations were also measured at multiple locations across a transect. An attempt was made to measure water surface elevations at the same location (station or distance from pin) across each transect at each calibration flow. Water surface elevation measurements were obtained by placing the bottom of the stadia rod at the water surface until a meniscus formed at the base or selecting a stable area next to the water's edge.

Pin and water surface elevations were calculated on-site during field measurement and compared to previous measurements. Changes in stage since the previous flow measurement were calculated. Patterns of stage change were compared between transects and determined if reasonable. If any discrepancies were discovered, potential sources of error were explored, corrected where possible, and noted.

The ADCP was used to collect water velocity data from stations along each transect where wading was not possible. High-quality and well-maintained current velocity meters were used to collect velocities of shallower, edge cell velocity data.

Prior to deployment, the ADCP was system checked, compass calibrated, moving bed test performed, and user configured for each individual transect with appropriate commands for the existing environmental conditions. Often several transect measurements were necessary to obtain the optimum configuration. Each transect measurement length and discharge calculation was compared to the actual values or to repetitive measurements in order to ensure accurate bottom tracking and velocity measurements. Real time graphic depictions of depth and velocity were examined during data collection for inconsistencies and obvious errors. As a precaution against data loss, all electronic data files were copied onto a separate USB drive at the end of each field day.

All calculations were completed in the field, given adequate time and daylight. Pin elevations and changes in water surface elevations were compared between flows on the same transect. Discharges were calculated on-site and were compared between transects during the same flow (high, mid, and low). If an excessive amount of discharge (greater than 10% of the stream flow) was noted for an individual transect cell, additional adjacent stations were established to more precisely define the velocity distribution patterns at that portion of the transect.

Photographs were taken of all transects, downstream, across, and upstream at the three calibration flows. Photographs were taken from the same location at each of the flows, if possible. Photographs provided a valuable record of physical conditions and water surface levels that were utilized during hydraulic model calibration.

All data (stationing, depth profiles, velocities, substrate/cover codes) were entered into the RHABSIM computer files. Internal data graphing routines were then used to review the bottom and velocity profiles for each transect separately and in context with others for quality control purposes. All data gaps (e.g., missing velocities) or discrepancies (e.g., conflicting records) were identified and corrected using available sources, such as field notes, photographs, or adjacent data points.

Transect Weighting

The number of transects selected for each habitat type was determined by the percentage of the study reach represented by each habitat type. In this way each habitat type was represented approximately in proportion to that which was mapped. Each transect was then weighted so that each habitat type was represented in the exact proportion to that existent in the study area.

Hydraulic Simulation

The purpose of hydraulic simulation under the PHABSIM framework is to simulate depths and velocities in streams under varying stream flow conditions. Simulated depth and velocity data were then used to calculate the physical habitat, either with or without substrate and/or cover information. All data was entered into the RHABSIM software used for this analysis.

Water Surface Prediction

The water surface elevations, in conjunction with the transect profiles, were used to determine water depths at each flow. Water depth is an important parameter for determining the physical habitat suitability. Either an empirical log/log regression formula of stage and flow based on measured data or a channel conveyance method (MANSQ) that relies on the Manning's N roughness equation was used to create the rating curves.

The log/log regression method uses a stage-discharge relationship to determine water surface elevations. Each cross section is treated independently of all others in the data set. A minimum of three stage-discharge measurement pairs were used to calibrate the stage-discharge relationship. The quality of the rating curves is evaluated by examination of mean error and slope output from the model. Mean errors of less than 10% is considered acceptable and less than 5% is very good. In general the slope between groups of transects should be similar.

MANSQ only requires a single stage-discharge pair and utilizes Manning's equation and channel shape to determine a rating curve; however, it is generally validated by additional stage-discharge measurements. This modeling method involves an iterative process where a beta coefficient is adjusted until a satisfactory result is obtained. In situations where irregular channel features occur on a cross section, for instance bars or terraces, MANSQ is often better at predicting higher stages than log/log. MANSQ is most often used on riffle or run transects and is generally not considered as effective in establishing a rating curves for transects that have backwater effects from downstream controls, such as pools. It can also be useful as a test and verification of log/log relationships.

Velocity Simulation

Simulated velocities were based on measured data and a relationship between a fixed roughness coefficient (Manning's n) and depth. In some cases roughness is modified for individual cells if substantial velocity errors are noted at simulation flows. Velocity Adjustment Factors (VAF's), the degree in which measured velocity and discharge is adjusted to simulated velocity and simulated discharge are an indication of the quality of hydraulic simulations. These are examined to detect any significant deviations and determine if velocities remained consistent with stage and total discharge. VAF's in the range of 0.8 to 1.2 at the calibration (measured) flow are considered acceptable, 0.95 to 1.05 is considered excellent.

Habitat Suitability Criteria

Method of Selection

Habitat Suitability Criteria (HSC) define the habitat requirements of the species/life-stages of interest. If no site specific HSC are developed, HSC are selected from the plethora of curves developed for other studies. Not all HSC are transferable from one stream to another. For example, HSC developed for *O. mykiss* inhabiting a small mountain stream upstream of an impassable barrier do not define the habitat requirements of steelhead in a large river. Likewise, habitat requirements vary with the life-stage of each species and HSC are typically specified for each life-stage. Although there are many HSC available, care must be taken to establish transferability by examining the source metrics (e.g. river size, geographic location, number of observations, etc.).

The results of a PHABSIM instream flow study are determined by both the hydraulic data collected and the HSC selected. Since the results of this PHABSIM study will be used in the BOR water resource model along with the results of the Middle Fork Hood IFIM Study (Watershed Professionals Network), it is important to use consistent HSC.

The method for selecting HSC for this PHABSIM study was:

1. Appropriate Middle Fork HSC (Watershed Network Professionals unpublished draft data) for the species/life-stages that were modeled in that study were also used in this study. The MFID HSC were compared to other HSC for informational purposes.
2. Additional HSC were selected based on literature and professional judgment.

Annexes A and A1 discuss the development of the HSC.

Target Species

Species and life stages selected for habitat modeling are presented in Table 3.

Table 3. Target species and life stages selected for modeling in each of the five stream reaches.

Species	Life Stage	Stream Reach				
		EF-Upper	EF-Lower	West Fork	Green Point	Neal Creek
Bull trout	Juvenile rearing			X		
	Adult rearing			X		
	Spawning			X		
Coho	Fry	X	X	X	X	X
	Juvenile rearing	X	X	X	X	X
	Adult holding	X	X	X	X	X
	Spawning	X	X	X	X	X
Cutthroat trout	Juvenile rearing	X	X	X	X	X
	Adult rearing	X	X	X	X	X
	Spawning	X	X	X	X	X
Spring Chinook	Fry	X	X	X	X	X
	Juvenile rearing	X	X	X	X	X
	Adult holding	X	X	X	X	X
	Spawning	X	X	X	X	X
Steelhead	Fry	X	X	X	X	X
	Juvenile rearing	X	X	X	X	X
	Adult holding	X	X	X	X	X
	Spawning	X	X	X	X	X

Habitat Simulation

Combining the hydraulic and HSC components generates the habitat suitability (AWS/WUA) index. Unlike hydraulic modeling and calibration, there are a limited number of decisions to make prior to production runs. Transects are weighted according to the percentage of habitat types present in the reach. The range of flows to model, and specific flows within that range, are determined largely by the suitability of the hydraulic data for extrapolation and general flows of interest. Generally the range of flows of interest are those mandatory either as minimum standards or seasonal requirements, but can also be based on natural flows. The habitat index was computed based on a multiplicative procedure:

$$Ci = Vi * Di * Si$$

Where:

Ci = Cell suitability composite index value
Vi = Velocity suitability value associated with cell
Di = Depth suitability value associated with cell
Si = Substrate or other channel suitability value associated with cell

The cell composite number is then multiplied by the cell width to produce number of square feet of area in that cell. For each transect, all the cells' areas are summed to produce a total number of square feet of usable habitat available at a specified flow. This result is then multiplied by the percentage the individual transect represents as a proportion of all transects being modeled. All transect results are then summed to produce overall habitat suitability in square feet.

Time Series Analysis

Utilization and interpretation of habitat modeling output, namely habitat index curves, presents a challenge from both a technical and functional perspective. The habitat versus flow relationships derived from PHABSIM represent a conceptual association between flow and habitat. Though some basic inference can be made from this relationship, evaluation without incorporating flow regimes can lead to erroneous interpretations. This analysis is particularly valuable when considering a suite of species and life stages with varying habitat versus flow relationships, and instances when known life history needs may not be directly exhibited in the habitat versus flow relationship output from PHABSIM.

The tendency to look at the maximum or "peak" of a habitat index curve greatly oversimplifies the results. For example, maximum spawning habitat may occur at a flow that rarely exists in a given reach. Additionally, the amount of habitat can be the same at two flows, one lower and one higher than the maximum (Figure 2). Because the amount of habitat available at any given time of year is a function of hydrology, incorporating a time-series analysis provides a more realistic view of available habitat. Such an analysis is important when determining effects of different flow regimes that may result from changes in water usage. Times series involves matching the habitat index for a given species or life stage to flow, as illustrated in Figure 3.

The major basis for habitat time series analysis is that habitat is a function of stream flow and that stream flow varies over time. Habitat time series displays the temporal habitat change for a particular species and life stage during selected seasons or critical time periods under various flow scenarios. Typically results are represented by habitat duration curves indicating the quantity of habitat that is equaled or exceeded over the selected time period.

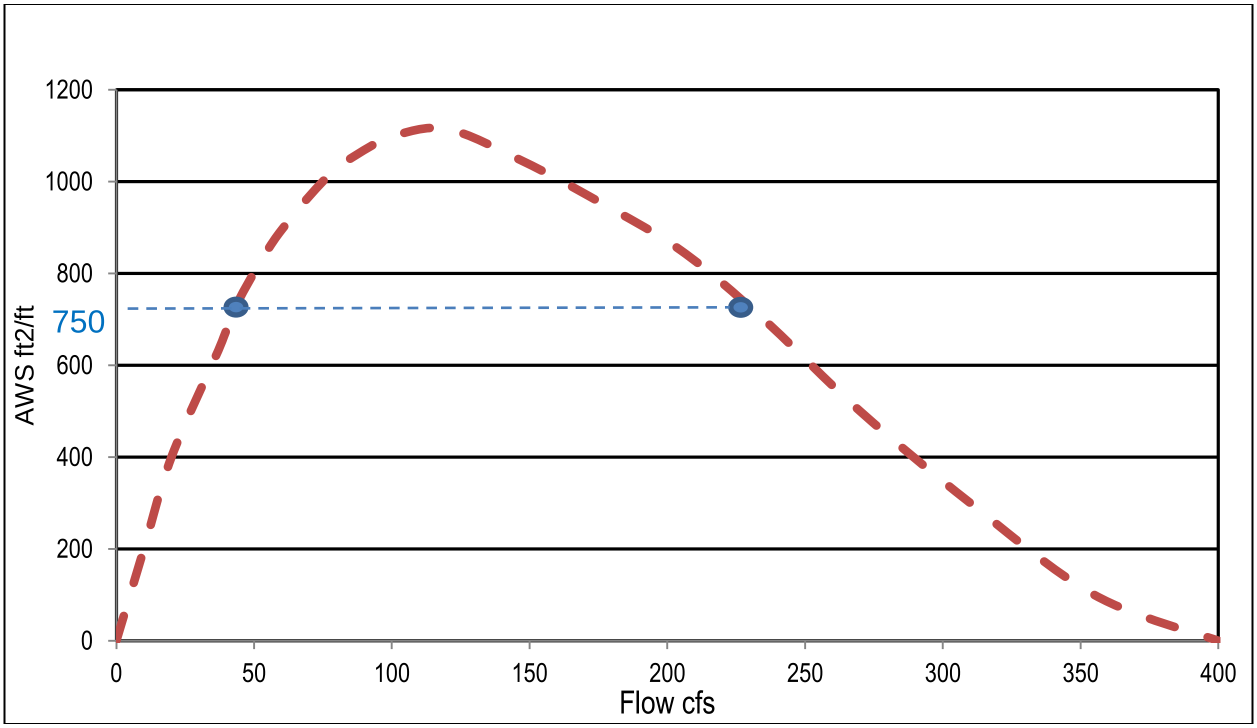


Figure 2. Generic habitat index curve illustrating equal AWS values at two different flows.

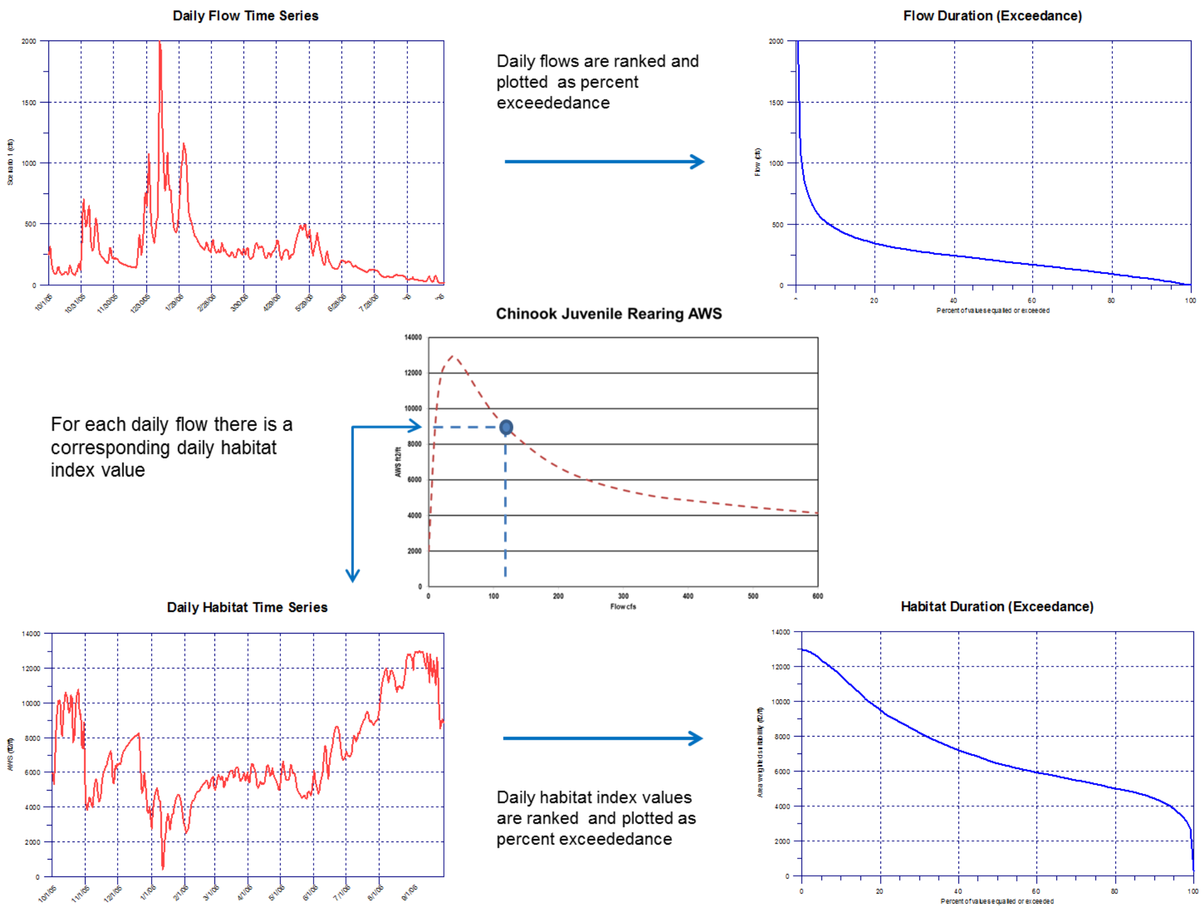


Figure 3. Time series process.

Results

Habitat Mapping

Habitat mapping was conducted on the five study reaches between September 19 and September 22, 2012. The following provides a brief overview of Habitat Mapping results by reach. Habitat unit types collected in the field were based on the ODFW Basic Level Stream Survey. These types were condensed into slow water types (pools) and fast water types which includes glide, riffle (low gradient), rapid (high gradient riffle) and cascade as per ODFW optional types. Complete Habitat Mapping summaries and database are provided in Appendix A.

Green Point Creek

Riffles and cascades were the dominant habitat type in Green Point Creek accounting for 68% of the reach followed by pools at 22% and glides at 8% (Table 4).

Table 4. Habitat mapping summary for Green Point Creek.

Habitat Type	*Number of Units*	*Length Feet*	*Length Percent*
Pool	45	1329	22.4
Glide	14	494	8.3
Low Gradient Riffle	38	2098	35.3
High Gradient Riffle	14	809	13.6
Cascade	25	1112	18.7
Other	12	103	1.7
Totals	148	5945	100.0

Neal Creek

Habitat Mapping results for Neal Creek show a dominance of low gradient riffle (66%) and an equal proportion of glide and pool accounting for 16% each (Table 5).

Table 5. Habitat mapping summary for Neal Creek

Habitat Type	*Number of Units*	*Length Feet*	*Length Percent*
Pool	40	894	16.0
Glide	33	895	16.0
Low Gradient Riffle	68	3696	66.2
High Gradient Riffle	3	74	1.3
Cascade	0	0	0.0
Other	2	23	0.4
Totals	146	5582	100.0

East Fork Hood River (lower reach)

Habitat Mapping results for this reach show a dominance of riffle types with 50% low gradient riffle and 27% high gradient. Glides only accounted for 2% of the reach (Table 6).

Table 6. Habitat mapping summary for East Fork Hood River (lower).

Habitat Type	*Number of Units*	*Length Feet*	*Length Percent*
Pool	14	702	17.0
Glide	2	89	2.2
Low Gradient Riffle	33	2080	50.4
High Gradient Riffle	15	1111	26.9
Cascade	3	148	3.6
Other	0	0	0.0
Totals	67	4130	100.0

East Fork Hood River (upper reach)

Habitat Mapping results for this reach show a dominance of riffle types with 44% high gradient riffle and 30% low gradient. Glides accounted for 17% of the reach and pools for 9% (Table 7).

Table 7. Habitat mapping summary for East Fork Hood River (upper).

Habitat Type	*Number of Units*	*Length Feet*	*Length Percent*
Pool	13	536	9.2
Glide	16	1020	17.5
Low Gradient Riffle	20	1718	29.4
High Gradient Riffle	23	2557	43.8
Cascade	0	0	0.0
Other	1	10	0.2
Totals	73	5841	100.0

West Fork Hood River

Habitat Mapping results for this reach show a dominance of riffle types with 13% high gradient riffle and 37% low gradient. Glides accounted for 16% of the reach and pools for 28% (Table 8).

Table 8. Habitat mapping summary for West Fork Hood River.

Habitat Type	Number of Units	Length Feet	Length Percent
Pool	13	1452	27.8
Glide	16	821	15.7
Low Gradient Riffle	19	1953	37.4
High Gradient Riffle	9	671	12.8
Cascade	4	327	6.3
Other	0	0	0.0
Totals	61	5224	100.0

Study Site and Transect Selection

Study sites were established by randomly selecting the least available habitat type, locating the habitat unit and placing a transect to represent the unit. Additional transects were then established in other habitat types in the immediate vicinity in general proportion to availability. A total of 7 cross sections were used to represent hydraulic and habitat conditions in each reach (Table 9).

Table 9. Number of transects by habitat type and reach with habitat selector identified (*).

	Number of Transects by Reach and Habitat Type				
Habitat Type	Green Point Creek	Neal Creek	E.F. Hood River (upper)	E.F. Hood River (lower)	West Fork Hood River
Pool	2	2	1*	2*	2
Glide	1*	2*	2	0	2
Low Gradient Riffle	3	3	2	3	2
High Gradient Riffle	1	0	2	2	1*
Cascade	0	0	0	0	0
Total	7	7	7	7	7

Hydraulic Simulation

Field data collection took place between September and December 2012. Low flow was measured in late September in all reaches except Neal Creek, which was deemed to be the approximate middle flow target. Middle flow and velocity acquisition took place in all other reaches in late October and high flow occurred in late November and early December. Transect profiles, calibration velocities, and calibration flow water surface elevation plots are depicted in Appendix B.

