Determination and Evaluation of Habitat – Flow Relationships in the Sultan River, Washington
- Sultan River Instream Flow Study – RSP 3 -

Prepared for:

Public Utility District No. 1
of Snohomish County
and
City of Everett

Prepared by:

R2 Resource Consultants, Inc.
15250 N.E. 95th Street
Redmond, Washington 98052

March 19, 2009

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Prepared by:

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EXECUTIVE SUMMARY

This report presents the results of the Sultan River Instream Flow Study completed by R2 Resource Consultants (R2) in accordance with Revised Study Plan 3 (RSP3). The need for the study was identified during stakeholder consultations as part of the Federal Energy Regulatory Commission (FERC) Integrated Relicensing Process (ILP) for the Henry M. Jackson Hydroelectric Project (Project) (FERC # 2157). The study focused on the following three operational reaches of the Sultan River, that are regulated to varying degrees and amounts by Project related operations:

- Operational Reach 3 – Culmback Dam to Diversion Dam: flows within this 6.8 mile reach of the Sultan River are controlled by releases from Culmback Dam, which under current operations requires a release flow of 20 cubic feet per second (cfs) directly below the dam. These minimum flow releases are supplemented via downstream flow accretion as well as tributary inflow. Because there are no upstream fish passage facilities at the Diversion Dam, anadromous salmonids are not currently present within this reach.

- Operational Reach 2 – Diversion Dam to Powerhouse: flows within this 5.4 mile reach of river under most conditions are strictly regulated to meet seasonal minimum instream flow requirements that range from 95 cfs to 175 cfs depending on season. These flows are provided via the diversion of water that first passes through two Francis turbines at the Powerhouse and then is transported through the Lake Chaplain pipeline to Lake Chaplain. Some of the water is then used for municipal supply, the remainder transported east via the original water diversion tunnel back to the Sultan River by the Diversion Dam to meet instream flow requirements.

- Operational Reach 1 – Powerhouse to Confluence: flows within the lower 4.3 mile reach of the Sultan River are controlled by releases from the Powerhouse in combination with Reach 2 flows entering the reach. Although minimum flows are specified (range from 165 to 200 cfs), in general, flows are typically higher than these due to flow releases associated with power generation. In addition to mainstem habitat, Reach 1 contains a series of side channels whose connectivity with the main river channel is influenced by flow releases.

The overall objective of the Sultan River Instream Flow Study and its component study elements was to provide a series of quantitative indices for evaluating the effects of flow related existing and alternative Project operational scenarios on resident and anadromous fish habitats within the three study reaches. As specified in RSP3, the primary analytical method used for making this evaluation was the Physical Habitat Simulation (PHABSIM) approach as described by Bovee and Milhous (1978); Bovee (1982); Bovee et al. (1998); and Stalnaker et al. (1995). Chronologically, the study involved completion of the following six steps:

1. Step 1 – Planning and Site Reconnaissance, to familiarize technical personnel with site characteristics and project operations, to select target flows, and to make a preliminary selection of transect locations;
2. Step 2 – Study Reach Delineation and Transect Selection, that included mainstem areas in Reach 3, Reach 2, and Reach 1, and side channel areas in Reach 1;
3. Step 3 – Field Data Collection, that included three trips to collect detailed depth and water velocity data from all transects under a low, mid- and high target flow condition, and two additional trips to collect supplemental water surface elevation (WSE) measurements at two higher flows;
4. Step 4 – Habitat Suitability Criteria Curve Development, that involved development and submittal of an HSC plan for review by stakeholders and agencies, collection of microhabitat data, data analysis, and derivation of modified curves for selected species;
5. Step 5 – Data Analysis and Modeling, that included hydraulic model calibrations for all transects, and subsequent derivation of species and life stage specific habitat indices (expressed as Weighted Useable Area – WUA) versus flow relationships for each site, and, based on channel widths, an estimation of the total habitat area of each species and life stage for each reach under different flow conditions; and
6. Step 6 – Time Series Analysis that linked habitat-flow relationships with hydrologic conditions involving three different flow scenarios (wet, average, and dry years), under Stage 1 (water supply project) and Stage 2 (hydroelectric Project in place) operations. The time series analysis and resulting habitat duration curves provided a means to compare effects of different project operations on the frequency and availability of habitats within the three reaches of the river.

Six mainstem study sites were established on the Sultan River from Culmback Dam to the confluence with the Skykomish River: two sites in Reach 3, two sites in Reach 2, and two in Reach 1. A total of 38 transects were identified as being broadly representative of channel characteristics and the overall composition of habitat within the mainstem Sultan River. Transects were arranged and numbered within each study site from downstream to upstream. Based on the results of detailed habitat surveys (conducted as part of RSP-18) and channel type classifications (defined as part of RSP-22), each transect was considered to be representative of a certain length of the river. River segment lengths were assigned to the nearest transect with similar channel morphology type. Three side channels located within Reach 1 were also evaluated during the study. The assessment of side channel habitats in this study focused on determining a) the relationship of habitat quantity within the side-channel to flow in the side-channel; and b) relationship of flow in mainstem river to flow in the side-channel; i.e., connectivity. A PHABSIM type analysis involving transect placement and measurement conducted in concert with the mainstem study was completed to address the flow-habitat quantity component; surveying of water surface and bed elevations at the inlets of each side channel was used to determine mainstem connectivity. Field data were collected at each transect under a series of five test flow releases. Habitat simulations were subsequently completed using the HABTAV habitat simulation modeling program. Output from the hydraulic simulation modeling was used in conjunction with modified and Fallback HSC criteria to simulate habitat conditions for selected target fish species including Chinook (*Oncorhynchus tshawytscha*), coho (*O. kisutch*), pink (*O. gorbuscha*), and chum (*O. keta*) salmon, and steelhead (*O. mykiss*), sea-run cutthroat (*O. clarki*), resident rainbow (*O. mykiss*) and cutthroat (*O. clarki*) trout.