Stage-Discharge

Overall, stage-discharge metrics fell well within the bounds of acceptability. All but one transect had a mean error of less than 5 percent for log/log rating curve (Table 10). Measured versus predicted WSL at the three calibration flows were generally less than 0.02 feet (Table 11).

Log/log rating curves were used for all pool transects and most glide transects (Table 10.) MANSQ was used on most riffle transects and some glide transects to correct for small errors at the upper extent of the rating curve?

Velocity

Some adjustments to roughness and Manning's N were made in selected cells to account for unrealistic simulated velocities at high flows. In addition, adjustments were made to edge cells if predicted velocities at higher flows were excessively high (i.e. higher than adjacent cells in the main channel) or remained excessively low.

With few exceptions, VAF's were within 5 percent of the measured flow (Table 10). Three transects, two in Green Point Creek and one in the West Fork had VAF's within 10 percent of the measured flow.

Table 10. Measured flow, calibration flow (velocity acquisition flow), stage-discharge rating curve mean error and method and VAF for transects in five reaches of the Hood River.

Reach	Transect #	Habitat Type	Measured Flow	Calibration Flow	% Mean Error log/log Rating Curve	Final Rating Curve Method	VAF at Calibration Flow
Green Point Creek	1	Glide	73.98	74.0	1.21	Log/Log	1.013
	2	Pool	75.42	74.0	1.06	Log/Log	0.989
	3	LGR	85.51	74.0	3.53	MANSQ	0.991
	4	LGR	81.37	74.0	3.16	MANSQ	0.980
	5	HGR	74.96	74.0	1.32	MANSQ	0.983
	6	LGR	81.84	74.0	0.51	MANSQ	0.907
	7	Pool	66.73	74.0	5.28	Log/Log	1.081
E.F. Hood Upper	1	Pool	149.58	147.45	0.10	Log/Log	0.987
	2	HGR	149.25	147.45	0.47	Log/Log	1.001
	3	HGR	148.73	147.45	1.03	Log/Log	1.047
	4	Glide	146.33	147.45	0.86	Log/Log	1.008
	5	LGR	152.03	147.45	1.81	MANSQ	0.968
	6	LGR	145.63	147.45	0.39	MANSQ	0.998
	7	Glide	142.08	147.45	0.79	Log/Log	1.029
E.F. Hood Lower	1	Pool	151.79	149.26	0.02	Log/Log	1.051
	2	Pool	149.26	149.26	2.01	Log/Log	0.990
	3	LGR	138.61	149.26	3.56	MANSQ	1.032
	4	LGR	151.20	149.26	1.12	MANSQ	1.047
	5	HGR	148.41	149.26	2.53	MANSQ	0.992
	6	LGR	156.40	149.26	0.95	MANSQ	0.968
	7	HGR	158.85	149.26	1.60	MANSQ	0.963
W.F. Hood	1	HGR	113.92	117.0	0.07	MANSQ	1.025
	2	Pool	255.37	250.0	2.97	Log/Log	0.986
	3	Glide	257.40	250.0	2.13	Log/Log	0.971
	4	LGR	246.00	225.0	2.93	MANSQ	0.965
	5	Glide	224.95	225.0	2.51	MANSQ	1.002
	6	Pool	235.43	225.0	0.44	Log/Log	0.985
	7	LGR	116.54	117.0	2.54	MANSQ	1.056
Neal Creek	1	Glide	12.86	12.23	3.19	Log/Log	1.016
	2	LGR	13.21	12.23	2.45	MANSQ	0.962
	3	LGR	13.59	12.23	2.03	MANSQ	0.951
	4	LGR	12.24	12.23	0.49	MANSQ	1.043
	5	Glide	12.63	12.23	0.55	MANSQ	0.975
	6	Pool	12.23	12.23	0.89	Log/Log	1.001
	7	Pool	12.42	12.23	3.64	Log/Log	0.994

Table 11. Measured versus predicted WSL for transects on Green Point Creek

Transect #	Habitat Type	Calibration Flow #	Calibration Flows (cfs)	Calibration WSL	Calculated WSL
1	Glide	1	224.0	98.47	98.48
		2	74.0	97.57	97.56
		3	10.2	96.50	96.50
2	Pool	1	224.0	98.48	98.49
		2	74.0	97.61	97.60
		3	10.2	96.56	96.56
3	LGR	1	224.0	97.70	97.76
		2	74.0	97.02	97.02
		3	10.2	96.13	96.16
4	LGR	1	224.0	98.83	98.81
		2	74.0	98.19	98.19
		3	10.2	97.41	97.40
5	HGR	1	224.0	100.54	100.56
		2	74.0	99.61	99.61
		3	10.2	98.59	98.60
6	LGR	1	224.0	100.56	100.59
		2	74.0	99.66	99.66
		3	10.2	98.76	98.77
7	Pool	1	224	102.12	102.08
		2	74	101.32	101.36
		3	10.2	100.62	100.61

Table 12. Measured versus predicted WSL for transects on E.F. Hood Upper

Transect #	Habitat Type	Calibration Flow #	Calibration Flows (cfs)	Calibration WSL	Calculated WSL
1	Pool	1	355.0	98.37	98.37
		2	147.45	97.53	97.53
		3	92.55	97.18	97.18
2	HGR	1	355	92.38	92.38
		2	147.45	91.92	91.92
		3	92.55	91.71	91.71
3	HGR	1	355.0	93.81	93.81
		2	147.45	93.36	93.34
		3	92.55	93.14	93.14
4	Glide	1	355.0	94.37	94.37
		2	147.45	93.94	93.93
		3	92.55	93.73	93.73
5	LGR	1	355.0	96.21	96.21
		2	147.45	95.59	95.60
		3	92.55	95.35	95.35
6	LGR	1	355.0	95.50	95.50
		2	147.45	94.83	94.83
		3	92.55	94.55	94.55
7	Glide	1	355.0	96.56	96.56
		2	147.45	95.83	95.84
		3	92.55	95.54	95.54

Table 13. Measured versus predicted WSL for transects on E.F. Hood Lower.

Transect #	Habitat Type	Calibration Flow #	Calibration Flows (cfs)	Calibration WSL	Calculated WSL
1	Pool	1	259.3	95.75	95.75
		2	149.3	95.36	95.36
		3	100.5	95.11	95.11
2	Pool	1	259.3	96.87	96.86
		2	149.3	96.43	96.45
		3	100.5	96.21	96.20
3	LGR	1	259.3	94.12	94.12
		2	149.3	93.73	93.77
		3	100.5	93.56	93.56
4	LGR	1	259.3	94.20	94.20
		2	149.3	93.87	93.88
		3	100.5	93.68	93.68
5	HGR	1	259.3	95.53	95.53
		2	149.3	95.04	95.08
		3	100.5	94.80	94.8
6	LGR	1	259.3	99.80	99.80
		2	149.3	99.51	99.50
		3	100.5	99.31	99.31
7	HGR	1	259.3	100.73	100.73
		2	149.3	100.44	100.42
		3	100.5	100.22	100.22

Table 14. Measured versus predicted WSL for transects on W.F. Hood River

Transect #	Habitat Type	Calibration Flow #	Calibration Flows (cfs)	Calibration WSL	Calculated WSL
1	HGR	1	117.0	94.81	94.81
		2	250.0	95.34	95.32
		3	450.75	95.84	95.84
2	Pool	1	117.0	95.34	95.32
		2	250.0	95.97	96.02
		3	450.75	96.74	96.71
3	Glide	1	117.0	96.06	96.05
		2	250.0	96.63	96.66
		3	450.75	97.30	97.28
4	LGR	1	117.0	97.56	97.56
		2	225.0	97.93	97.95
		3	450.75	98.53	98.53
5	Glide	1	117.0	97.91	97.91
		2	225.0	98.30	98.34
		3	450.75	98.92	98.92
6	Pool	1	117.0	97.41	97.41
		2	225.0	97.83	97.91
		3	450.75	98.41	98.41
7	HGR	1	117.0	95.49	95.49
		2	225.0	95.92	95.97
		3	450.75	96.62	96.61

Table 15. Measured versus predicted WSL for transects on Neal Creek.

Transect #	Habitat Type	Calibration Flow #	Calibration Flows (cfs)	Calibration WSL	Calculated WSL
1	Glide	1	30.0	96.71	96.72
		2	12.2	96.44	96.43
		3	6.3	96.25	96.26
2	LGR	1	30.0	94.24	94.24
		2	12.2	93.97	93.96
		3	6.3	93.80	93.80
3	LGR	1	30.0	97.49	97.49
		2	12.2	97.30	97.29
		3	6.3	97.17	97.17
4	LGR	1	30.0	97.87	97.87
		2	12.2	97.64	97.63
		3	6.3	97.50	97.50
5	Glide	1	30.0	98.50	98.50
		2	12.2	98.26	98.26
		3	6.3	98.12	98.12
6	Pool	1	30.0	96.64	96.64
		2	12.2	96.38	96.38
		3	6.3	96.22	96.22
7	Pool	1	30.0	96.66	96.67
		2	12.2	96.41	96.40
		3	6.3	96.23	96.24

Calibration summaries for individual transects are presented in Appendix C and simulated water surface elevations and velocities are presented in Appendix D.

Habitat/Flow Relationship

AWS values in tabular format are presented in Appendix E.

Green Point Creek

Juvenile rearing AWS curves for all species and adult rearing for cutthroat trout show the greatest response at flows less than 100 cfs before a trending downward slightly or remaining flat as flows increase. Fry curves for Chinook, coho, and steelhead exhibit the greatest response at flows between 10 cfs and 25 cfs and maintain a slight downward trend at higher flows. The most suitable flows for Chinook and steelhead spawning occur between 150 cfs and 300 cfs and for coho spawning between 150 cfs and 400 cfs. Cutthroat spawning is most suitable at flows between 100 cfs and 200 cfs (Figures 4-5).

Neal Creek

Juvenile and adult rearing AWS curves for all species are relatively flat indicating that flow does not have an effect on habitat suitability. Fry curves for Chinook and coho exhibit a trend upward from the lowest to highest simulated flows, a product of low velocities being maintained near the banks due to vegetation. Chinook and steelhead spawning curves reach maximum suitability between 20 and 40 cfs and remain relatively flat through the highest simulated flow (Figures 6-7).

East Fork Hood River (upper reach)

AWS curves for juvenile rearing and fry for all species, and adult rearing for cutthroat trout decline sharply between the lowest simulated flow and approximately 400 cfs. Chinook, coho and steelhead spawning AWS is highest between 100 cfs and 200 cfs, and then drops until 400 cfs before maintaining a flat response. The cutthroat spawning curve shows most suitable habitat at the lowest flows then becomes flat up to 600 cfs before declining (Figures 8-9).

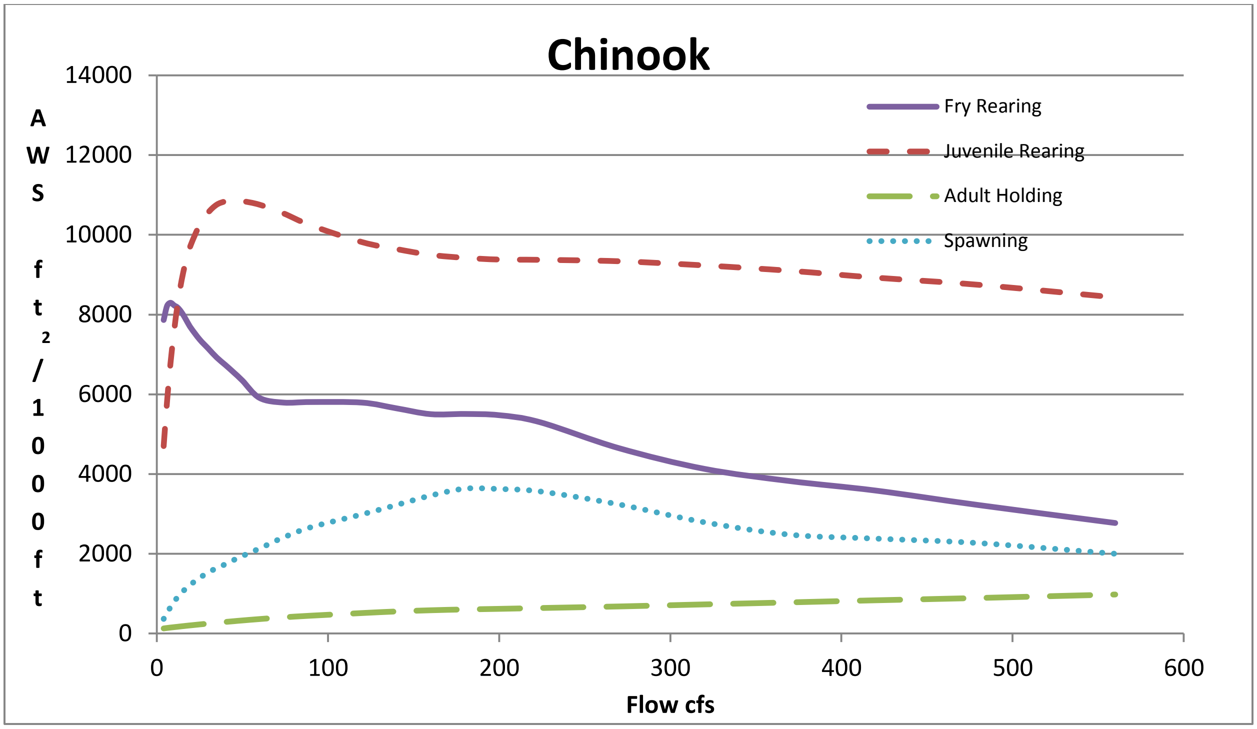
East Fork Hood River (lower reach)

Juvenile rearing, with the exception of coho, show maximum suitability between 50 and 150 cfs before declining. Fry (Chinook, coho and steelhead) decline from lowest flows to approximately 200 cfs before remaining flat. Coho juveniles show a relatively flat response, likely due to the inclination for slow velocities which are only maintained along the margins as flows increase. Chinook, coho and steelhead spawning suitability is maximized between 50 and 300 cfs. The cutthroat spawning curve shows most suitable habitat at the lowest flows then declines to 200 cfs before becoming flat (Figures 10-11).

West Fork Hood River

Juvenile rearing AWS varies between species. Chinook curves show maximum suitability for flows between 100 cfs and 350 cfs. Steelhead juvenile rearing increases from low flows, with the greatest suitability between 200 cfs and 400 cfs, then remain relatively flat. Cutthroat juvenile and adult trend slightly upward with increasing flows while bull trout juvenile rearing show a gradual decline and the adult curve is flat. Coho suitability is greatest at low flows then drops slightly as flows increase, though the curve is essentially flat past 200 cfs. Fry rearing for all species declines as flows increase.

Spawning AWS curves for Chinook, coho and steelhead are similar with abrupt increases from low flows to maximum suitability at 200-400 cfs for Chinook, 100-350 cfs for coho and 150-450 cfs for steelhead. Spawning suitability for bull trout and cutthroat is highest at flows less than 200 cfs, and declines gradually as flow increase (Figures 13-14).



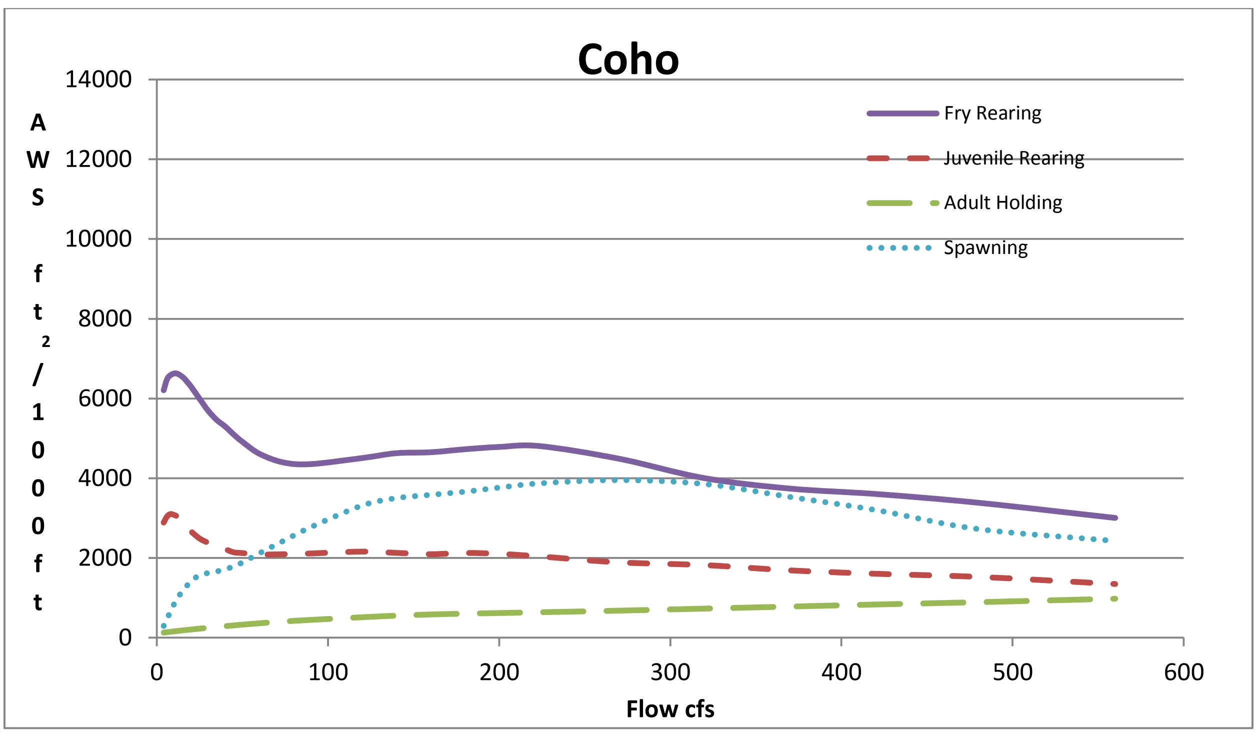
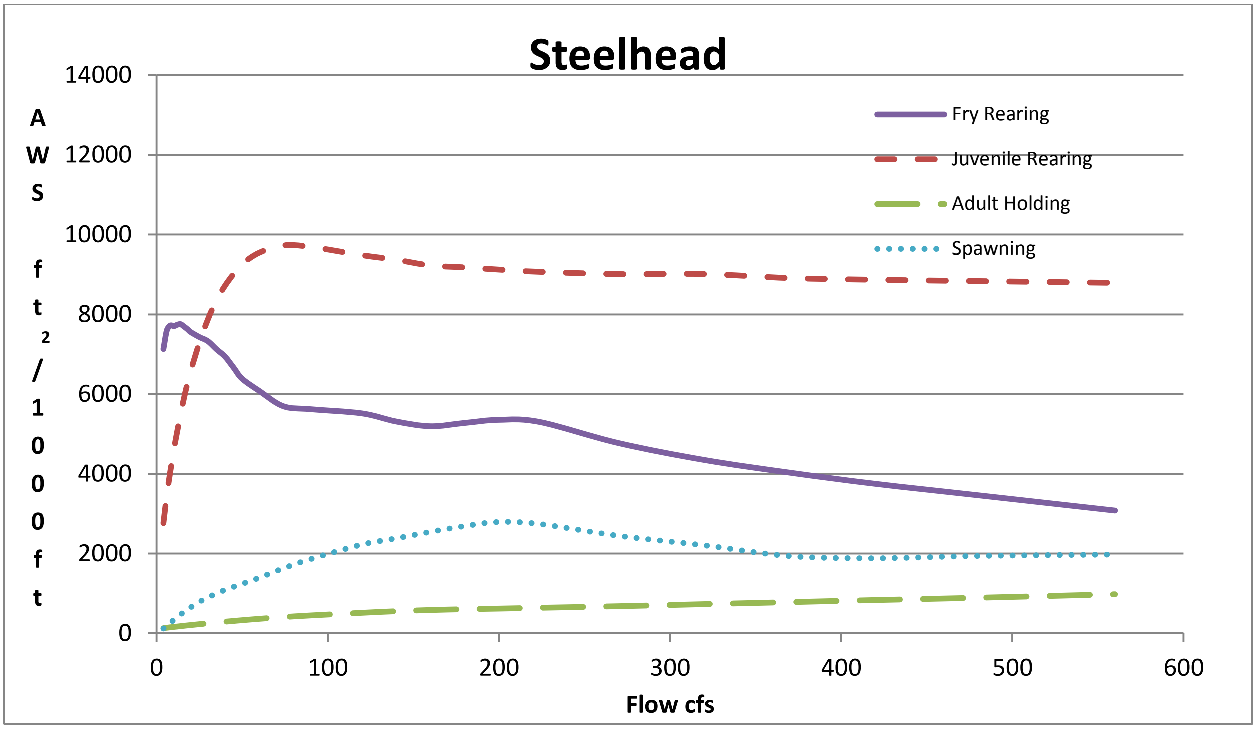


Figure 4. Chinook and coho AWS curves for Green Point Creek.



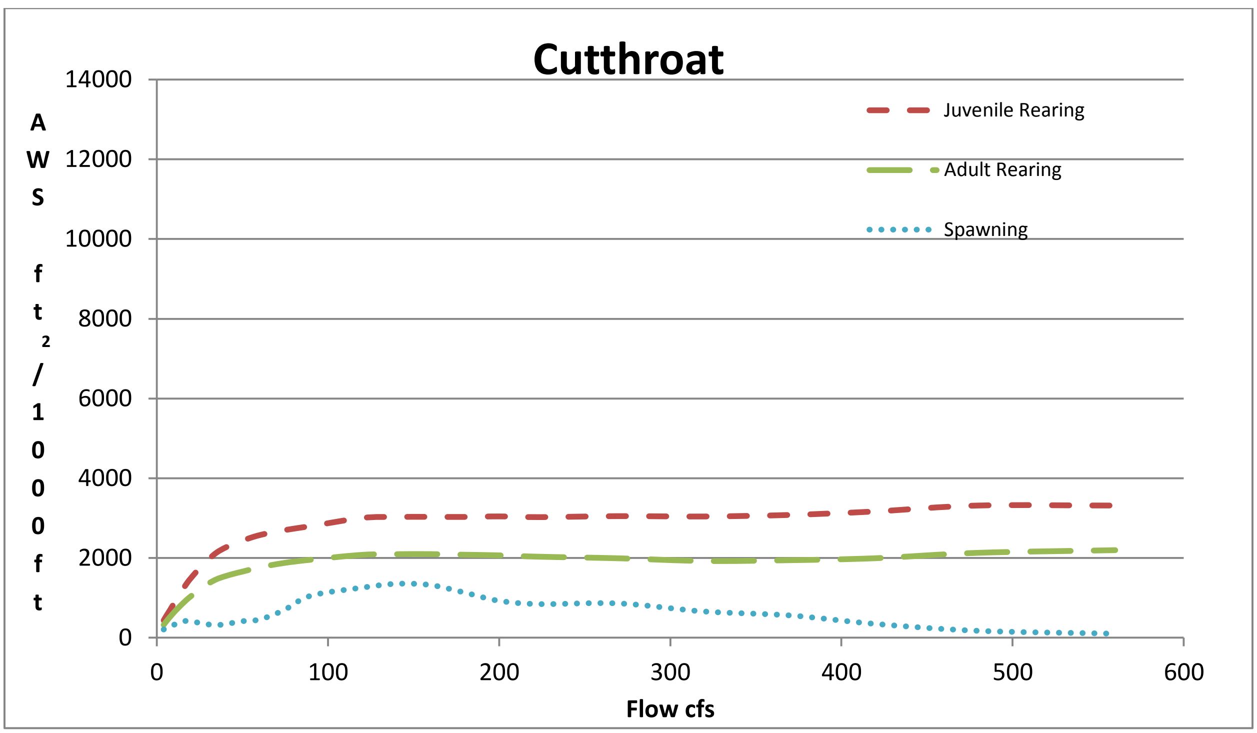
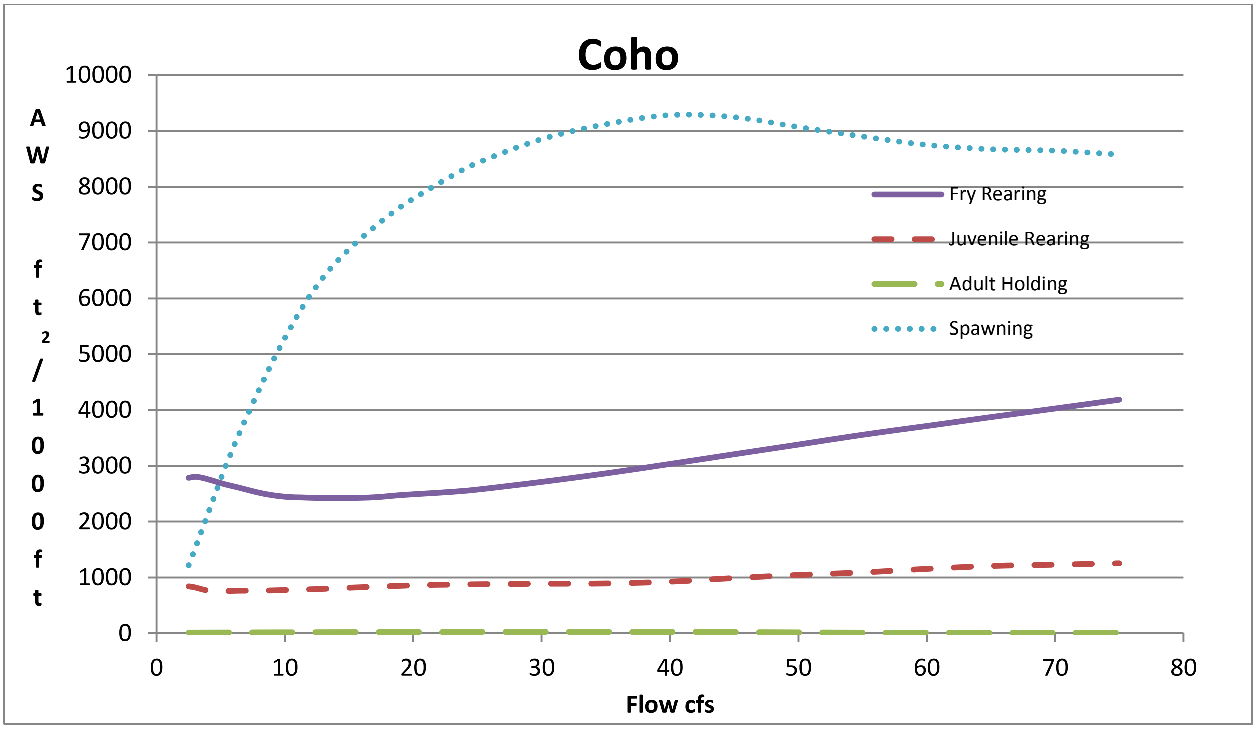


Figure 5. Steelhead and cutthroat AWS curves for Green Point Creek.



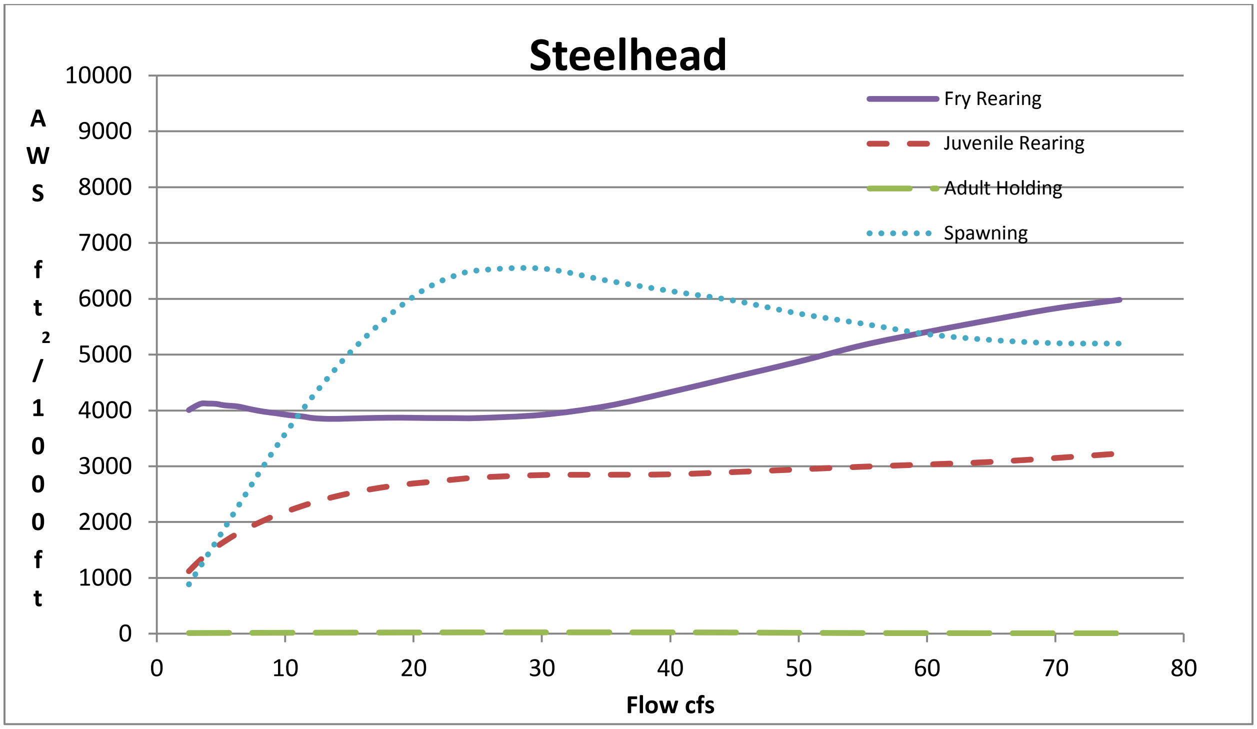


Figure 6. Steelhead and coho AWS curves for Neal Creek.

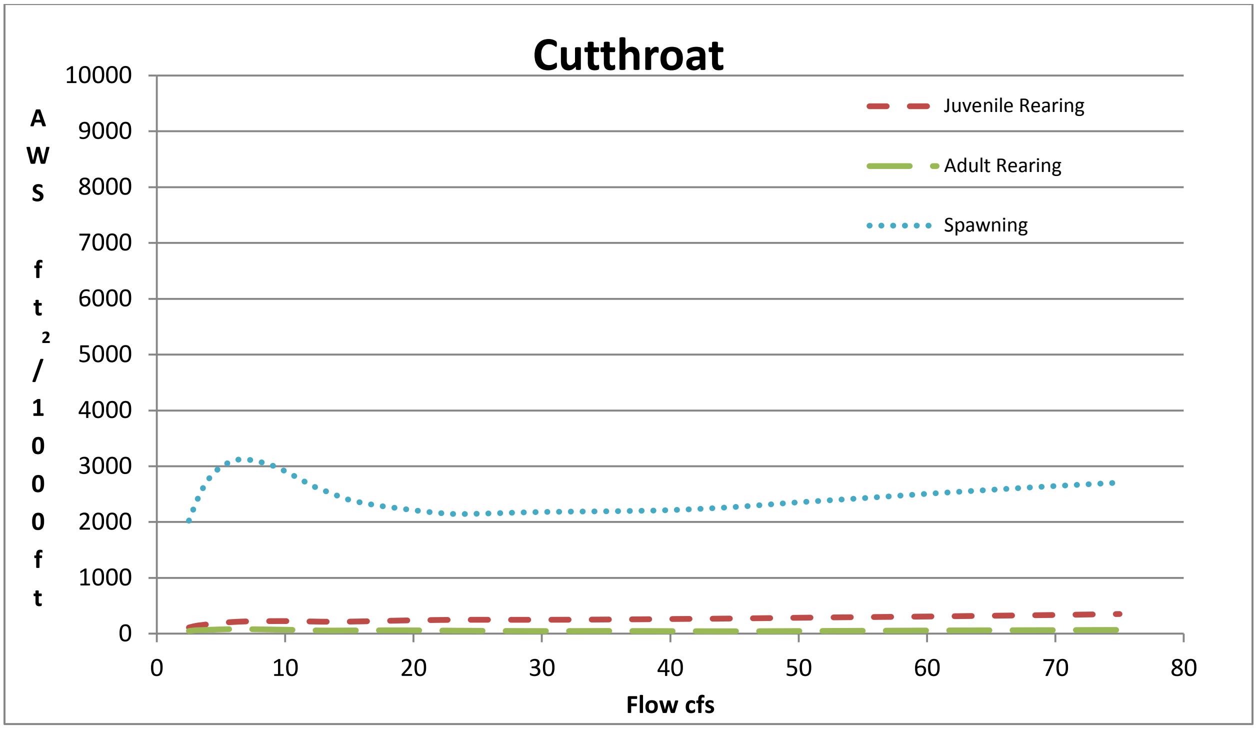
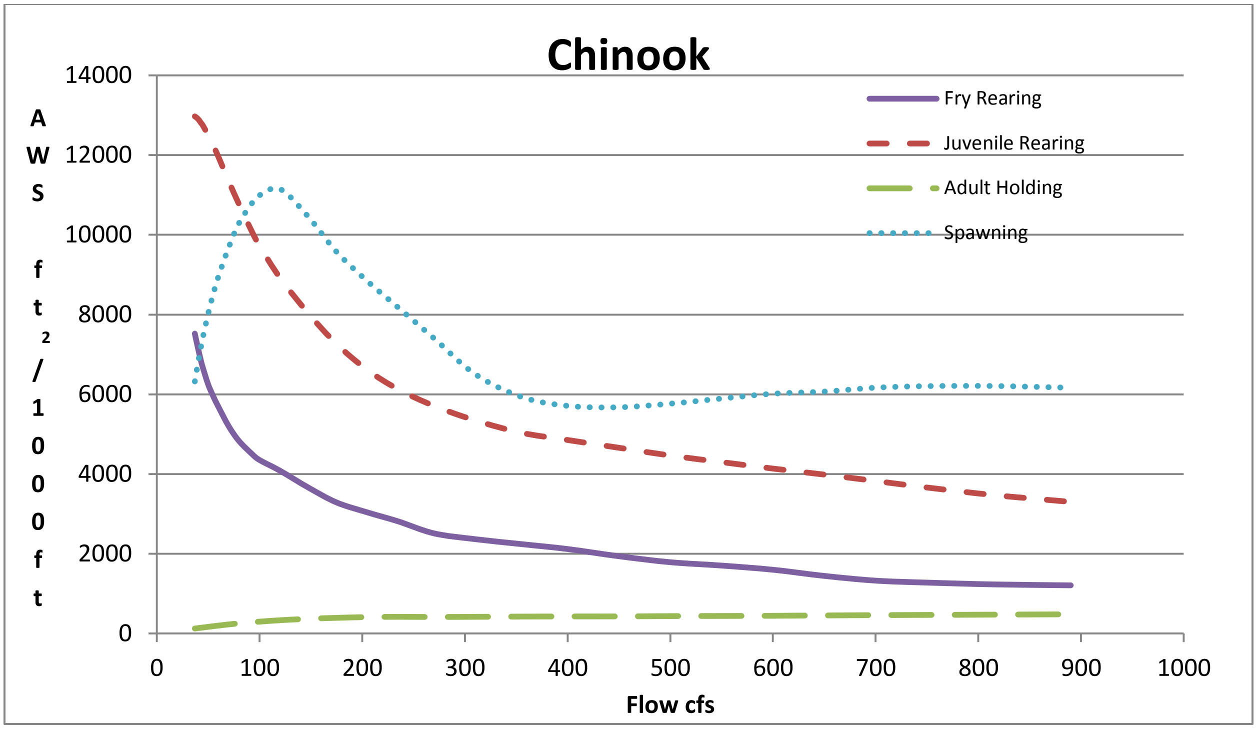


Figure 7. Cutthroat AWS curves for Neal Creek.



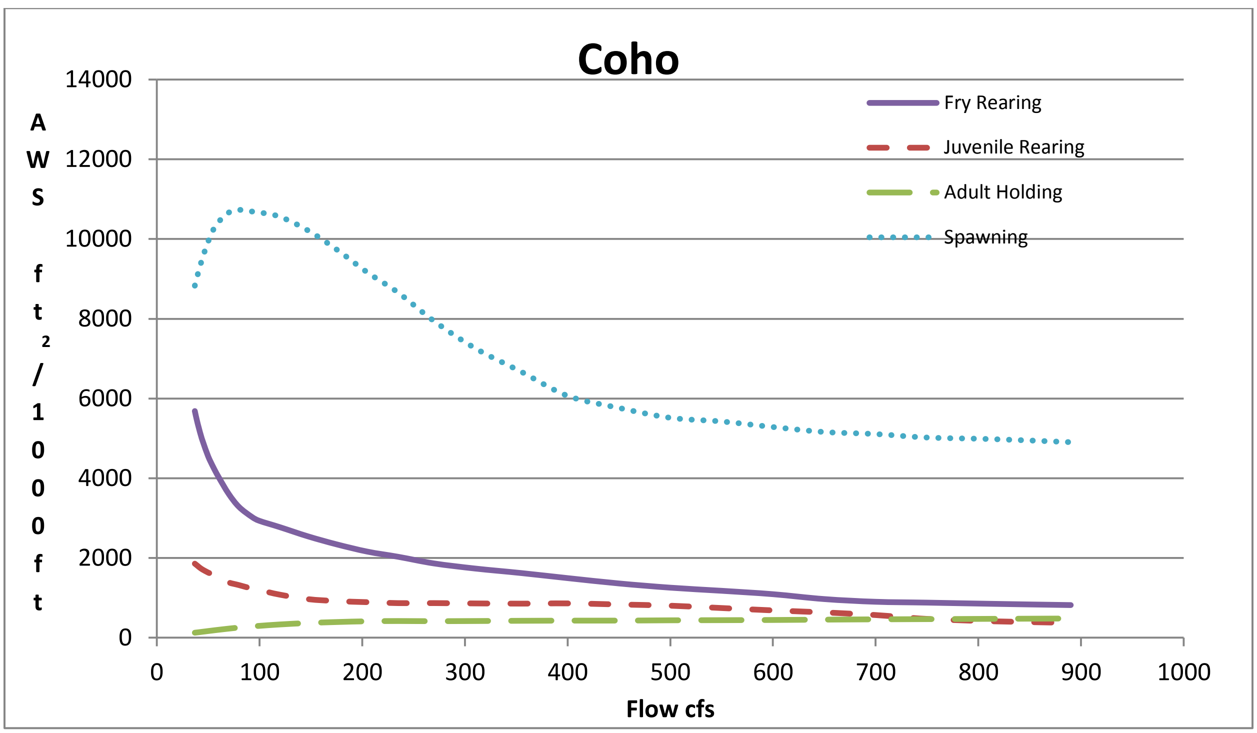
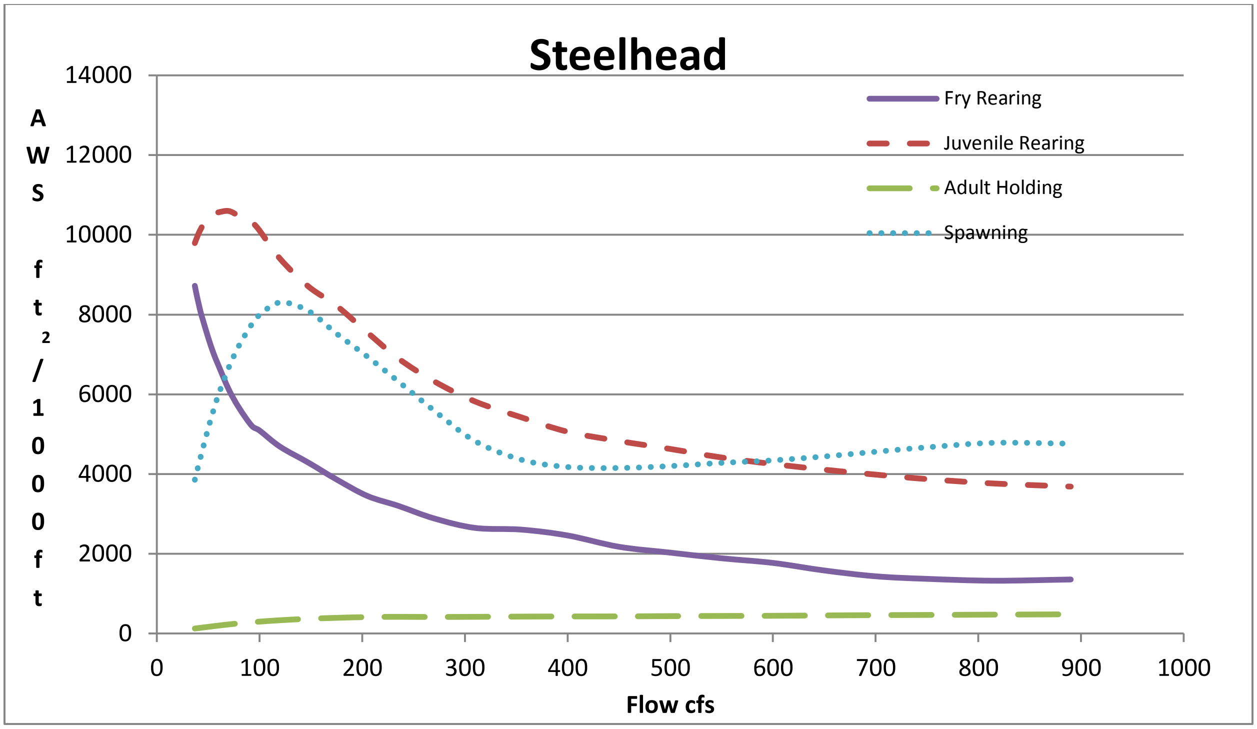


Figure 8. Chinook and coho AWS curves for E.F. Hood (upper).