The study resulted in the development of a series of habitat-flow relationships for each operational reach of the mainstem Sultan River, as well as for the three side channels in the lower reach (Reach 1). Such relationships can serve as indices of how changes in flow may influence the quantity of habitats of various target fish species and life stages. Relative to flow connectivity in the side channels, the study also defined the relationship of mainstem flow to side channel flow and determined the amount of surface areas available in each. In addition, time series and habitat duration analysis were completed that estimated the amounts of habitat for a given species and life stage that would occur under both Stage 1 and Stage 2 conditions for three different water year types. The information provided from this study should be useful for evaluating tradeoffs relative to gains in habitat versus changes in flow both on a reach scale basis as well as for the overall system, In combination with information provided in a number of other studies, the results can also be used for identifying and evaluating potential protection, mitigation and enhancement measures.

1. INTRODUCTION

This report presents the results of the Sultan River Instream Flow Study completed by R2 Resource Consultants (R2) in accordance with Revised Study Plan 3 (RSP3). The need for the study was identified during stakeholder consultations as part of the Federal Energy Regulatory Commission (FERC) Integrated Licensing Process (ILP) for the Henry M. Jackson Hydroelectric Project (Project) (FERC # 2157). The study is one of 21 others that were proposed by the Public Utility District No. 1 of Snohomish County (District) and the City of Everett, Washington (City), and that were approved by the FERC on October 12, 2006.[1]

The Sultan River Instream Flow Study was requested in 2006 by several resource agencies including the Washington Department of Fish and Wildlife (WDFW), Washington Department of Ecology (Ecology), U.S. Forest Service (USFS), National Marine Fisheries Service (NMFS), and the U.S. Fish and Wildlife Service (USFWS), as well as the Tulalip Tribes to identify the types and amounts of habitat potentially available under different flow conditions to fish species in three reaches of the Sultan River influenced by the Project operations. Depending on location, such species may include Chinook (*Oncorhynchus tshawytscha*), coho (*O. kisutch*), pink (*O. gorbuscha*), and chum (*O. keta*) salmon, steelhead (*O. mykiss*), sea-run cutthroat (*O. clarki*), resident rainbow (*O. mykiss*) and cutthroat (*O. clarki*) trout, and bull char (*Salvelinus confluentus*). The three reaches, which for purposes of this report have been termed Operational Reaches since the flows within each are all influenced by the Project, include Reach 3 which extends from Culmback Dam at River Mile (RM) 16.5 to the Diversion Dam at RM 9.7, Reach 2 extending from the Diversion Dam to the Powerhouse (RM 4.3), and Reach 1 from the Powerhouse to the confluence with the Skykomish River (Figure 1-1). Flows within these reaches are regulated to varying degrees and amounts by operations of the Project, which are generally described below and more specifically so in Section 2.2:

- Operational Reach 3 – Culmback Dam to Diversion Dam: flows within this 6.8 mile reach of the Sultan River are controlled by releases from Culmback Dam, which under current operations requires a release flow of 20 cubic feet per second (cfs) directly below the dam. These minimum flow releases are supplemented via downstream flow accretion

[1] See Public Utility District No. 1 of Snohomish County and City of Everett. 2006. Revised Study Plans and Studies Not Proposed. Henry M. Jackson Hydroelectric Project, FERC 2157. In accordance with 18 CFR §5.13