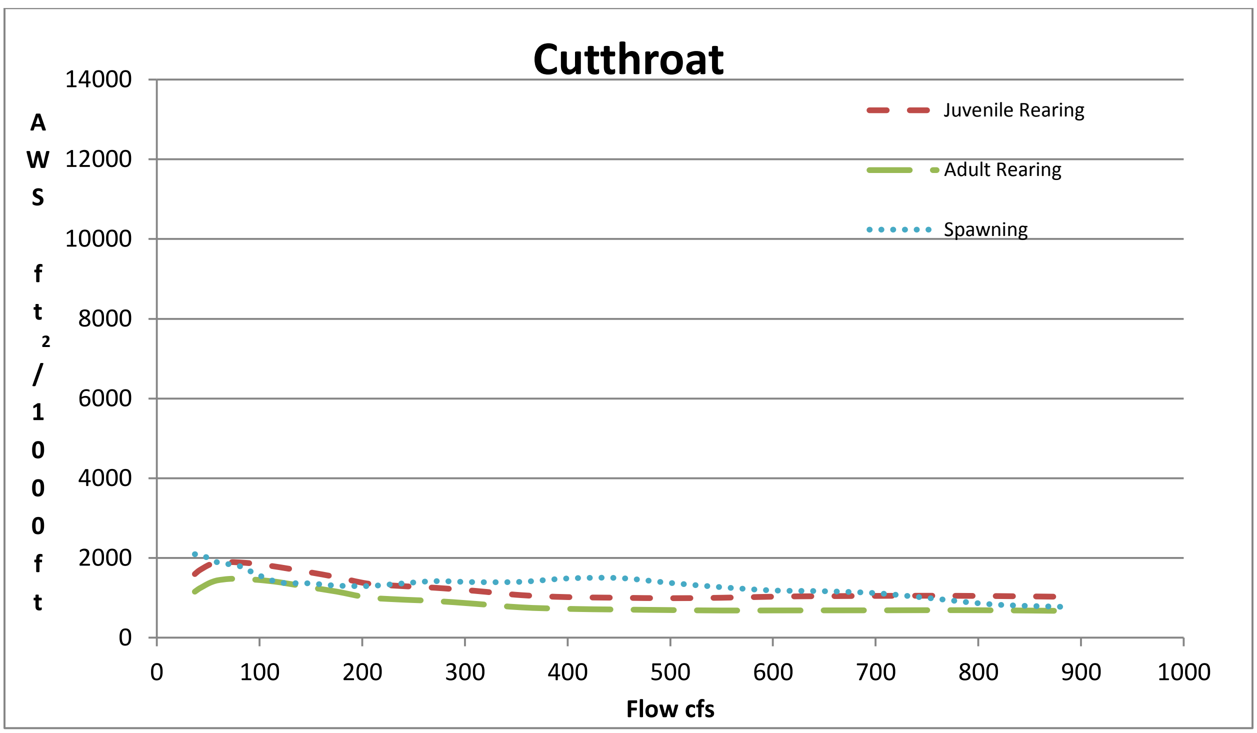
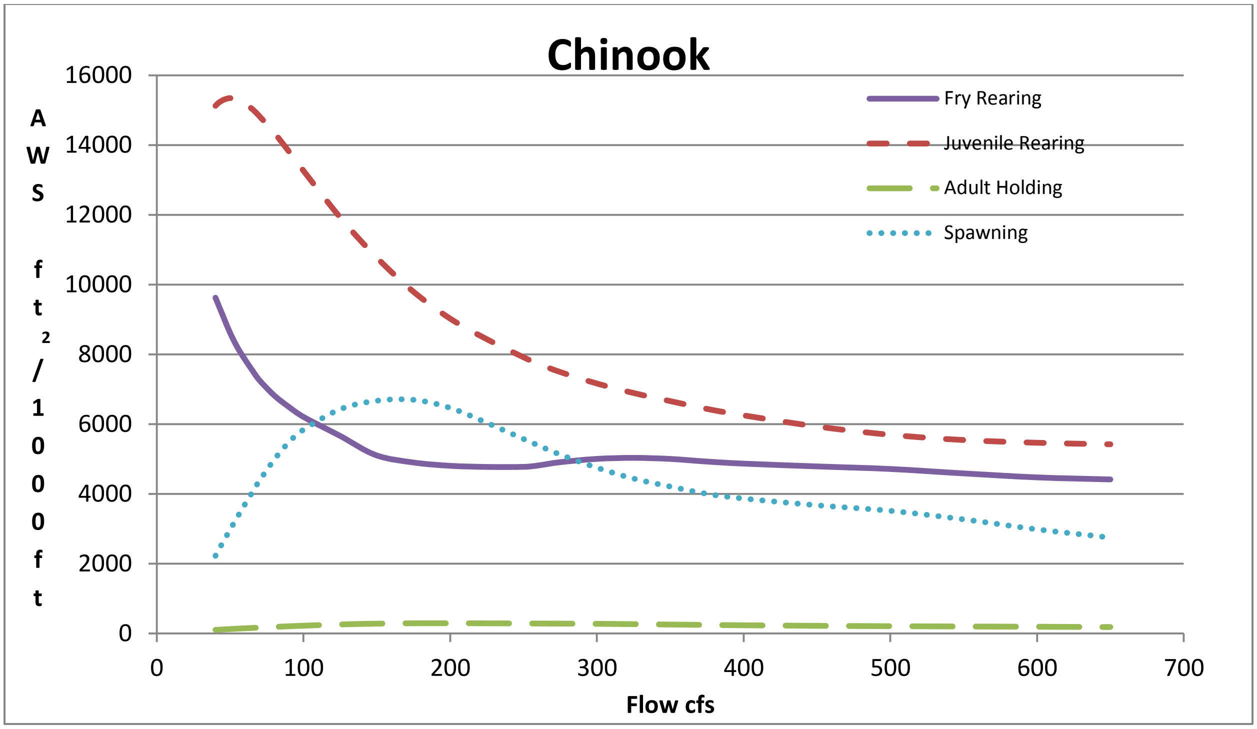


Figure 9. Steelhead and cutthroat AWS curves for E.F. Hood (upper).



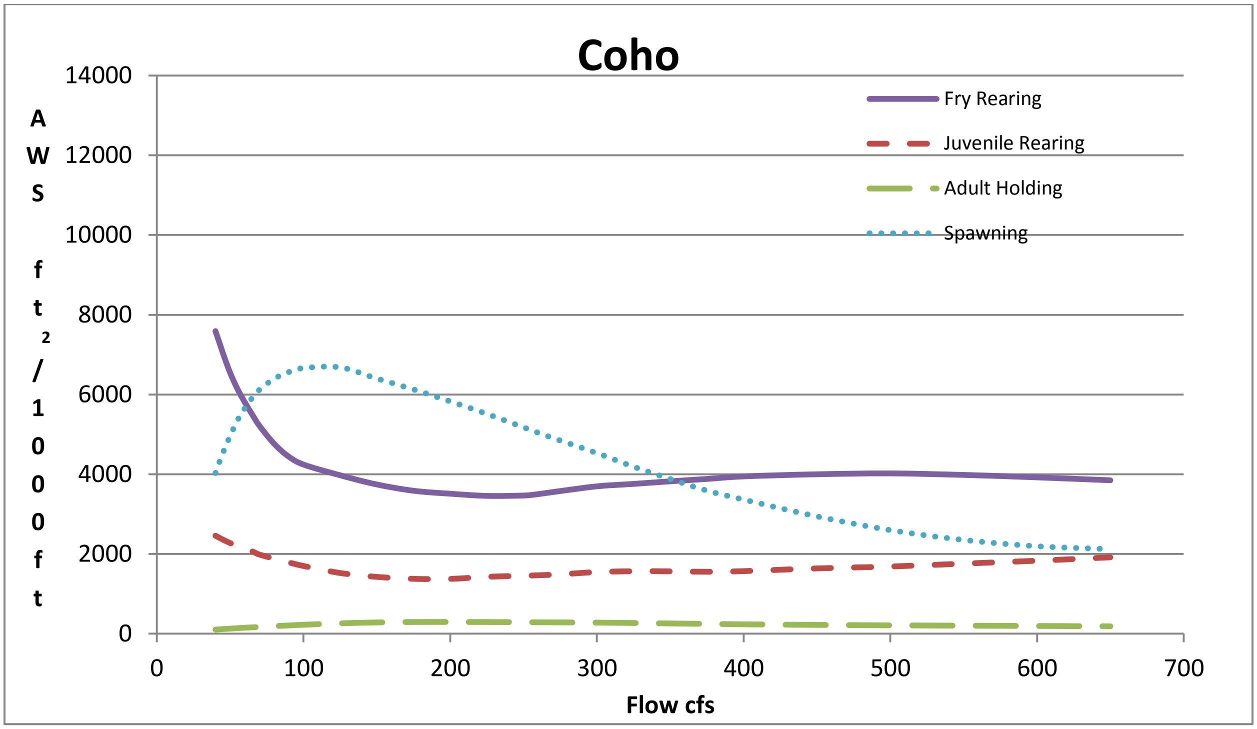
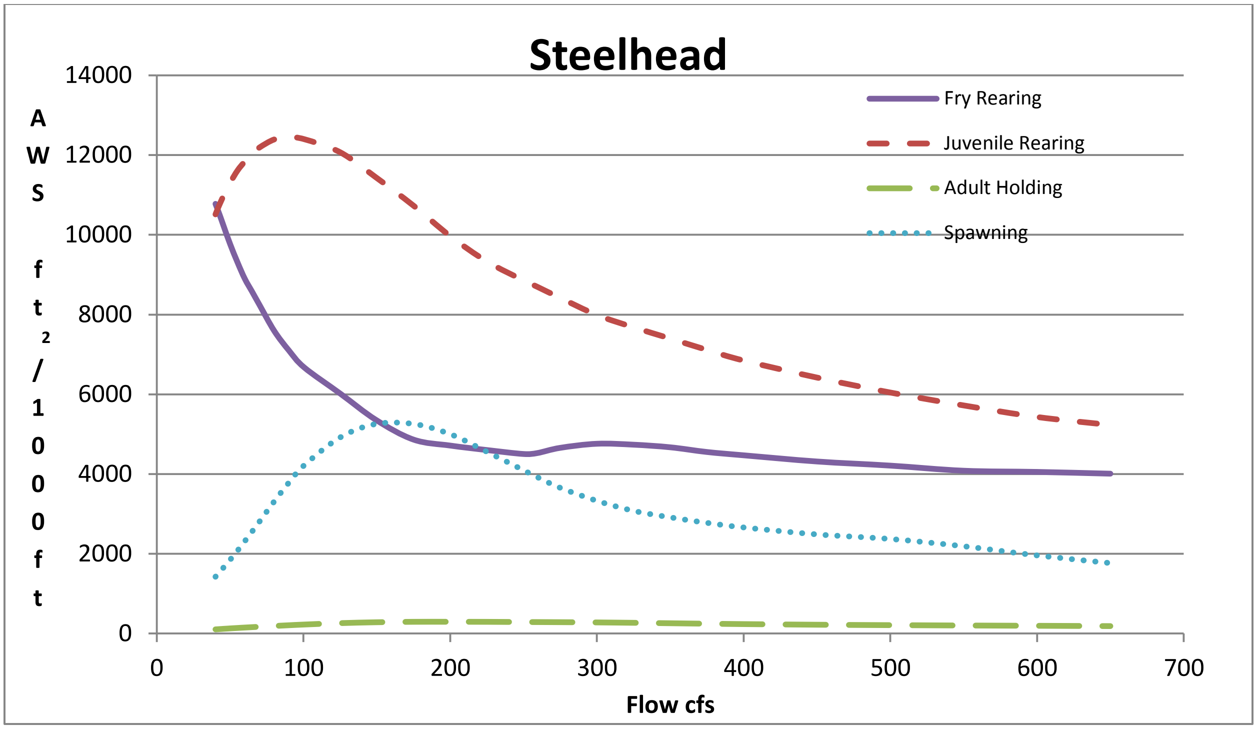


Figure 10. Chinook and coho AWS curves for E.F. Hood (lower).



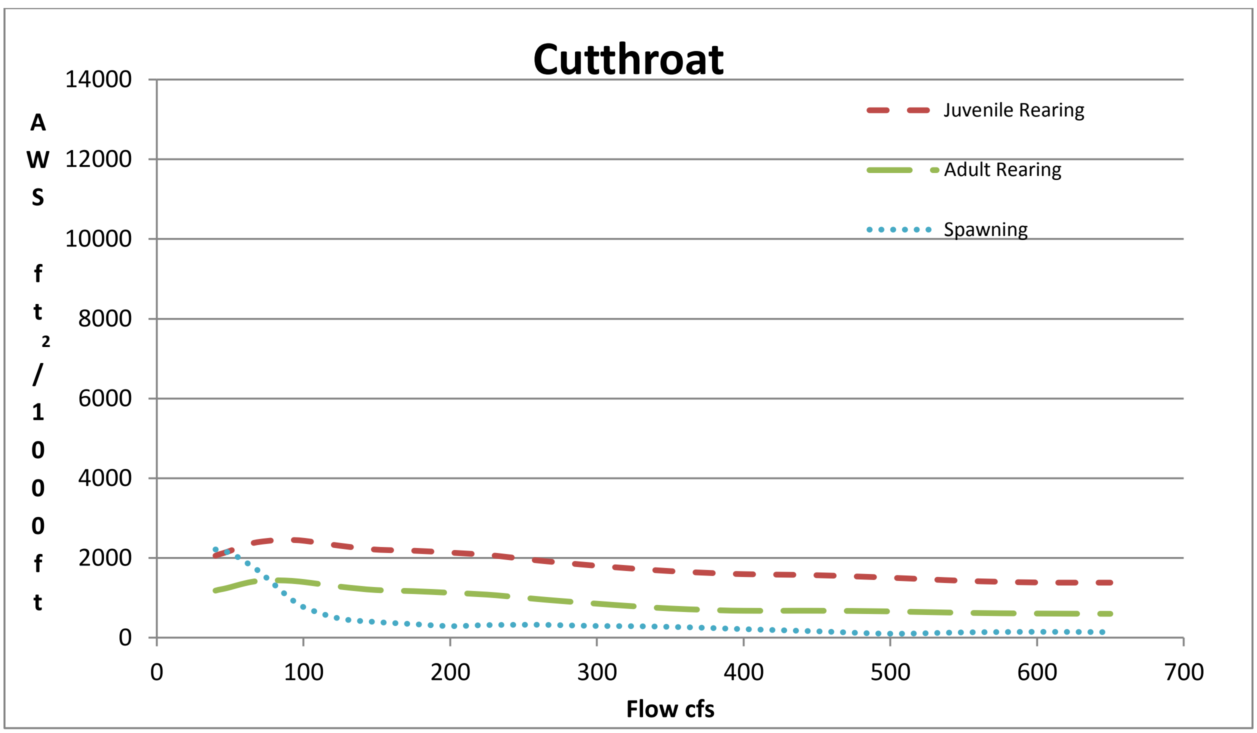
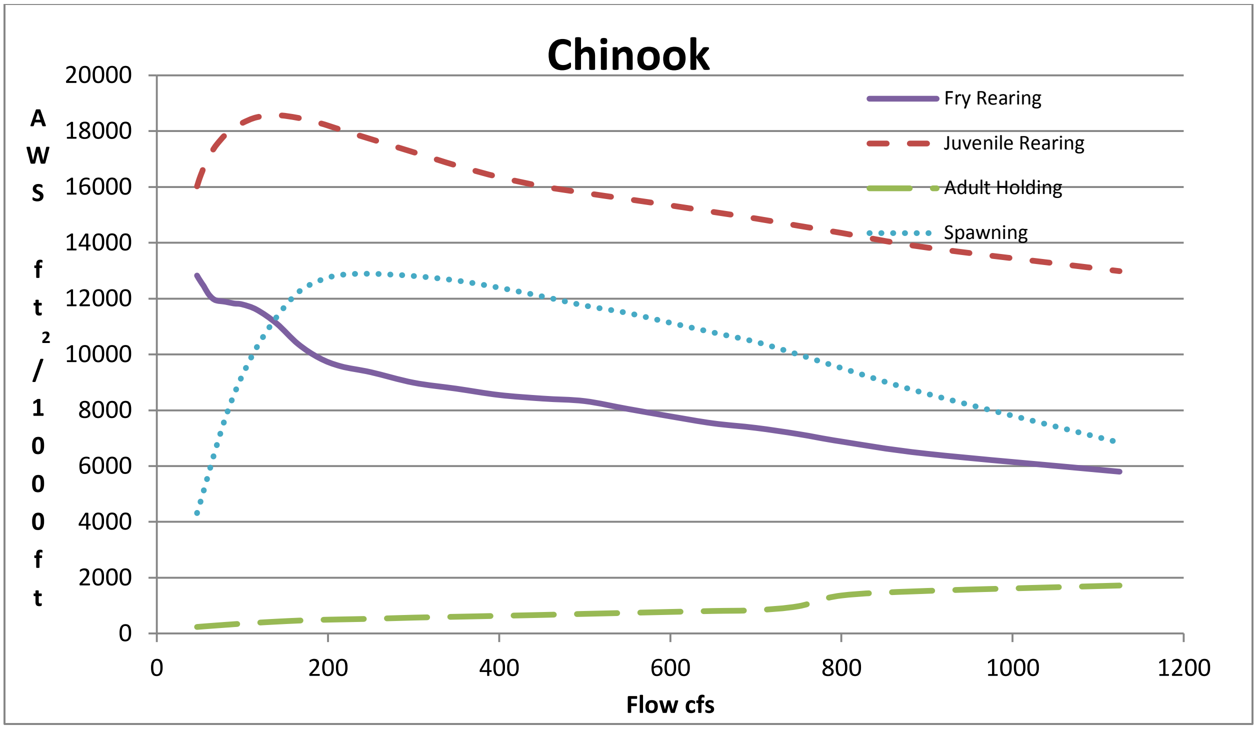


Figure 11. Steelhead and cutthroat AWS curves for E.F. Hood (lower).