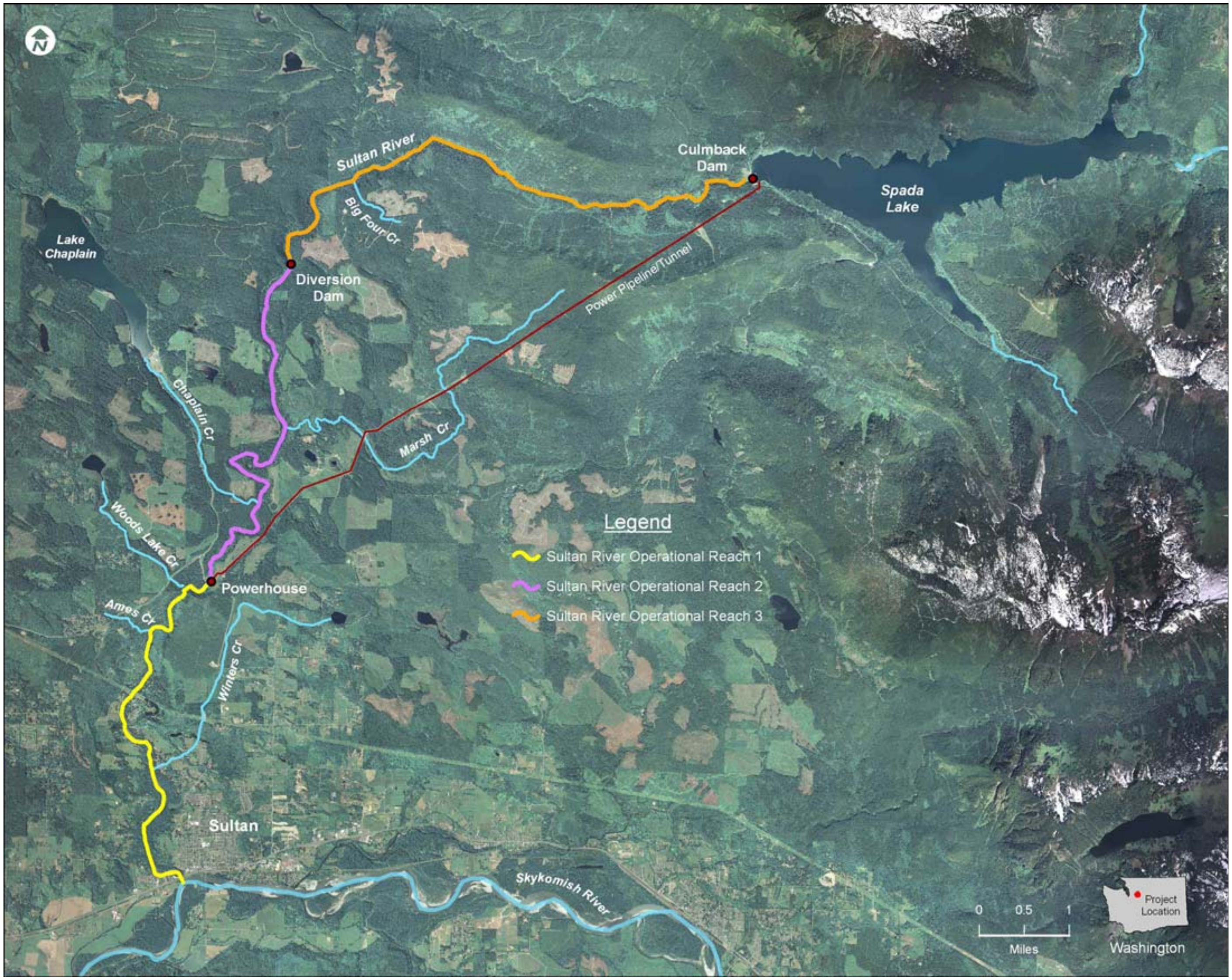


Figure 1-1. Site map depicting locations of Project facilities, operational reaches, and major tributaries to the Sultan River, Washington.

as well as tributary inflow. Because there are no upstream fish passage facilities at the Diversion Dam, anadromous salmonids are not currently present within this reach.[2]

- Operational Reach 2 – Diversion Dam to Powerhouse: flows within this 5.4 mile reach of river under most conditions are strictly regulated to meet seasonal minimum instream flow requirements that range from 95 cfs to 175 cfs depending on season. These flows are provided via the diversion of water that first passes through two Francis turbines at the Powerhouse and then is transported through the Lake Chaplain pipeline towards Lake Chaplain. Some of the water is then used for municipal supply and released into Lake Chaplain, the remainder is transported east via the original water diversion tunnel back to the Sultan River by the Diversion Dam to meet instream flow requirements. Downstream accretion and tributary flows contribute to the total flows in this reach.
- Operational Reach 1 – Powerhouse to Confluence: flows within the lower 4.3 mile reach of the Sultan River are controlled by releases from the Powerhouse in combination with Reach 2 flows entering the reach. Although minimum flows are specified (range from 165 to 200 cfs), in general, flows are typically higher than these due to flow releases associated with power generation. Downstream accretion and tributary flows likewise contribute to the total flows in this reach. In addition to mainstem habitat, Reach 1 contains a series of side channels whose connectivity with the main river channel is influenced by flow releases.

A more detailed description of the physical and hydrologic characteristics of each reach is presented in Section 2.1; details on the fish species composition within each reach is found in Section 2.3.

1.1 STUDY OBJECTIVES

The overall objective of the Sultan River Instream Flow Study and its component study elements is to provide a series of quantitative indices for evaluating the effects of flow related existing and alternative project operational scenarios on resident and anadromous fish habitats within the three study reaches. As specified in RSP3, the primary analytical method used for making this evaluation was the Physical Habitat Simulation (PHABSIM) approach as described by Bovee and Milhous (1978); Bovee (1982); Bovee et al. (1998); and Stalnaker et al. (1995). This method provides a means to incrementally evaluate changes in the amount of habitat of different fish species and life stages resulting from changes in flow, and has been widely used in assessing flow regulation effects associated with hydroelectric projects (Annear et al. 2004).

[2] The feasibility of providing upstream passage at the Diversion Dam is the subject of RSP20 the results of which are presented in CH2M HILL 2008a. Fish passage feasibility at the Sultan River Diversion Dam, Phase 2, Fish Passage Assessment, Draft Report. Prepared for Public Utility District No. 1 of Snohomish County.

The study was designed to assist in answering the following technical questions related to evaluating operational and flow regulatory effects of the Project on fish populations in the Sultan River:

- What are the species and lifestage specific habitat – flow relationships in each of the three mainstem reaches?
- How much habitat of a given fish species and life stage is available in each of the three mainstem reaches under existing operations and instream flow requirements of the Project?
- How much habitat of a given fish species and life stage would be available in each reach of the three mainstem reaches if the Project was not in place?
- What are the incremental gains or losses of habitat for a given fish species and life stage corresponding to incremental flow increases in each reach above those provided under existing operations?
- How much anadromous salmonid habitat would be available in Reach 3 under varying flow conditions if fish passage facilities were provided?
- What mainstem flows in Reach 1 provide connectivity to adjoining side channel areas?
- What are the species and life stage specific habitat – flow relationships in side channel areas associated with Reach 1?

1.2 LINKAGES TO OTHER STUDIES

The Sultan River Instream Flow Study is closely linked to and has relied on results from a number of other RSPs, including and in particular the following:

- Stillwater Sciences and Meridian Environmental. 2008a. Study Plan 18: Riverine, Riparian and Wetland Habitat Assessment of the Sultan River below Culmback Dam, technical report. Prepared for Snohomish County Public Utility District No. 1 and City of Everett.
    - *RSP3 utilized habitat mapping results generated from RSP18.*
- R2 Resource Consultants. 2008a. Study Plan 23. Indicators of Hydrologic Alteration/Range of Variability Analysis (IHA/RVA) in the Sultan River Downstream of Culmback Dam. Prepared for Public Utility District No. 1 of Snohomish County and City of Everett.