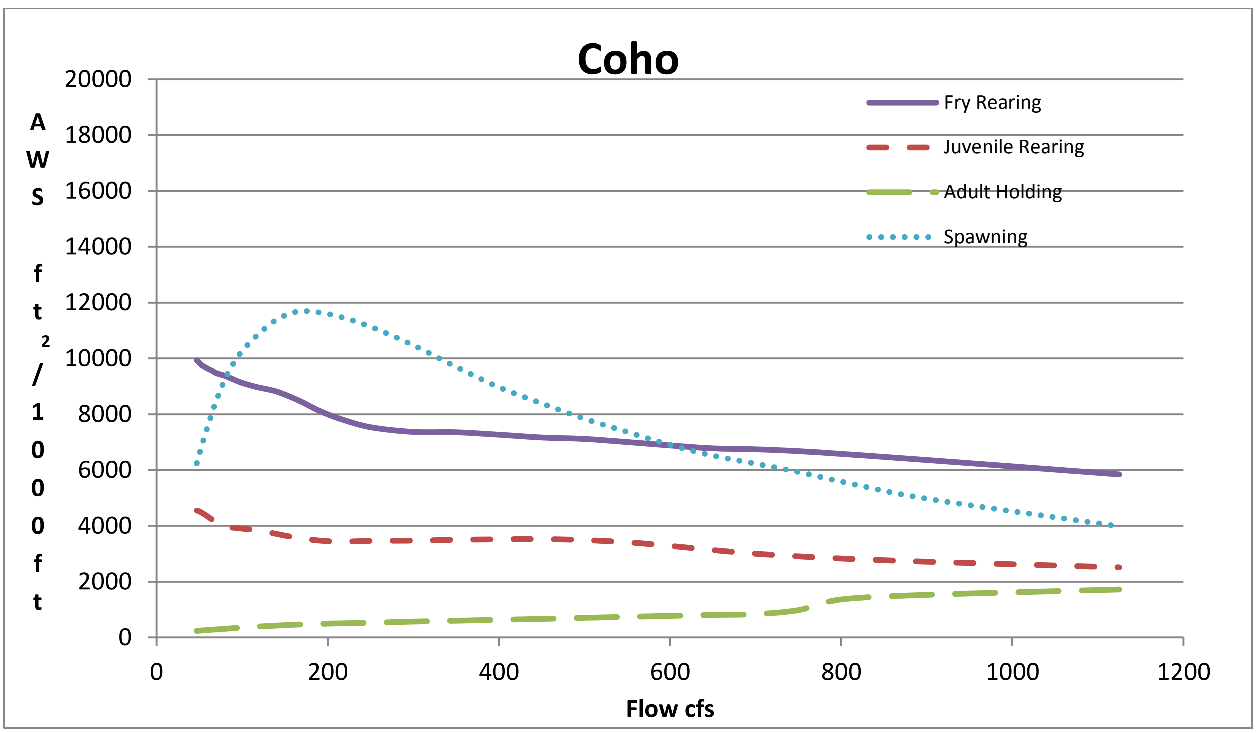
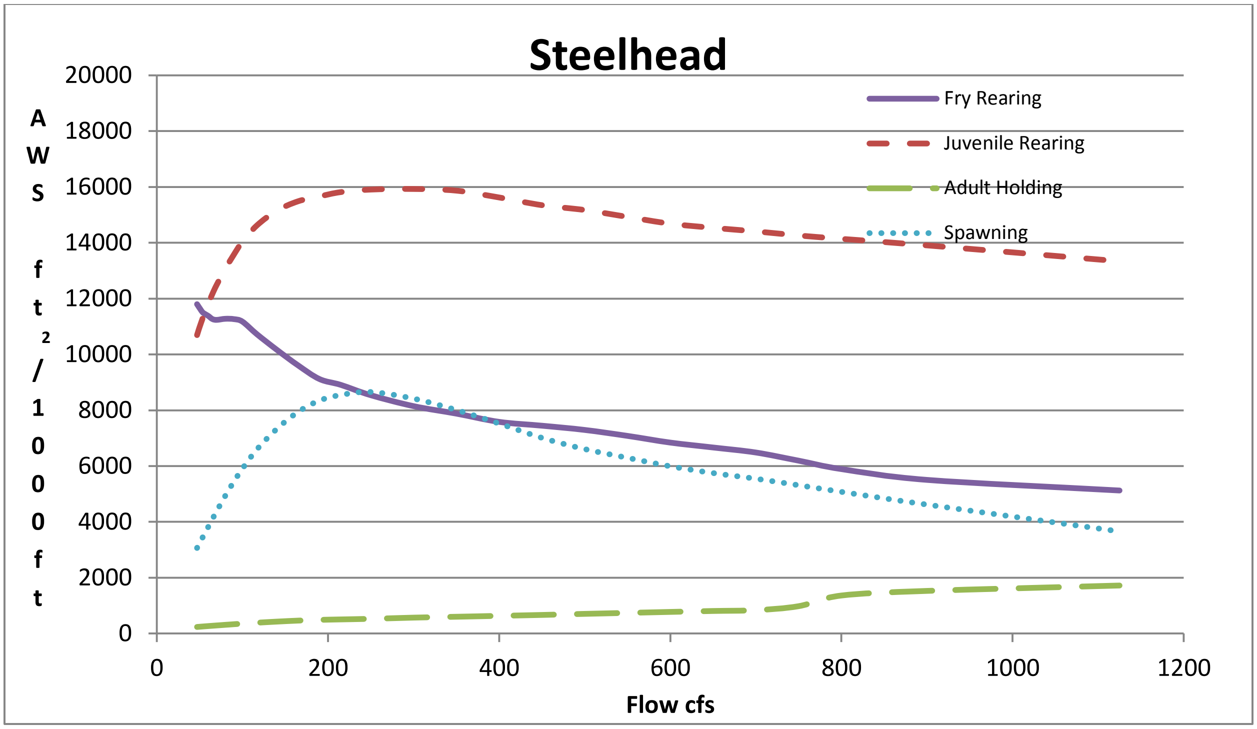


Figure 12. Chinook and coho AWS curves for W.F. Hood River.



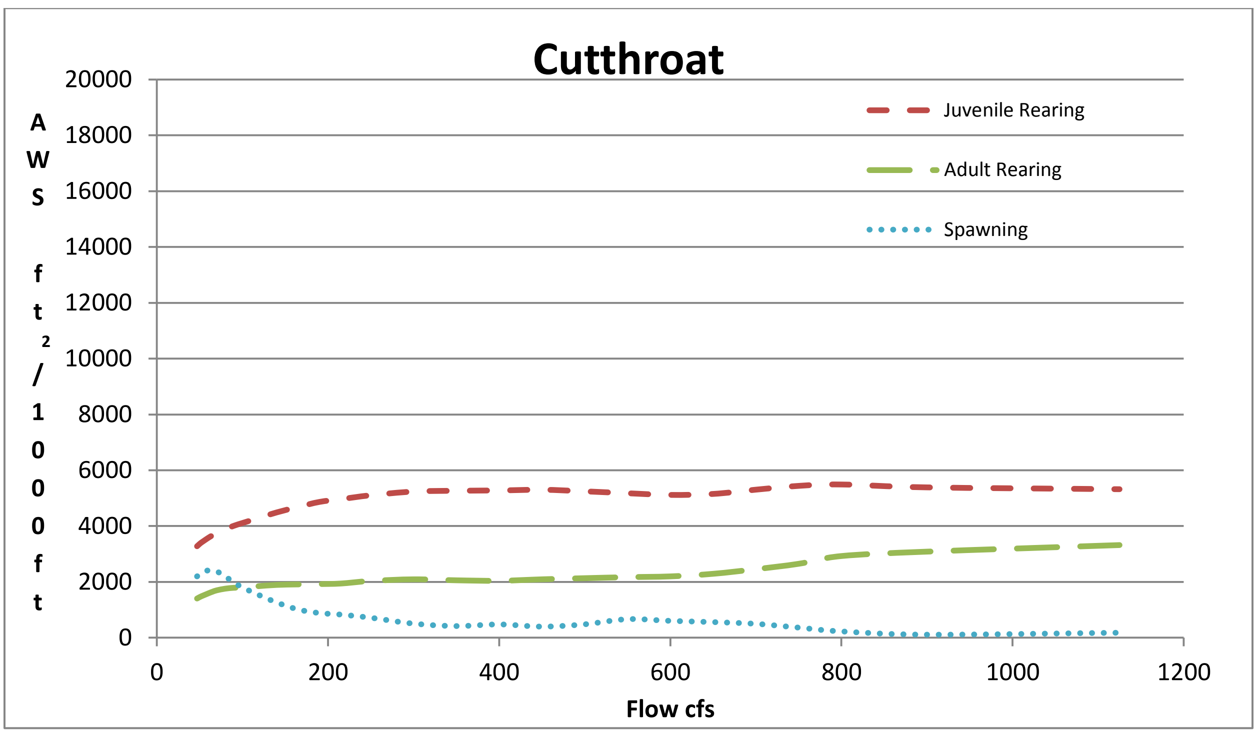


Figure 13. Steelhead and cutthroat AWS curves for W.F. Hood River.

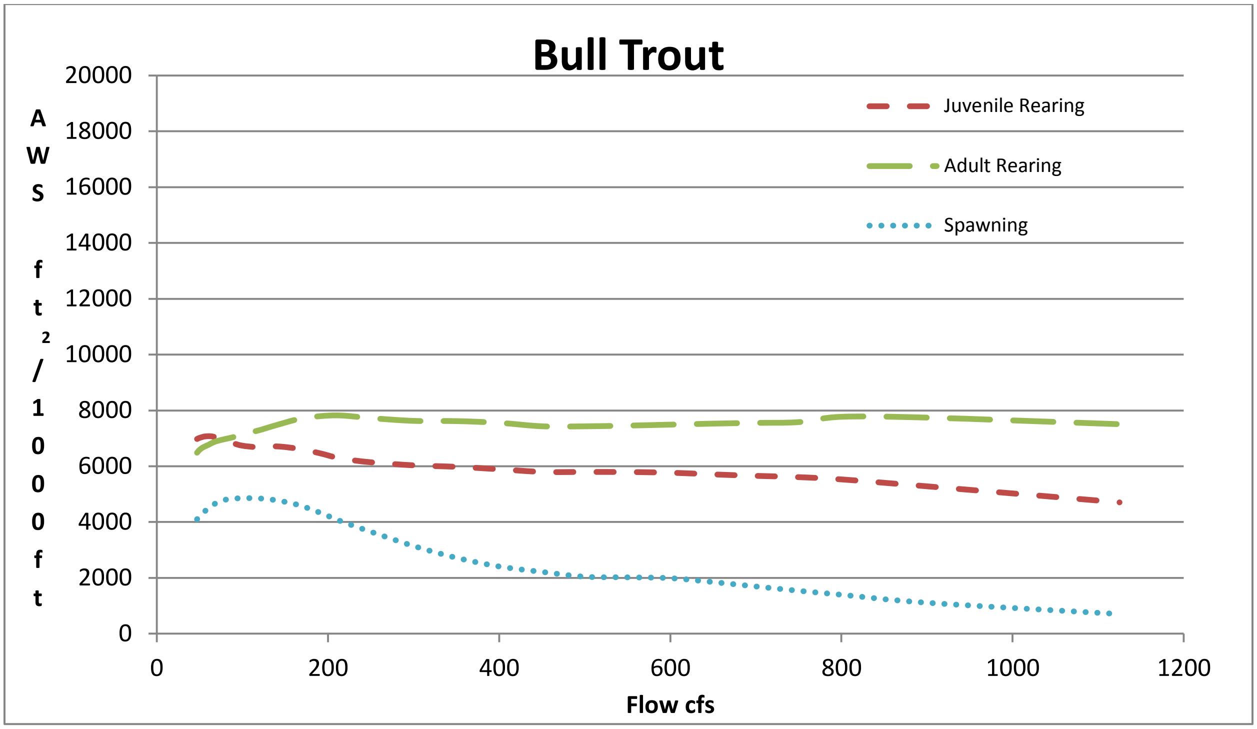


Figure 14. Bull trout AWS curves for W.F. Hood River.

Habitat Time Series Analysis

Species and life stages identified for time series habitat analysis in the five stream reaches are shown in Table 16. Spawning and rearing habitat for two species, Coho salmon and steelhead were evaluated in all reaches. Chinook salmon spawning and rearing was assessed in four reaches and bull trout spawning and rearing in a single reach. Based on the five reaches, 13 flow scenarios and 30 species/life stages being evaluated, a total of 390 individual habitat time series were run. Rearing habitat was analyzed for all months while spawning habitat was examined for the time periods identified in Table 17.

Table 16. Stream reaches, species and life stages utilized in habitat time series.

Species	Life Stage	Stream Reach					
		EF-Upper	EF-Lower	West Fork	Green Point	Neal Creek	Total for Life Stage
Spring Chinook	juvenile rearing	x	x	x	x		4
	spawning	x	x	x	x		4
Coho	juvenile rearing	x	x	x	x	x	5
	spawning	x	x	x	x	x	5
Steelhead	juvenile rearing	x	x	x	x	x	5
	spawning	x	x	x	x	x	5
Bull trout	adult rearing			x			1
	spawning			x			1
						Total	30

Table 17. Species and life stage periodicity table for the Hood River Tributaries Instream Flow Study time series.

Species	Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Spring Chinook	juvenile rearing	■	■	■	■	■	■	■	■	■	■	■	■
	spawning								▐	■	▌		
Coho	juvenile rearing	■	■	■	■	■	■	■	■	■	■	■	■
	spawning									▐	■	■	▌
Steelhead	juvenile rearing	■	■	■	■	■	■	■	■	■	■	■	■
	spawning		▐	■	■	■	■						
Bull trout	adult rearing	■	■	■	■	■	■	■	■	■	■	■	■
	spawning									■	■		

The results of the 390 separate habitat time series are presented in interactive Excel files included in Annexes B1 – B5. Each Annex contains a habitat time series Excel file for a single reach. In order to provide an example of output and interpretation, results are presented here are for Chinook spawning and juvenile rearing for the upper East Fork Hood River. Additional discussion is presented in Annex C, a presentation to the HRCWPG. A new method of presenting habitat time series data, raster plots, was utilized to present the results to the HRCWPG. Raster plots are pixel-based plots for visualizing and identifying variations and changes in large multidimensional data sets.

Originally developed by Keim (2000) they were first applied in hydrology by Koehler (2004) as a means of highlighting inter-annual and intra-annual changes in streamflow. The raster hydrographs in WaterWatch (http://waterwatch.usgs.gov/?id=wwchart_rastergraph), like those developed by Koehler, depict years on the y-axis and days along the x-axis.

Hydrology

Hydrology was developed for the five stream reaches identified in Table 18. Long term synthesized daily streamflows for 12 future scenarios (2030 to 2060) were used to forecast conditions based on climate change, water year type (median, hot/dry and warm/wet), water usage and additional storage (Table 18). Daily streamflow for historical existing conditions (1980 to 2009) are used as a baseline for comparisons to these future streamflow scenarios.

Table 18. Hydrology scenarios used to evaluate potential changes in flow and habitat of selected fish species and life stages in the Hood River tributaries study.

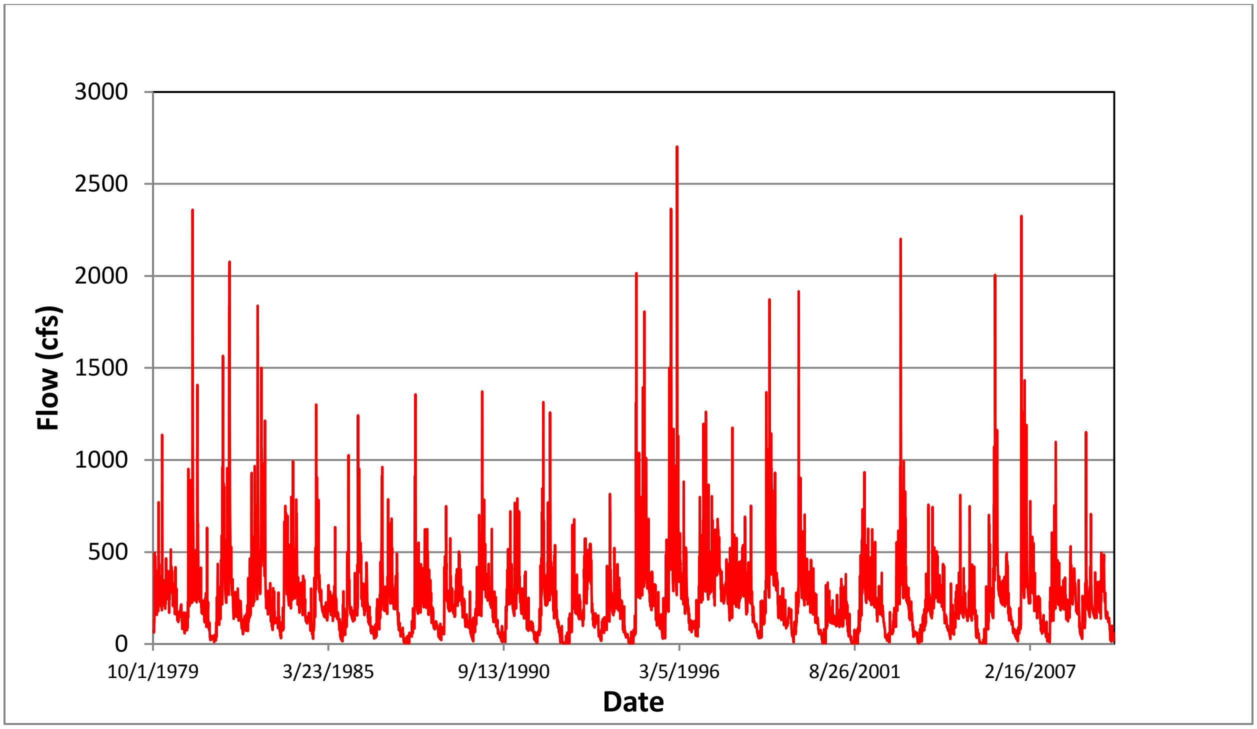
Scenario	Climate	Water Demands	Water Conservation	Water Storage
1	Historical	Existing	Existing	Existing
2.1	Future scenario 1 median	Existing	Existing	Existing
2.2	Future scenario 2 hot/dry	Existing	Existing	Existing
2.3	Future scenario 3 warm/wet	Existing	Existing	Existing
3.1	Future scenario 1 median	Future – (increase)[1]	Existing	Existing
3.2	Future scenario 2 hot/dry	Future – (increase)[1]	Existing	Existing
3.3	Future scenario 3 warm/wet	Future – (increase)[1]	Existing	Existing
4.1	Future scenario 1 median	Future – (increase)[1]	Future – (conserve)[2]	Existing
4.2	Future scenario 2 hot/dry	Future – (increase)[1]	Future – (conserve)[2]	Existing
4.3	Future scenario 3 warm/wet	Future – (increase)[1]	Future – (conserve)[2]	Existing
5.1	Future scenario 1 median	Future – (increase)[1]	Future – (conserve)[2]	Existing & New Storage[3]
5.2	Future scenario 2 hot/dry	Future – (increase)[1]	Future – (conserve)[2]	Existing & New Storage[3]
5.3	Future scenario 3 warm/wet	Future – (increase)[1]	Future – (conserve)[2]	Existing & New Storage[3]

[1] potable and irrigation [2] irrigation [3] larger FID & MFID, new FID

Streamflow and Habitat Time Series

An example flow time series for the historic scenario and corresponding Chinook juvenile habitat time series are presented in Figure 15. When dealing with an extensive period of 30 years, details can be lost but certain events stand out, high peak flows in 1994 and 1995, relatively higher summer flows and lower peak winter flows in 1996 and 1997, extremely low winter flows in 2000 and low summer flows in 2000 and 2001. These events are depicted in more detail in Figure 16. As can be seen, lower habitat values occur at flows over 300 cfs, with near zero habitat indexes at extreme peak flows, and the highest habitat index values are during lower flow periods (e.g. summer). But low habitat values can also occur at very low flows, in this case flows less than 10 cfs as in the summers of 1994 and 2001. An alternative visually enhanced means of identifying these events are illustrated in Raster hydrograph (Figure 17) and habitat (Figure 18) plots. The high flows of February 1996 and November of 2006 are easily identified in Figure 17.

By examining the relationship between flow and habitat for Chinook juvenile, the basis for these events becomes apparent (Figure 19). From the peak of the curve to an inflection point around 300 cfs, AWS is relatively high. Past this point AWS gradually decreases. Similarly AWS is relatively high at the low end of the curve before its drops precipitously at flows less than 10 cfs.



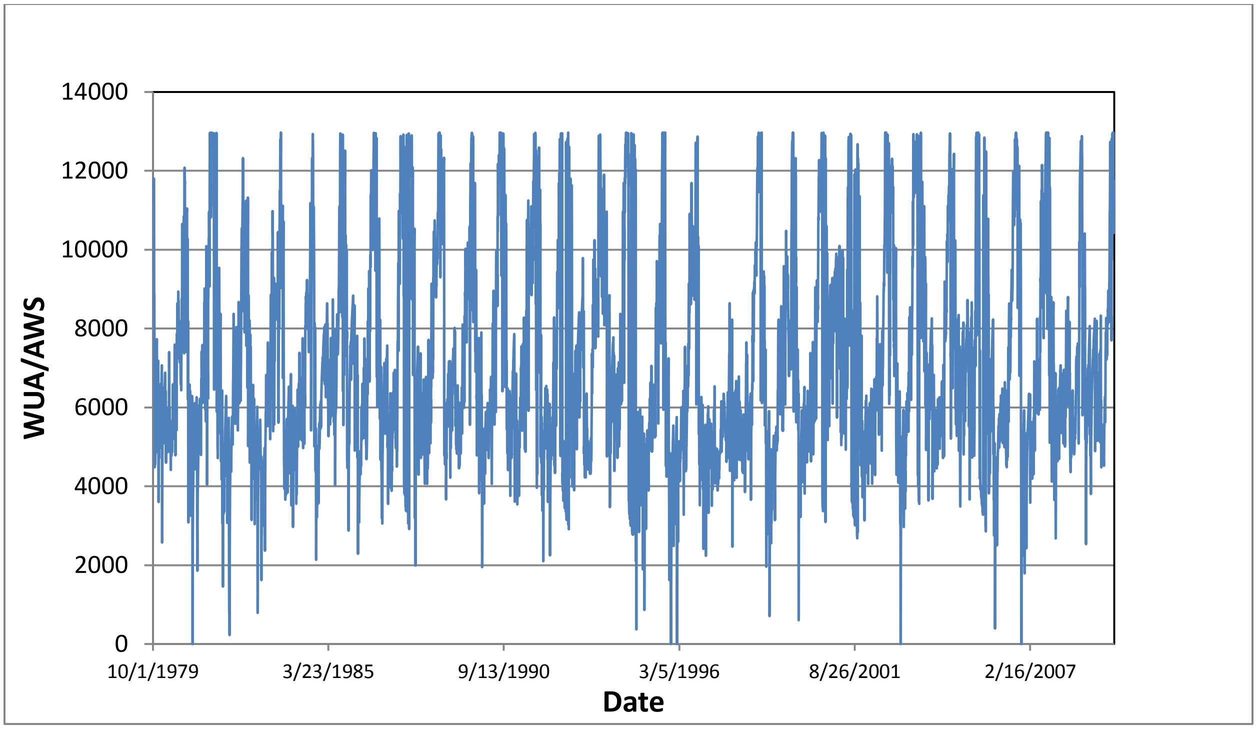


Figure 15. Flow time series (top) and Chinook juvenile habitat time series (bottom) for 30 years of historic flow in the East Fork Hood River..

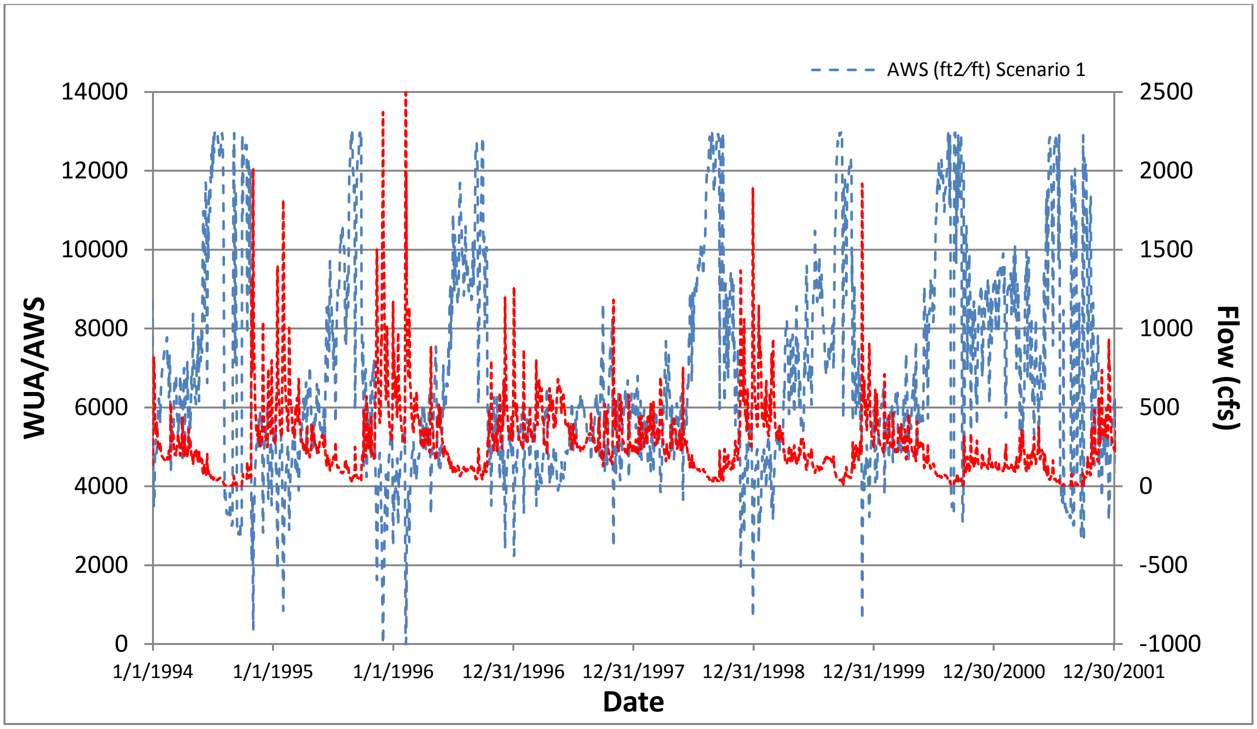


Figure 16. Overlay of flow time series and Chinook juvenile habitat time series for a selected time period from the upper East Fork Hood River.

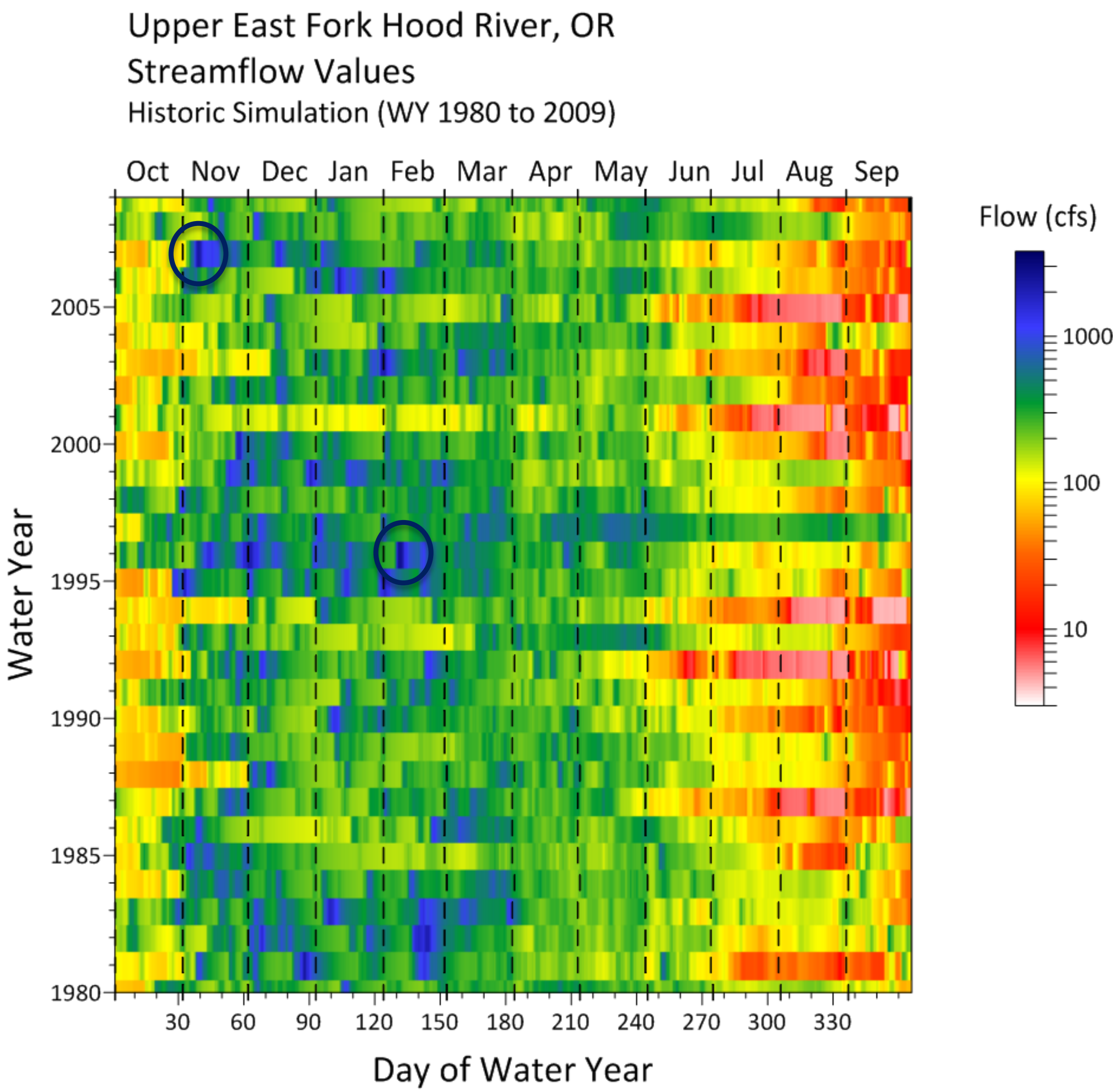


Figure 17. Raster hydrograph of historic flows in the Upper East Fork Hood River.

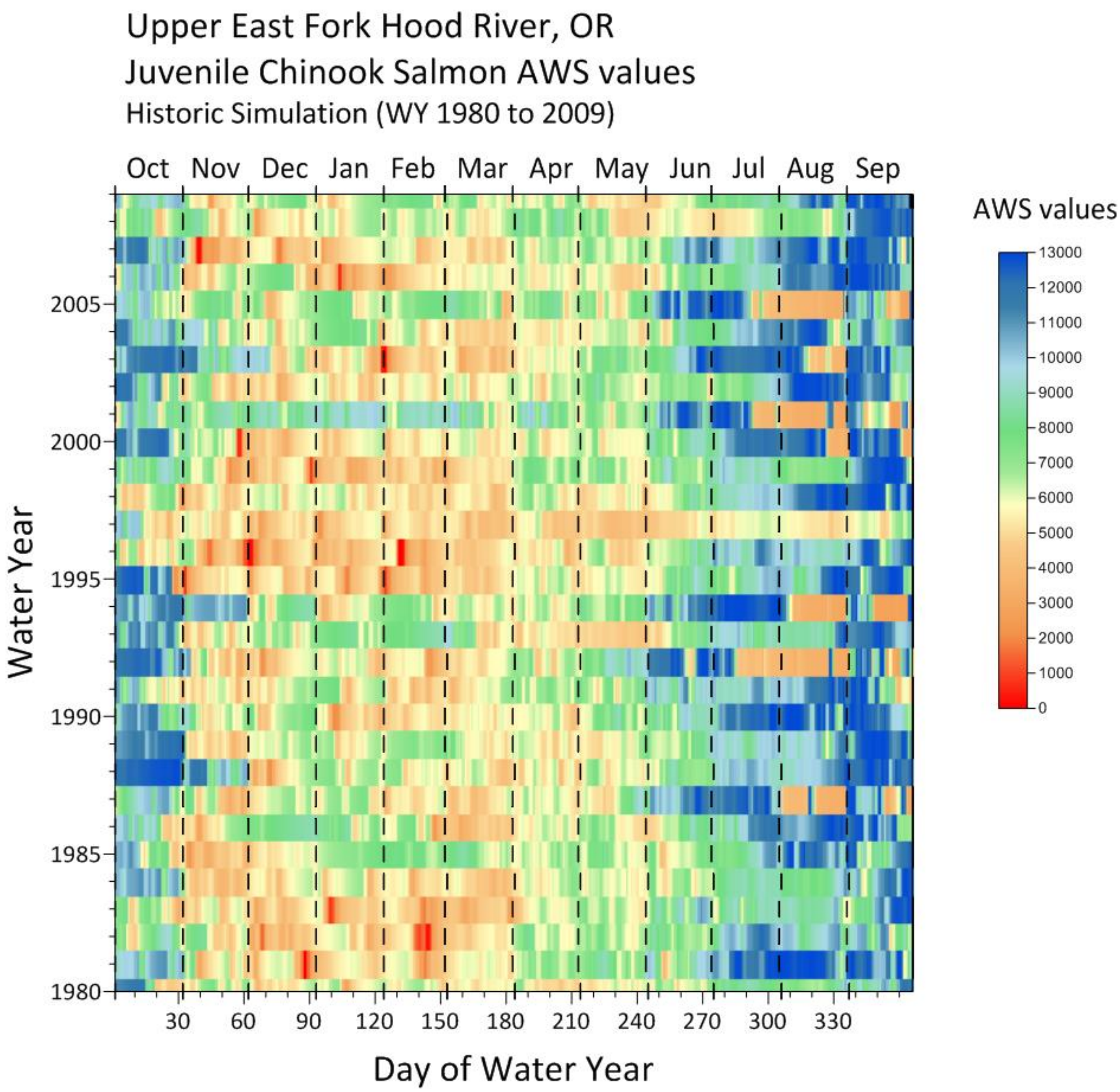


Figure 18. Raster plot of Chinook juvenile habitat (AWS) for historic flows in the Upper East Fork Hood River.

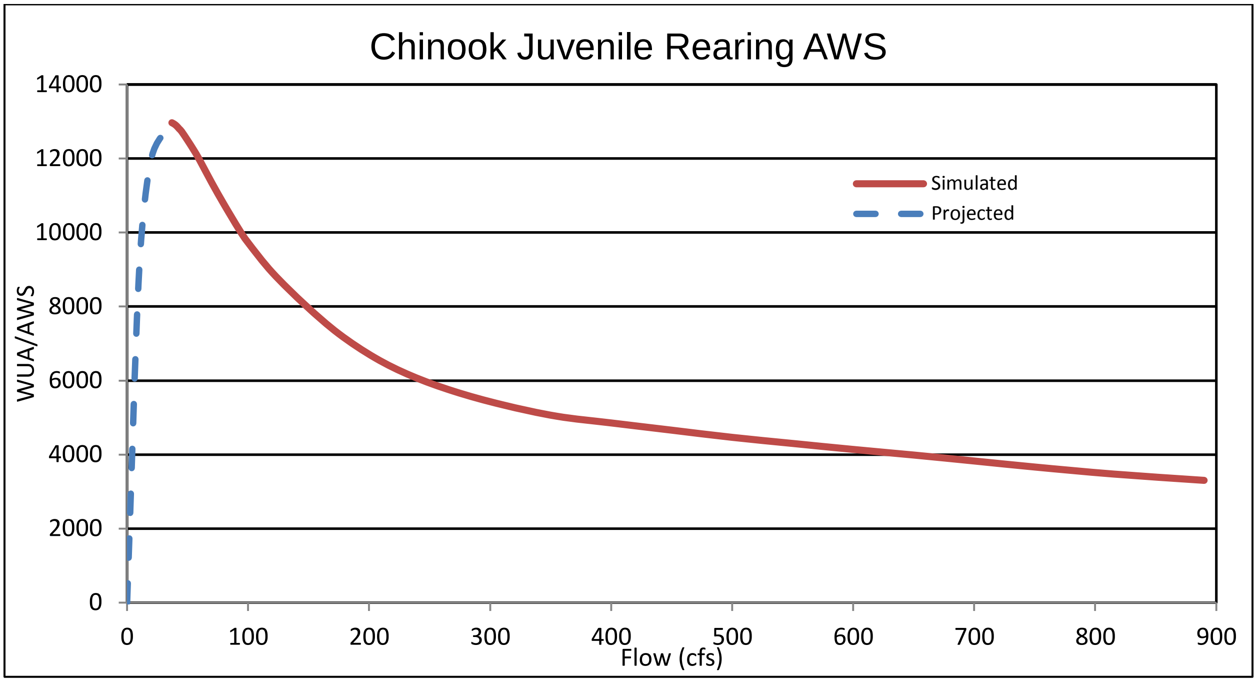
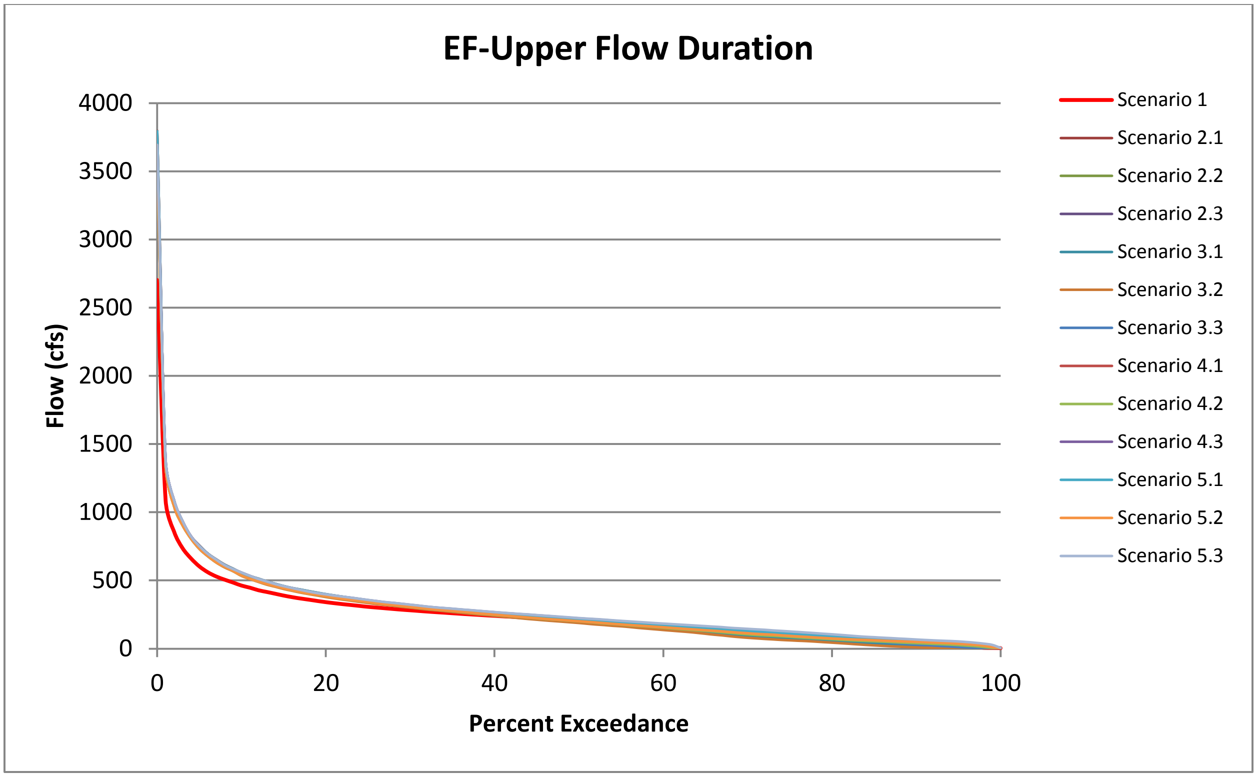


Figure 19. Chinook juvenile WUA/AWS curve for the upper East Fork Hood River.