  - *RSP3 relied on hydrologic data and analysis generated from RSP23.*

- R2 Resource Consultants. 2008b. Study Plan 5. Juvenile Fish Occurrence Life History and Distribution, Progress Report. Prepared for Public Utility District No. 1 of Snohomish County.

  - *RSP3 relied on selected fish distribution data being collected as part of RSP5 for confirming habitat utilization within Reaches 2 and 1 and adjoining side channels.*

- Stillwater Sciences and Meridian Environmental. 2008b. Study Plan 22: Sultan River Physical Process Studies, draft technical report. Prepared for Snohomish County Public Utility District No. 1.

  - *RSP22 provides a physical process – flow relationship context that will need to be considered in addition to the habitat – flow relationship context provided in RSP3.*

Results from RSP3 have or will provide input to several other studies associated with evaluating habitat – flow considerations within the different reaches of the Project. These include:

- CH2M HILL. 2008a. Fish Passage Feasibility at the Sultan River Diversion Dam, Phase 2, Fish Passage Assessment, Relicensing Study Plan No. 20. Draft report. Prepared for Public Utility District No. 1 of Snohomish County.

  - *Results of habitat-flow modeling within Reach 3 from RSP3 provided input to RSP20 for estimating potential anadromous salmonid production within the reach if upstream fish passage facilities were provided.*

- CH2M HILL. 2008b. Water Quality Parameter Study. Relicensing Study Plan No. 1. Draft report. Prepared for Public Utility District No. 1 of Snohomish County.

  - *Results of hydraulic modeling within Reach 3 from RSP3 provided input to RSP1 for developing an SNTEMP temperature model for evaluating flow – temperature relationships and potential effects on anadromous salmonid production within the reach if upstream fish passage facilities were provided.*

- Confluence Research and Consulting. 2008. Flow Recreation Study. Study Plan No. 14. Draft report. Prepared for Public Utility District No. 1 of Snohomish County.

  - *Results of RSP3 can be used in evaluating potential effects of whitewater boating flows on fish habitats within each of the study reaches.*

Although linkages exist between this study and those noted above, this report does not attempt to synthesize the results of these into an overall assessment of flow related effects of the Project on each of the individual study elements. The synthesis of that information will be completed and presented in the Preliminary License Proposal.

1.3 REPORT ORGANIZATION AND CONTENT

Organizationally, the report contains five main sections:

- Section 1 – INTRODUCTION (this section): provides the context for the study, lists study questions and objectives, and describes linkages to other studies.
- Section 2 – BACKGROUND: provides important background information relevant to the Project including: a Description of the study area and study reaches; a review of important fishery resources within the basin that includes distribution and life history information; a review of the Project's facilities and operations and how these influence flow conditions within each reach; a discussion of the Sultan River hydrology both with and without the Project in place; and a discussion of the current instream flow requirements mandated under the existing license, and a brief summary of studies that resulted in the specified flows.
- Section 3 – METHODS: describes the six (6) steps involved in completing the study including Step 1 – Site Reconnaissance; Step 2 – Study Reach Delineation and Transect Selection; Step 3 – Field Data Collection; Step 4 – Habitat Suitability Criteria Curve Development; Step 5 – Modeling; and Step 6 – Time Series Analysis.
- Section 4 – HABITAT MODELING: presents the overall results of the habitat modeling and times series analysis. The section is organized first by presenting the PHABSIM results for the three mainstem reaches on a site, species, and life stage basis followed by a wet, normal, and dry time series analysis with and without the Project in place; and then results for the side channels that includes surface area, lineal, and PHABSIM estimates.
- Section 5 – SUMMARY AND DISCUSSION.
- Section 6 – REFERENCES.

The report also contains the following appendices:

- Appendix A – Transect Selection Presentation – June 12, 2008
- Appendix B – Target Flow Memorandum – June 11, 2007

- Appendix C – Habitat Suitability Criteria (HSC) – includes a) Proposed Habitat Suitability Criteria (HSC) Curves for Application in Habitat-Flow Modeling for the Sultan River Instream Flow Study – RSP 3, June 5, 2008; b) Technical Memorandum: Sultan River Instream Flow Study – HSC Preference Analysis and Revised Steelhead and Chinook Curves, July 31, 2008; c) HSC curves used in habitat-flow modeling
- Appendix D – Habitat:Flow Relationships and Time Series Analysis
- Appendix E – Transect Photographs
- Appendix F – Transect Cross Sectional Profiles and Model Calibration Details
- Appendix G – Field Notes

2. BACKGROUND INFORMATION

This section presents important background information that describes the physical, biological, hydrologic, and operational setting of the instream flow study. Such information is needed in order to understand the rationale behind the methods and analysis used in completing the study, and as well, to facilitate the interpretation of study results.

2.1 DESCRIPTION OF STUDY AREA AND STUDY REACHES

The Henry M. Jackson Project is located on the Sultan River, approximately 24 miles east of Everett, Washington, in south central Snohomish County. From its headwaters near Vesper Peak on the western slope of the Cascade Mountains, the Sultan River flows west for approximately 19 miles, then south-southwest for 11 miles to its confluence with the Skykomish River at the City of Sultan (RM 34.4). The Skykomish River drains the northern 835 square miles of the Snohomish River Basin, the second largest river basin draining into Puget Sound (Haring 2002).

The basin is bounded on the east by the Cascade Mountains, on the north and south by lateral ridges extending westward from the Cascade crest, and on the west by the Puget Sound lowlands. Elevations in the basin range from the 6,617-foot summit of Del Campo Peak to 130 feet at the confluence of the Sultan and Skykomish rivers. Major tributaries to the Sultan River above Culmback Dam include the South Fork Sultan River, North Fork Sultan River, Elk Creek, and Williamson Creek. Downstream of Culmback Dam, major tributaries include Big Four Creek, Marsh Creek, Chaplain Creek, Woods Creek (drains Woods Lake), Ames Creek, and Winters Creek (Figure 1-1).