Flow and Habitat Duration

Flow duration curves provide a means to compare different flow regimes with respect to the amount of time certain flow levels occur. For the upper East Fork Hood River graphs are provided that depict flow exceedance from 0-100 % and 5-95 % for the period of record (Figure 20). Future hydrology for all scenarios shows an increase in high flows and somewhat lower low flows for most of the scenarios compared to historical. Examination of Chinook juvenile habitat duration curves shows slightly more habitat 25% of the time and slightly less 50% of the time for all future scenarios over historical (Figure 21). Because it has been shown that both high flows and very low flows can lower the habitat index, this follows what is shown in the flow duration curve.

Flow duration curves for spring Chinook spawning cover a short period of time (August 15 to October 15) and flows exceed 250 cfs just 5% of the time (Figure 22). Future flow scenarios based on climate change (2.1-2.3) and water demand (3.1-3.2) display lower flows than historical all the time. Scenarios based on water conservation and storage exhibit higher high flows, but also greater low flows. The overall lower flows under climate change and water demand scenarios result in a reduction of spawning habitat (Figure 22). Under water conservation and storage scenarios spawning habitat is greater for approximately 50% of the time for scenarios 4.1 and 4.2, and most of the time for scenarios with water storage incorporated.



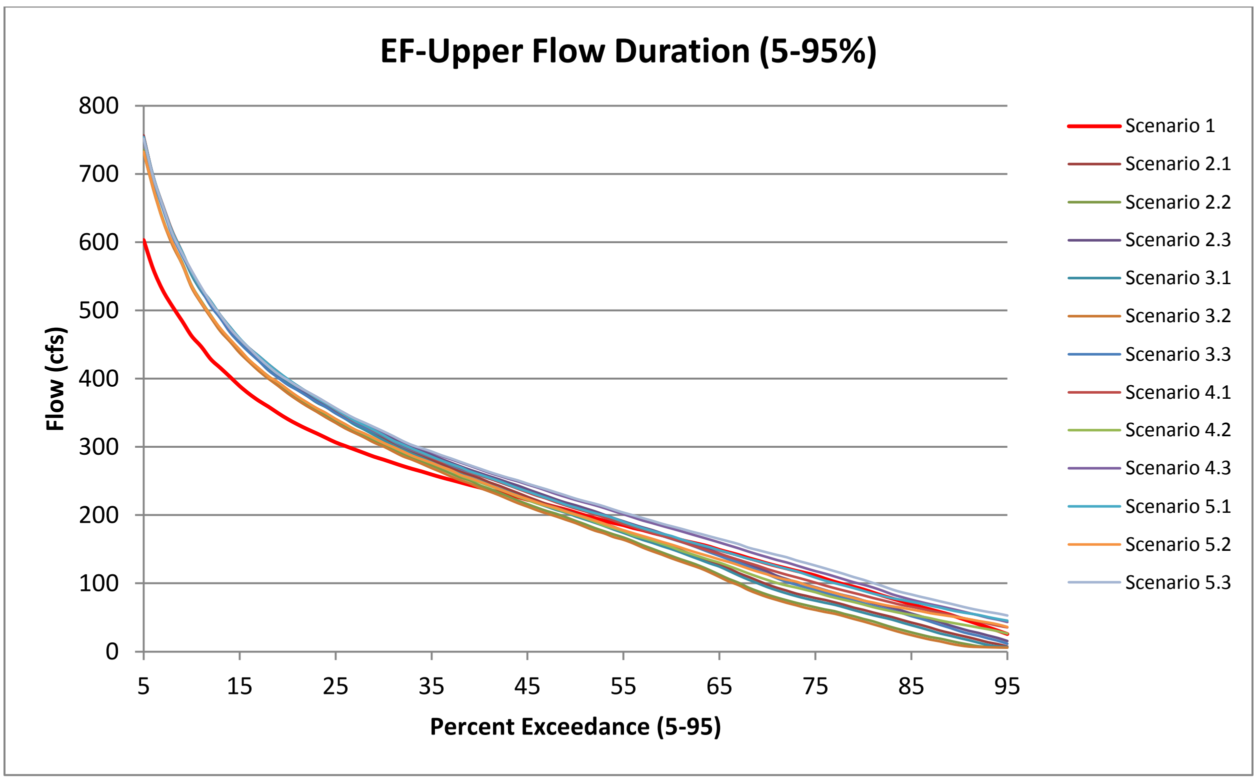
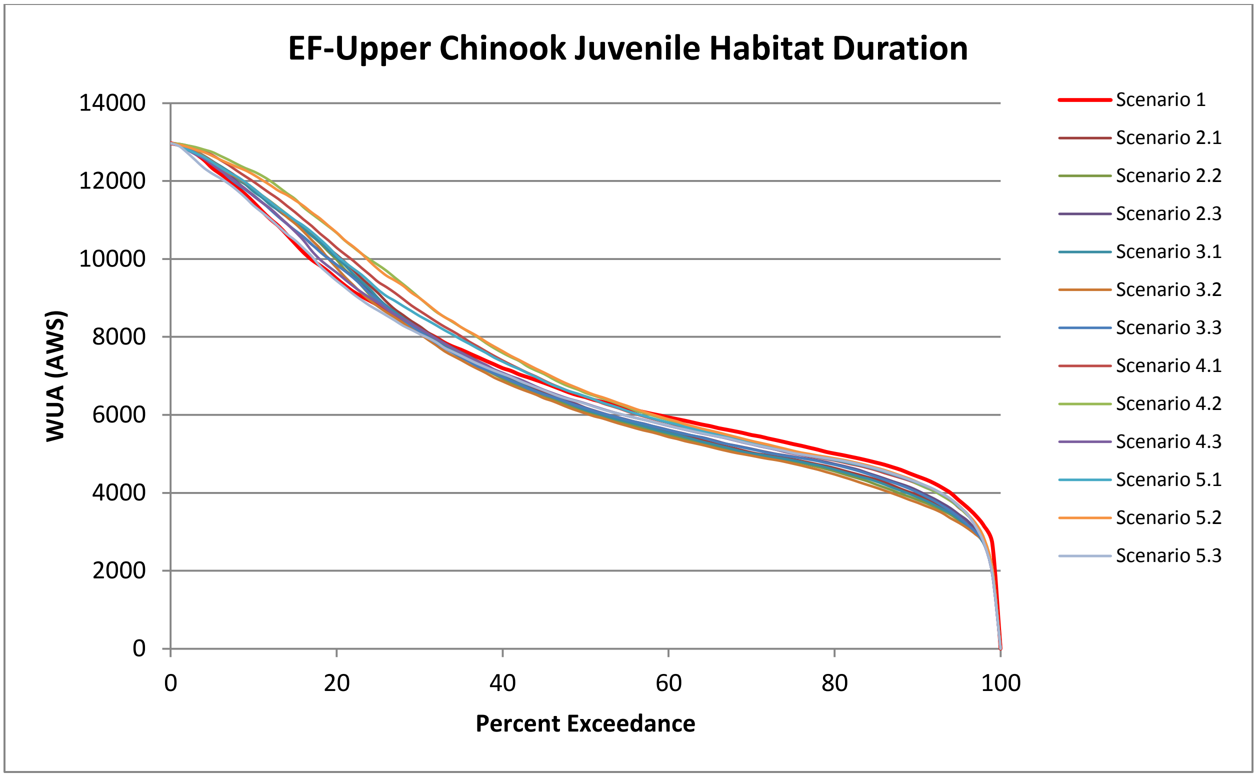


Figure 20. Flow duration curves for 13 flow scenarios on upper East Fork Hood River. Top, 0-100% exceedance; bottom, 5-95% exceedance.



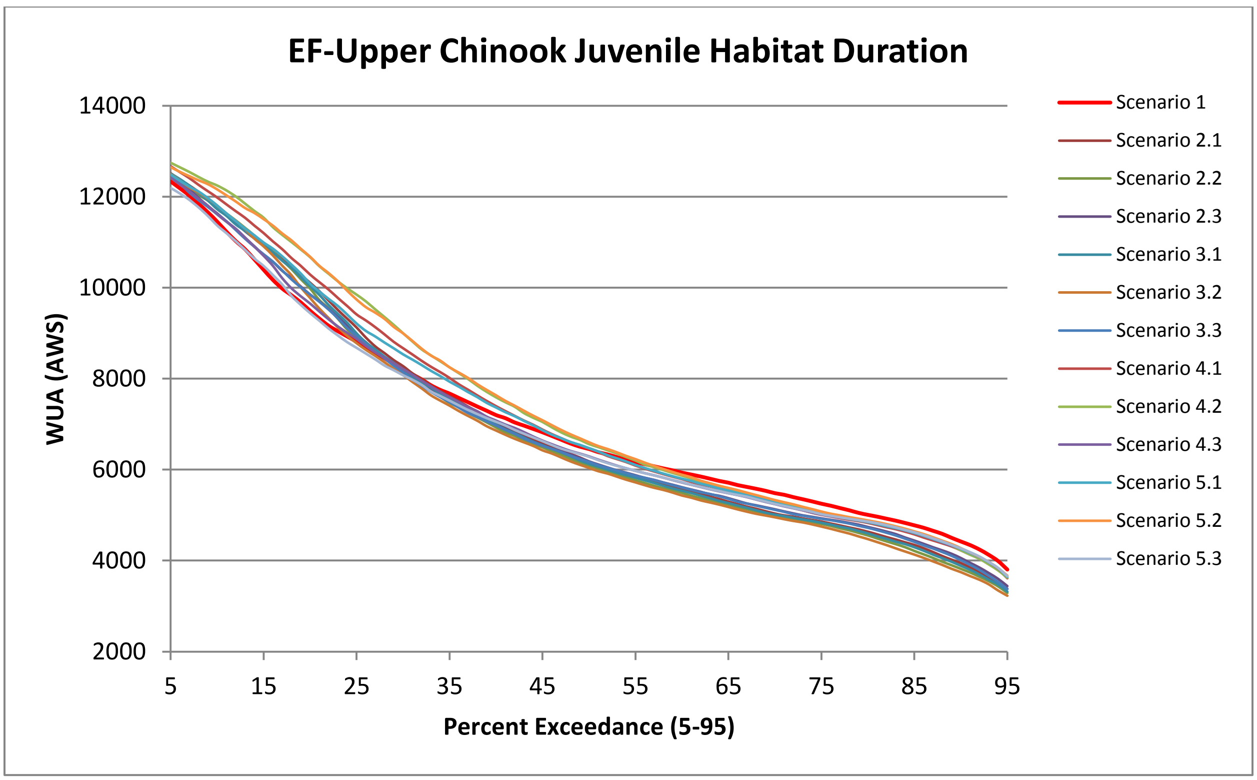
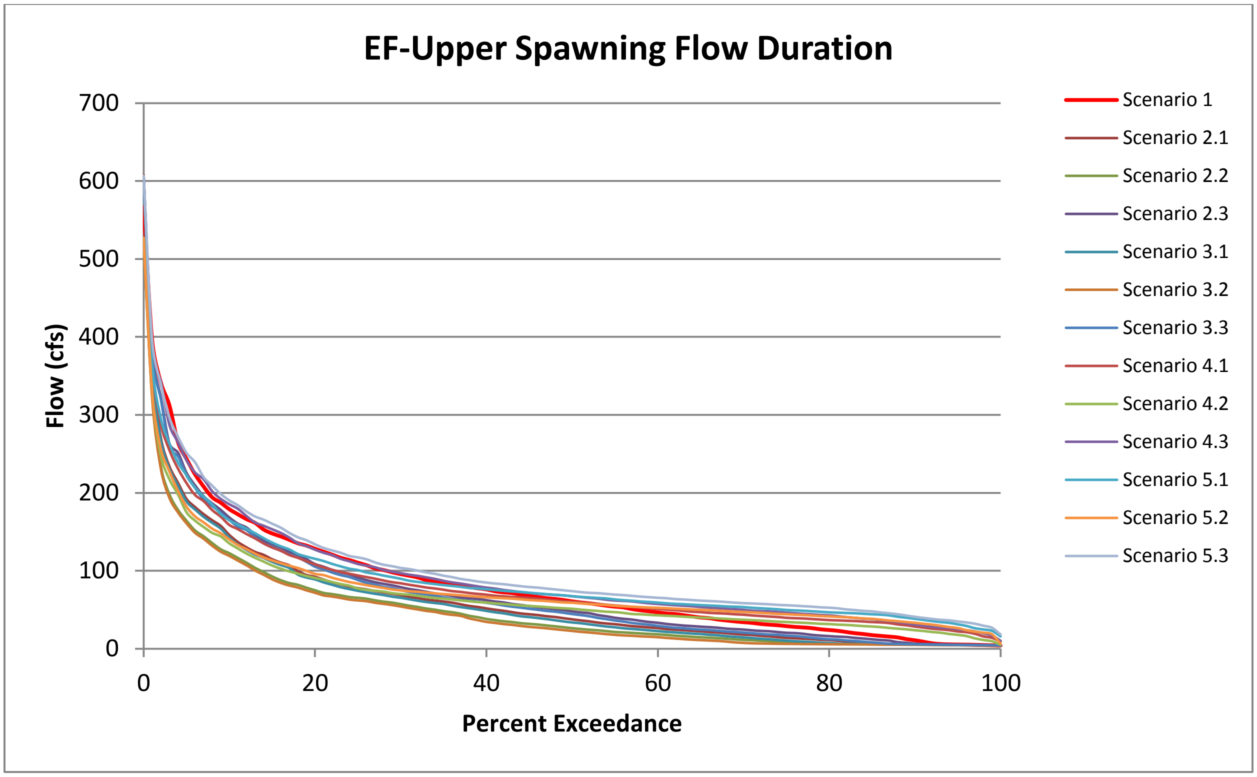


Figure 21. Chinook juvenile habitat duration for the upper East Fork Hood River.



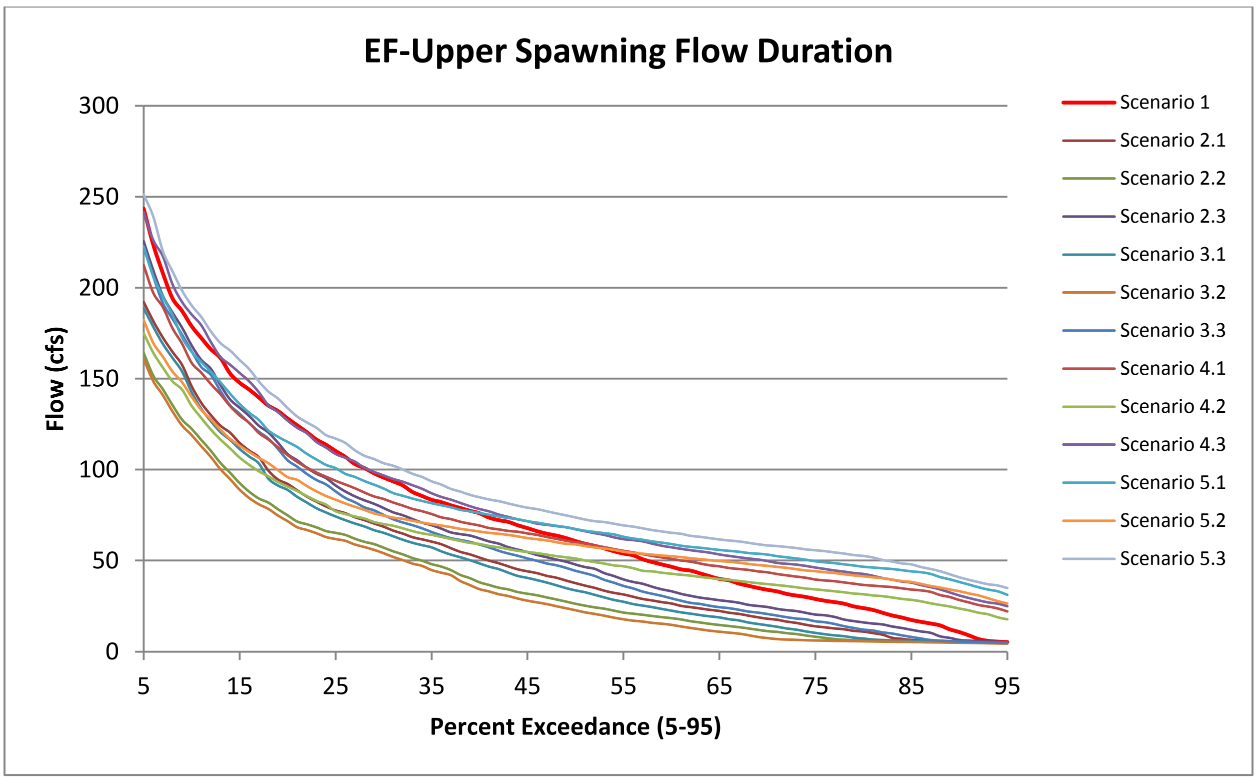
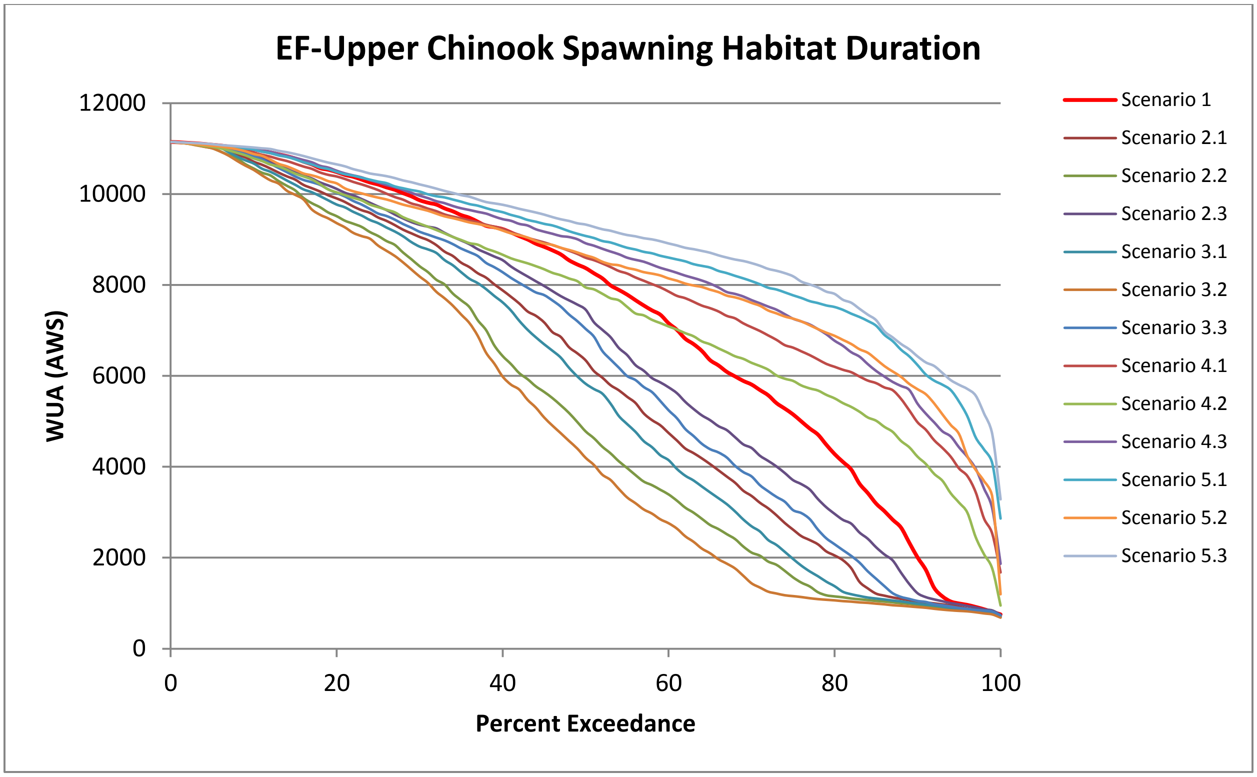


Figure 22. Flow duration curves for Chinook spawning for 13 flow scenarios on the upper East Fork Hood River. Top, 0-100% exceedance; bottom, 5-95% exceedance.



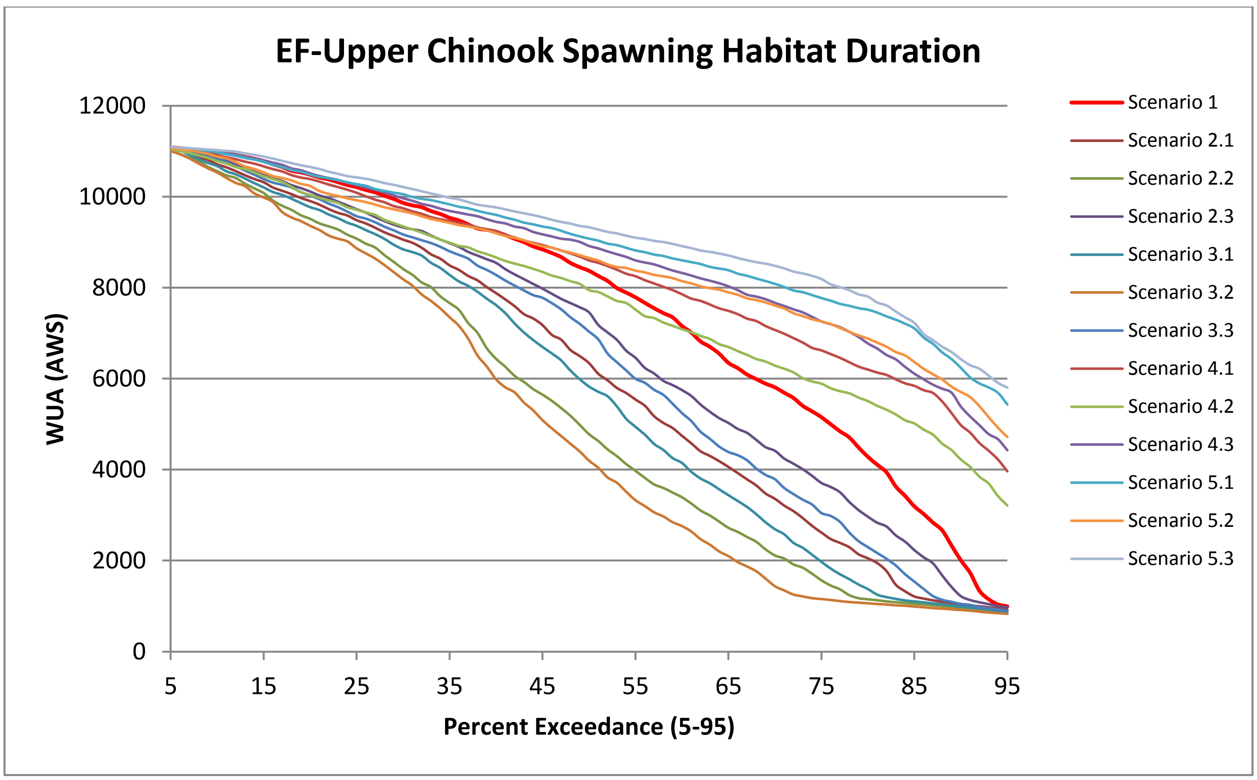


Figure 23. Chinook spawning habitat duration for the upper East Fork Hood River.

Discussion

Although we are reporting on all four streams in a single report, there are four separate instream flow studies; one each for Green Point Creek, Neal Creek, East Fork Hood River, and West Fork Hood River. Even though all four streams are tributaries of the Hood River in the same vicinity, they vary in size and respond differently to hydrologic events. This became painfully evident when we mobilized for the field work targeting the calibration flows. Subsequent to a rain event after which we hoped to measure high flow data, both the East and West Forks responded and became torrents, Green Point Creek responded moderately, and Neal Creek flow barely increased. Of course the elevation, size, and orientation of each watershed are responsible for the different hydrologic responses to the same rain event. Likewise, the hydraulic habitat characterized by each instream flow study will vary differently in response climatic induced changes in flow.

There is one conclusion common to all streams: the hydraulic habitat index, AWS, indicates low habitat suitability for adult holding in all reaches for all reasonable flows. Low, flat AWS curves indicate that changes in flow have little influence on adult holding habitat. Deep habitats are scarce. If feasible, restoration of holding habitat would have more influence on the availability than changes in flow.

A controversial indication of the AWS/flow relationship for adult and juvenile salmonids in the East Fork is the favourability of low flows (Annex A1 and D). This resulted in changing the Chinook spawning HSC for the larger East and West Forks from the MFID HSC to the WDFW River HSC. It was noted early in the HSC discussion (Annex A) that the MFID Chinook spawning HSC indicated shallow suitability. Although appropriate for the smaller streams, the shallow suitability was not appropriate for the larger streams. No rational changes could be made to the juvenile or fry HSC. Analysis of the depth and velocity components of the transect data show that the East Fork reaches (particularly the Upper site) are shallow and fast limiting suitability at higher flows (Annex A1). Recent channel changes and aggradation may contribute to this. Expansion of the reaches to include more of the river and additional transects would will help determine if the AWS/flow relationships are influenced by sites randomly selected.

Instream flow studies rarely answer the question, "What is the best flow?" That question is answered by balancing biological, social, and economic needs. Even when considering only a single species, the index of hydraulic habitat for different life-stages will respond differently to changing flow and no one flow will be the best for all life-stages. The results of these instream flow studies provide tools to assess the biological impacts to hydraulic habitat for the species of interest in each stream. The primary tools for assessing responses to changing flow are the Excel files in Annexes B1 through B5. Each file contains the results for one study reach. Each specie/life-stage habitat time series exceedance statistics and habitat duration graphs are presented in separate worksheets. The habitat duration graphs are presented both as a group of all climate scenarios and as interactive graphs enabling the user to select a scenario to compare to the historical graph. The user can select any one of the 12 climate altered scenarios to compare with the historical scenario. Each of the graphs are also presented including all exceedance values (0% to 100%) and the 5% to 95% range of exceedance values. The 5% to 95% graph eliminates the extremes and enables the range scale to be reduced for greater resolution of the graphs when comparing scenarios.

An overview of the instream flow studies and detailed comparisons of the climate scenarios and habitat time series for Chinook spawning and Chinook juvenile rearing in the Upper East Fork Reach is presented in Annex C, the final presentation to the HRCWPG. The presentation relies heavily on raster plots, a new way to visualize the time series data set. In presentation mode, the user can toggle between two comparative raster plots on the same slide and see where and when changes to the raster hydrograph and hydraulic habitat index occur anywhere in the time series. Another use of the raster plot is to plot the difference in habitat index values between a climate scenario and the historical record. Figure 24 depicts decreases in Chinook rearing AWS comparing the future 5.3 climate scenario to the historical record for most of the East Fork Hood River time series. However, increases in AWS due to scenario 5.3 occur in the summer concurrent with low flow and the lowest habitat values. The increases in habitat values, although much less frequent, may be of greater biological significance occurring in a potential habitat bottleneck. This is further demonstrated by Figures 25 and 26. The times when the 50% AWS value (historical) are equalled or exceeded are plotted with a black dot over the raster hydrograph of the historical (Figure 25) and 5.3 (Figure 26) scenarios. The July through September low habitat values in the historical scenario (Figure 25) correspond to dry periods without the black dot overlay. Those low AWS values are not existent in the 5.3 scenario summer (Figure 26).

It is important to note that for a flow prescription in any of these streams, additional habitat mapping and potentially additional transects will be required to determine the applicability of the AWS/flow relationship to reaches not habitat mapped in this study. Due to available funding each reach was limited to one mile of stream. Many considerations were included in the reach selection process and reaches that are productive and representative were chosen. This does not, however, guarantee that each reach will represent the entire stream. Additional habitat mapping will either verify the representativeness or indicate the need for additional transects.

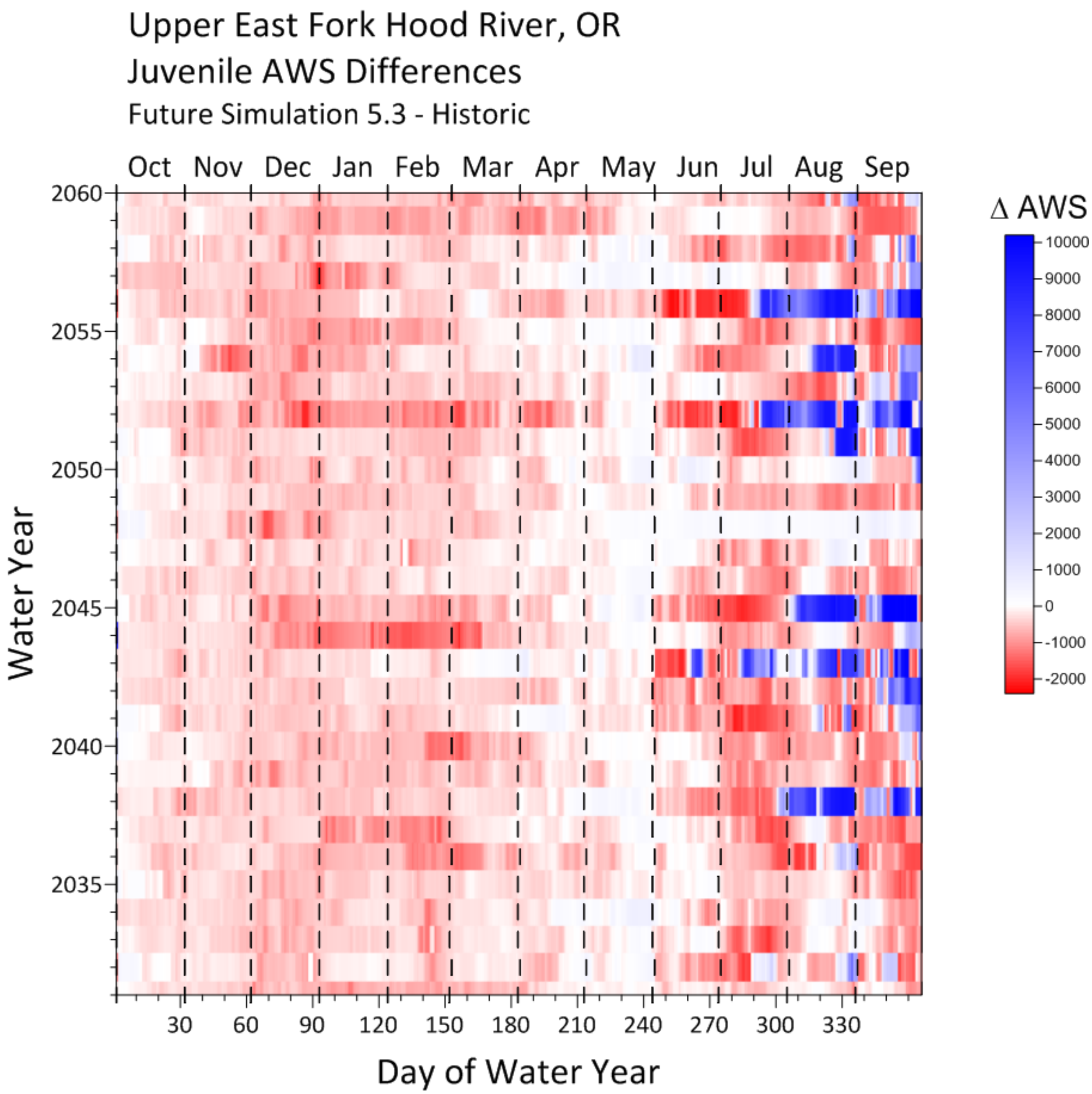


Figure 24. Change in AWS between the historic climate scenario and scenario 5.3 for Chinook rearing habitat in the East Fork Hood River.

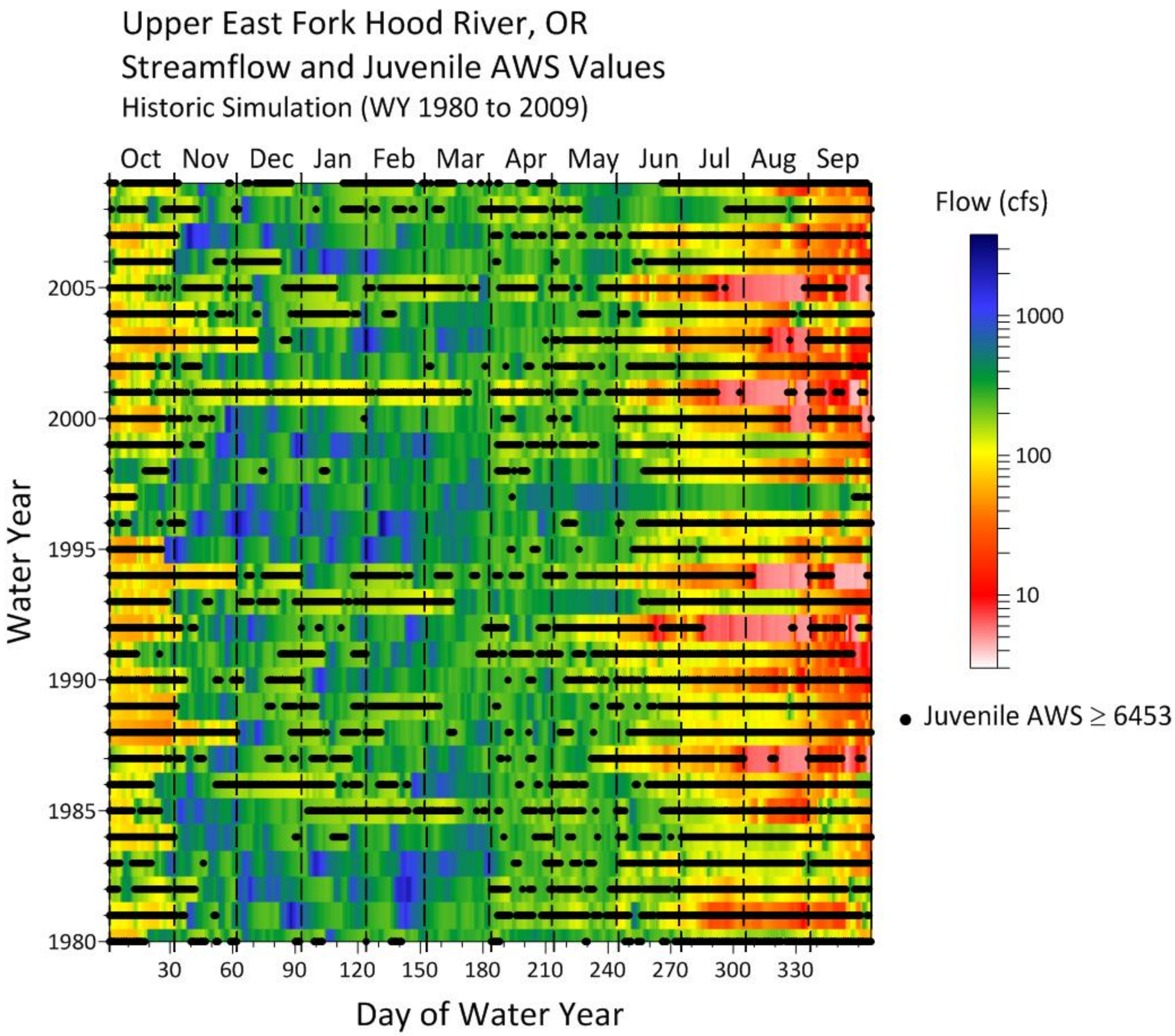


Figure 25. Upper East Fork Hood historical raster hydrograph with black dots plotted for each day that the AWS is greater or equal than the 50% exceedance value for juvenile Chinook rearing.

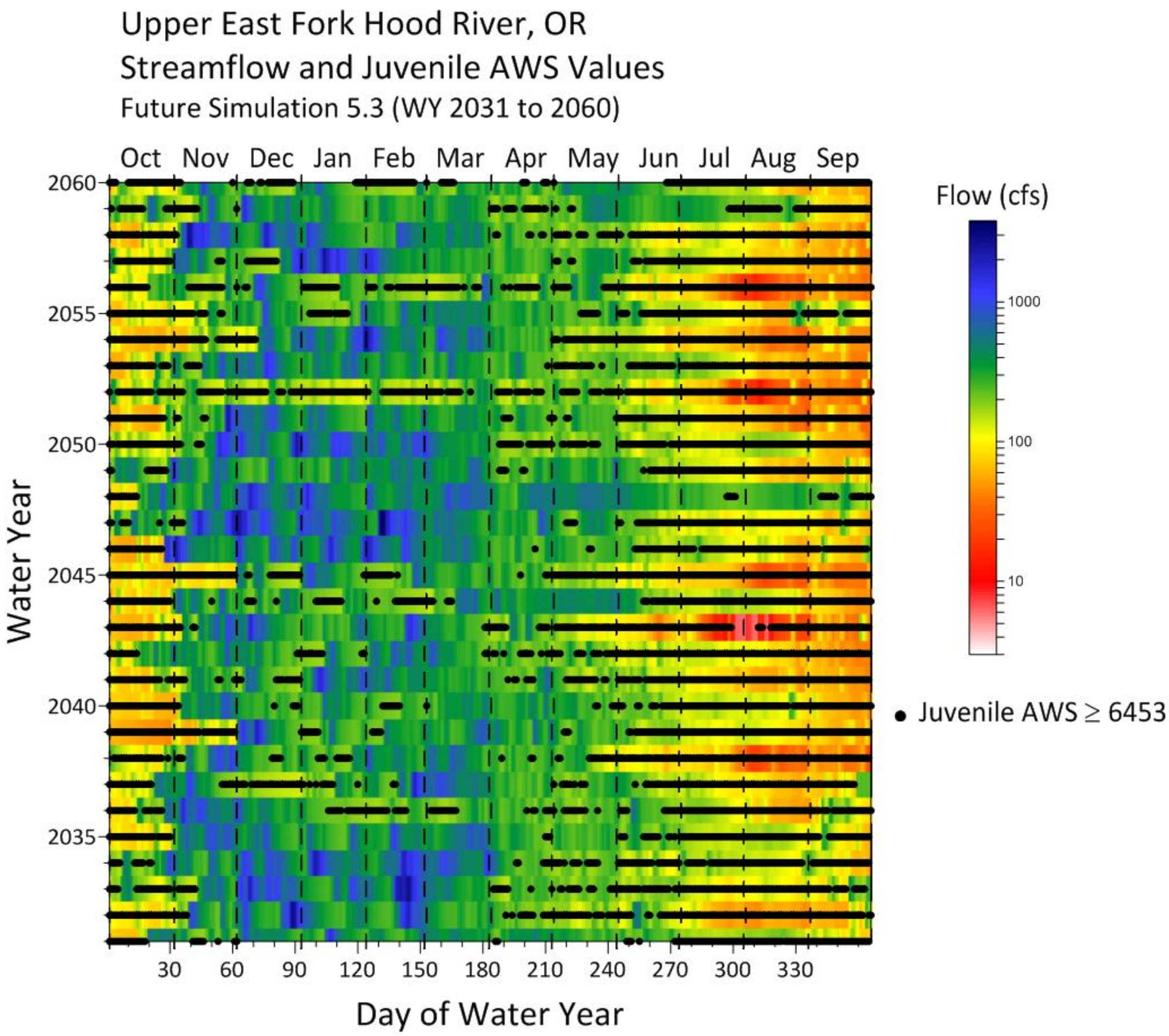


Figure 26. Upper East Fork Hood climate scenario 5.3 raster hydrograph with black dots plotted for each day that the AWS is greater or equal than the 50% exceedance value for juvenile Chinook rearing.

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Appendix A: Habitat Mapping

Appendix B: Transect Profiles, and Calibration Flow Velocities and Water Surface Elevations

Appendix C: PHABSIM Calibration Summaries

Appendix D: Simulated Water Surface Elevations and Velocities

Appendix E: Tabular AWS Values