In the headwaters upstream from Elk Creek (RM 22.8), the Sultan River flows through a narrow steep-sloped, densely forested valley. The river channel is relatively steep and narrow, containing numerous small falls, cascades, and rapids, and a few short pool-riffle stretches. From Elk Creek downstream to Spada Lake (formed by Culmback Dam), the channel gradient is moderate with only a few steep areas.

Downstream of Culmback Dam (RM 16.5), the Sultan River flows through a deep gorge for nearly 14 miles. The steep side slopes above the channel are densely forested with conifer and mixed deciduous growth. The river channel in this reach is relatively high gradient and confined, containing numerous cascades and rapids separated by short pool-riffle, stretches. Much of the streambank is sheer rock face or large rock cuts (Williams et al. 1975). The City's Diversion Dam at RM 9.7 historically directed a portion of the river's flow to the City's water supply reservoir, Lake Chaplain. While that method of diversion remains in place and is used when maintenance of the Project or other reasons require, water now is normally supplied to Lake Chaplain through the Lake Chaplain pipeline after passing through the Project Powerhouse (RM 4.6). Near RM 3, the Sultan River emerges from the canyon reach onto a broad, relatively flat valley floor containing intermittent stands or strips of deciduous trees, underbrush, and some mixed conifers. The river channel in this reach has a moderate gradient with a number of split channel sections.

2.1.1 Study Area

For relicensing purposes, the Study Area as defined by the District includes approximately 16.5 miles of the Sultan River from Culmback Dam to its confluence with the Skykomish River. In general, the Sultan River from Culmback Dam to its confluence travels through three distinct process reaches (PR) based on physical characteristics and topographic features (see Figure 2-1, page 7 in Stillwater Sciences and Meridian Environmental 2008b). These include the lowermost process reach (PR 1) comprised of a low gradient alluvial valley that includes a broad floodplain (RM 0 to 3), a terrace bounded valley process reach (PR 2) extending from RM 3 to RM 11, and a relatively high gradient V-shaped valley reach (PR 3) from RM 11 to RM 16.5. Side channels are prevalent in the alluvial valley reach area as a result of vegetation encroachment into areas that were once part of the active channel (RSP 22).

Land ownership within the Study Area consists of a mixture of federal, state, and local government, and private holdings. Land use activities in the Project Area are predominately timber production and forest recreation with a limited amount of agricultural and rural residential development.

As noted above, there are two dams in the Sultan River Basin – Culmback Dam and the City of Everett's Diversion Dam (Figure 1-1). Culmback Dam is located at RM 16.5 and forms Spada Lake which has a storage capacity of 153,260 acre-feet. The water stored in Spada Lake is used for hydroelectric generation, municipal water supply, and to meet instream flow requirements downstream of Culmback Dam. The Diversion Dam is located at RM 9.7 and creates a small headpond measuring only a few acres in size. Both of these dams preclude upstream fish passage. Additional information on operation of these facilities and the effect on flows in the Sultan River can be found in RSP 23 (R2 2008a).

2.1.2 Sultan River Study Reaches

Operationally, and for purposes of this study, the Sultan River has been divided into three reaches (Operational Reaches), demarcated by physical structures that serve to regulate flows within the system. For consistency between relicensing studies, descriptions of operational reaches and channel characteristics of each reach have borrowed heavily from RSP 18 (Stillwater Sciences and Meridian Environmental 2008a), RSP 22 (Stillwater Sciences and Meridian Environmental 2008b), and the Pre-Application Document (PAD) (PUD #1 of Snohomish County and City of Everett 2005). Figures 1-1 and 2-1 illustrate the geographic location of each of the operational reaches.

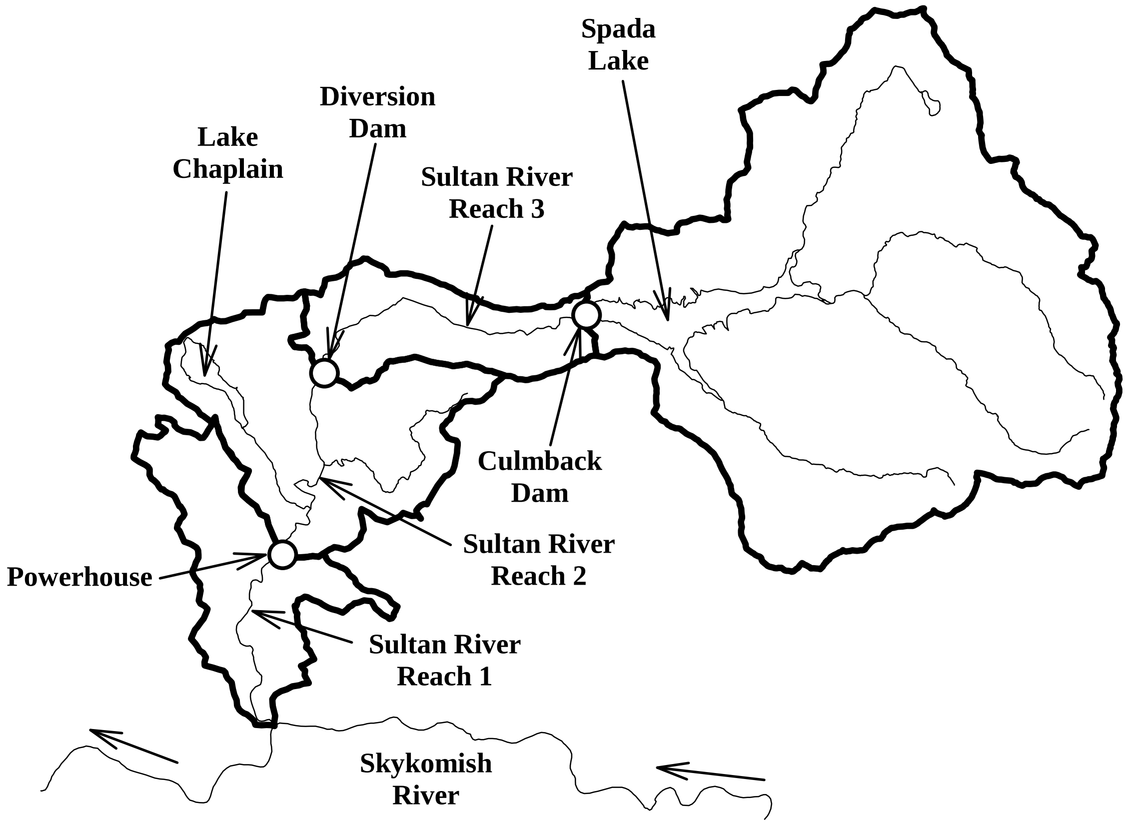


Figure 2-1. Study reaches (Operational Reaches) 1, 2, and 3 on the Sultan River, Washington below Culmback Dam.

2.1.2.1 Operational Reach 3

The upstream most Operational Reach (Reach 3) extends for approximately 6.8 miles from Culmback Dam (RM 16.5) to the Diversion Dam (RM 9.7). Reach 3 is referred to as the bypass reach and is best described as a high gradient, highly confined bedrock gorge characterized by higher rates of sediment transport compared to subsequent downstream reaches. Flows in Reach 3 are generally controlled by releases from Culmback Dam with a year-round minimum instream flow release of 20 cfs. Lateral inflows (side flows) can be significant during short duration storm events. Big Four Creek is the primary tributary to this reach, but numerous other intermittent tributaries contribute flow as well.

Channel gradients range from 0.7 to 13.7 percent and average 1.6 percent. Channel gradient becomes progressively steeper in upper portions of the reach with the highest gradient located near (>RM 15.8) Culmback Dam. Fish habitat in the reach as determined by the RSP 18 study is comprised primarily of pool and glide (65%) (Stillwater Sciences and Meridian Environmental 2008a; Figure 2-2). Most of the pool habitat units (38 of 45) were controlled by bedrock formations. Channel substrate was generally coarse with boulder, bedrock, cobble, and large gravels as the dominant substrates. Bankfull channel width averaged approximately 50 feet, and there were approximately 100 pieces (including debris jam pieces) of large woody debris per mile.

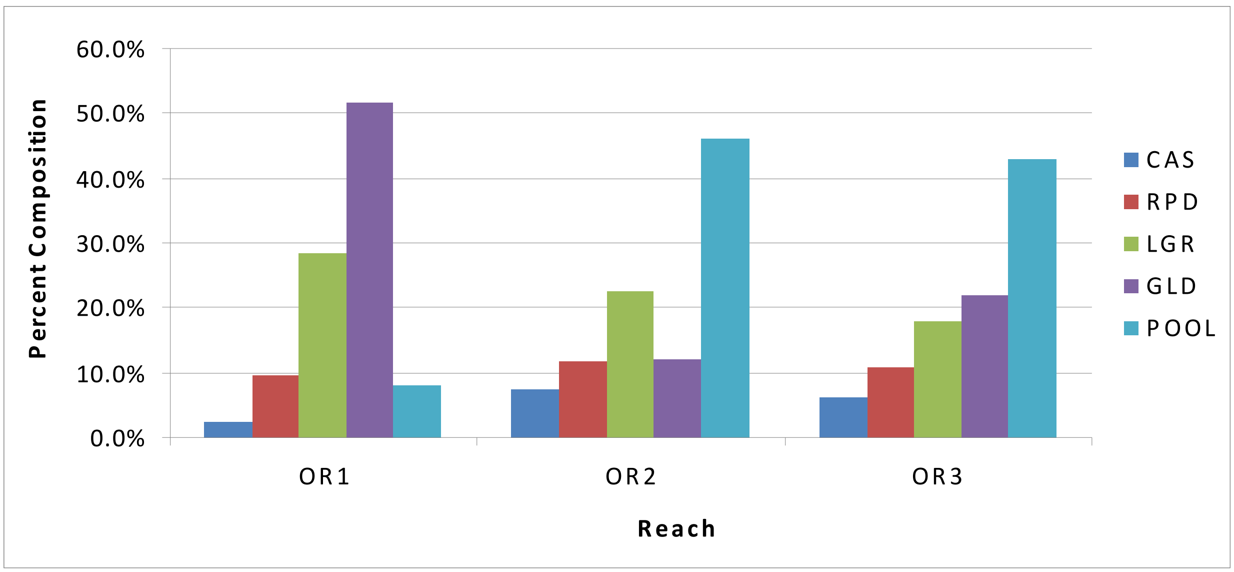


Figure 2-2. Percentage composition of habitat types within each of the three operational reaches (OR) of the Sultan River, Washington. Data and analysis from Stillwater Sciences and Meridian Environmental (2008a). (CAS=cascade, RPD=rapid, LGR, low gradient riffle, GLD=glide).

2.1.2.2 Operational Reach 2

Operational Reach 2 (Reach 2) is located between the Powerhouse (RM 4.5) and the Diversion Dam (RM 9.7) and is approximately 5.4 miles long (Figure 2-2). Median monthly flows (as measured at USGS Gaging Station 12137800) range from 119 to 212 cfs. Flows immediately downstream of the Diversion Dam are a combination of releases from Culmback Dam, accretion flows in the bypass reach, and return flow from Lake Chaplain (RSP 23). Although minimum flows in this reach range between 95 and 175 cfs (Section 2.2) lateral inflows can be significant during short duration storm events.

Reach 2 is largely confined within a narrow, deep canyon with channel gradients ranging from 0.7 to 3.4 percent. Marsh Creek enters from the east and is the major tributary to this section of the river. Of note is that on December 11, 2004, a landslide occurred within a narrow canyon segment of the river just downstream from Marsh Creek at RM 7.6. The landslide, often referred to as the Marsh Creek landslide, presumably, at least temporarily blocked or reduced the upstream passage success of adult anadromous salmonids. Since then, the characteristics and geometry of the landslide have changed to where the results of a recent study (Ruggerone 2008) now suggest that steelhead, Chinook and coho salmon could potentially swim through the existing cascade when minimum flows are about 107 cfs. However, analysis indicated that pink and chum salmon would still not likely be able to pass through this area.

Results of the habitat mapping surveys conducted in 2007 indicated a habitat composition comprised of pools (45.9%), low gradient riffles (22.7%), rapids and glides (11.9% each), and cascades (7.5%) (Stillwater Sciences and Meridian Environmental 2008a) (Figure 2-2). More than two-thirds (43 of 60) of the pool habitat units were controlled by bedrock and boulder substrates. Channel substrates were comprised primarily of boulder, bedrock, cobble, and large gravels. Bankfull channel width averaged nearly 70 feet, and there were just slightly over 160 pieces (including debris jams) of large woody debris per mile (Stillwater Sciences and Meridian Environmental 2008a).

2.1.2.3 Operational Reach 1

Operational Reach 1 (Reach 1) extends approximately 4.3 miles from the confluence with the Skykomish River upstream to the Powerhouse (Figure 2-1). Median monthly flows under existing conditions (as measured at USGS Gaging Station 12138160) range from 219 to 1,442 cfs. Flows immediately downstream of the Powerhouse are a combination of releases from the Diversion Dam, releases from the Powerhouse, and accretion flows in Reach 2. Low flows generally occur in August and September and peak flows occur in November. The upstream most 1.6 miles (referred to as Reach 1B in the PAD) of the reach are deeply incised and largely confined within a bedrock canyon. Widths in this section range from 40 to 160 feet and channel gradients range from 0.7 to 2.9 percent.

The downstream most 2.7 miles of the reach (referred to as Reach 1A in the PAD) are largely unconfined with a broad floodplain and a number of split channel sections. Channel gradients range from 0.2 to 0.7 percent. There are three major (>1,000 feet-long) and several minor side channels located within the reach. Channel widths range from 60 to over 200 feet.

Fish habitat within Reach 1 was comprised of glide (51.7%) followed by low gradient riffles (28.4%), rapid (9.6%), pool (8%), and cascades (2.3%) (Stillwater Sciences and Meridian Environmental 2008a) (Figure 2-2). Channel substrate in the lower portion of Reach 1 was predominately large and small cobble, coarse gravel, and boulder. The number of large woody debris pieces was much lower than the two upstream reaches with fewer than 60 pieces (including debris jams) per mile.

2.2 PROJECT FACILITIES AND CURRENT OPERATIONS

Major facilities of the Project and their influence on the flow conditions within the different operational reaches of the river are presented in this section. Much of the information has been taken directly from various portions of Section 4 of the PAD (Public Utility District No. 1 of Snohomish County and City of Everett 2005).

2.2.1 Project Facilities

2.2.1.1 Culmback Dam

Culmback Dam, located at RM 16.5 on the Sultan River, has a crest elevation of 1,470 feet msl (Figure 2-3). The crest of the dam is 25 feet wide, 640 feet long, and is 262 feet above the original streambed. A concrete morning glory spillway, with an inside diameter of 38 feet, is located within the reservoir approximately 250 feet from the right bank. This spillway has a 94-foot diameter ogee crest, vertical shaft, and a horizontal tunnel section. The morning glory spillway crest elevation is at 1,450 feet msl and is designed to pass the probable maximum flood of 57,790 cfs at elevation 1,464.6 feet, or 5.4 feet below the crest of the dam. Reservoir outlet works consist of two 48-inch-diameter conduits embedded in the concrete plug of the diversion tunnel that join the horizontal tunnel section of the spillway. The downstream ends of the conduits are equipped with three slide gate valves (two 42-inch and one 48-inch) and one 48-inch Howell Bunger valve. A 16-inch diameter pipeline runs through the right side of the dam at elevation 1,408 feet, then along its downstream face. This pipeline provides 20 cfs minimum flow releases when the spillway tunnel is dewatered for maintenance or safety inspections. Normal flow releases are accomplished through a 10-inch cone valve piped upstream of the 48-inch Howell Bunger valve. A 60 kilowatt (kW) turbine generator in the dam outlet works provides onsite electrical power and contributes about 5 cfs to the reach below Culmback Dam. The total flow released by the 10-inch cone valve and the 60 kW turbine generator is 20 cfs. The Powerhouse intake structure is located near the left abutment, approximately 250 feet upstream of the dam. The 110-foot-tall concrete structure has three 20-foot moveable panels. Positioning of these panels allows the selective withdrawal of stored water from various depths to facilitate the control of water temperature in the Sultan River below the Powerhouse and the Diversion Dam.

Figure 2-3. Aerial view of Culmback Dam which forms upper extent of Operational Reach 3 of the Sultan River. Photo from PAD (Public Utility District No. 1 of Snohomish County, and City of Everett).

2.2.1.2 Diversion Dam

The Sultan River Diversion Dam has been in place since 1930, and was originally used to divert water from the Sultan River into Lake Chaplain for the City of Everett's water supply. It is a concrete ogee crest gravity structure that is 25 feet high and 120 feet wide (Figure 2-4). The Diversion Dam creates only a small headpond measuring a few acres in size. Water from Portal 2, which is located at Lake Chaplain, flows into the forebay and is measured through a weir in the main sluice gate. All flow below 280 cfs is routed through this weir. Higher flows are passed over the 120-foot-wide concrete spillway. There are no upstream or downstream fish passage facilities at the Diversion Dam.

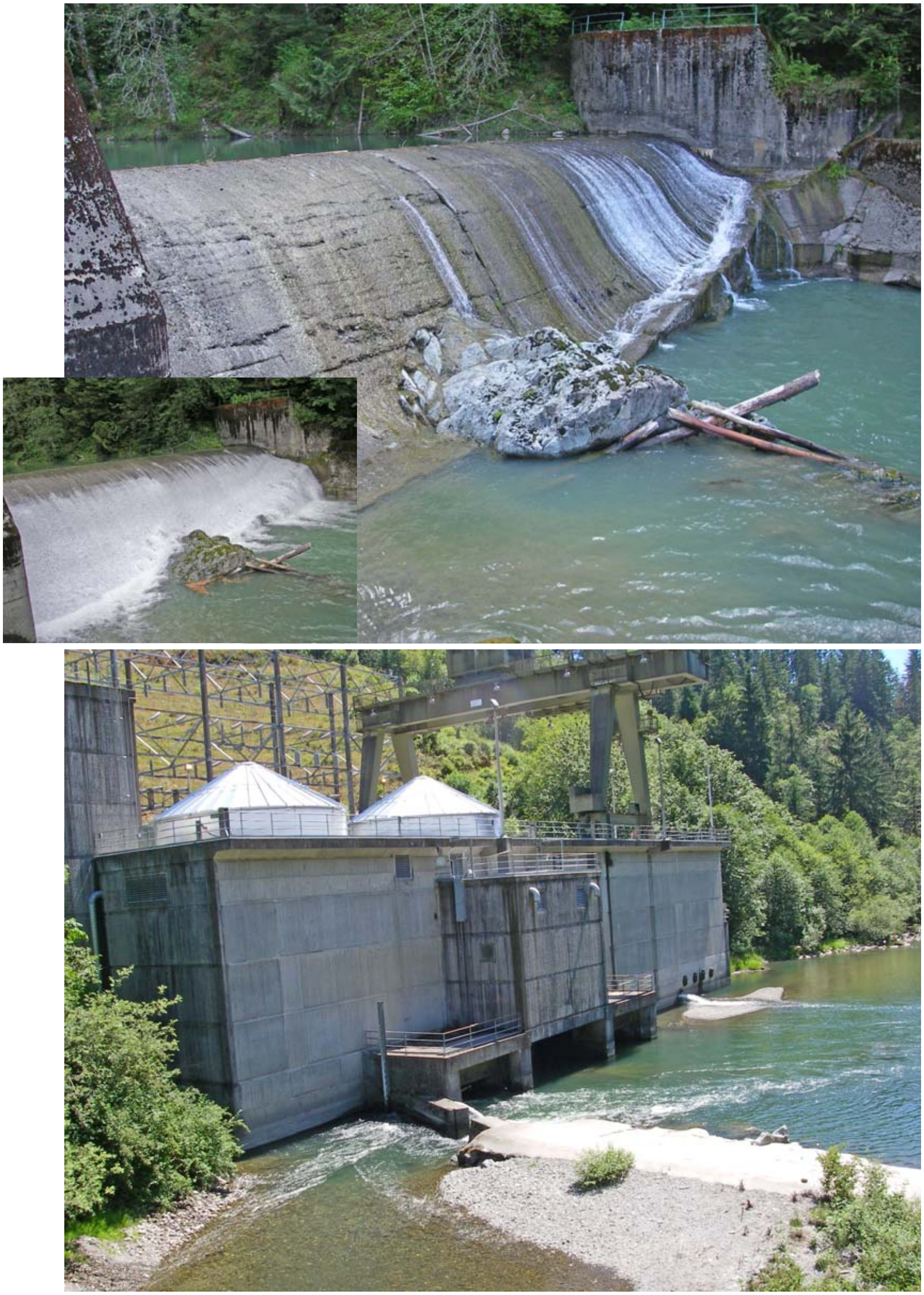


Figure 2-4. Photographs of Diversion Dam (upper photo and inset photo) and Henry M. Jackson Powerhouse (lower photo) on Sultan River, Washington.

2.2.1.3 Powerhouse

A semi-outdoor-type powerhouse is located adjacent to the left river bank at RM 4.3 (Figure 2-4). The structure is reinforced concrete with the top deck at elevation 316 feet, approximately 30 feet above peak river level for a 100-year flood. Two Pelton turbines and two Francis turbines are housed inside on the lower generator floor of the two-story 200-foot by 71-foot structure. The two Pelton turbines discharge water directly into 40-foot-long discharge canals that transport water to the main river channel. The Pelton turbine runners are located 16.25 feet above the floor of the canal. The actual distance between the water surface and the Pelton turbine runners is dependent on discharge and tailrace elevation. During an average water year at average flow the turbine runner is approximately 11.5 feet above the water surface. The Francis turbines re-route a portion of flow to Lake Chaplain and the City's Diversion Dam via a pipeline under the river (the Lake Chaplain pipeline). In response to concerns that at certain flows power generation might cause confusion of adult fish migrating upstream past the Powerhouse, the District constructed and maintains a low-head fish passage berm at the upstream end of the Powerhouse. This berm has a passageway or slot near the Powerhouse to concentrate the up-river flows into an area that is more attractive to and can be more easily detected by migrating fish. The berm has successfully facilitated fish passage upstream of the Powerhouse since its construction in 1983.

2.2.2 Project Operations

Current operations of the Project are best understood by reviewing how the water supply Diversion Dam and facilities in place operated prior to construction of the hydroelectric Project. In 1930, the City of Everett constructed the Diversion Dam that exists today. This dam was used to divert water from the Sultan River through a pipeline and tunnel, west to Lake Chaplain for municipal water supply storage. In 1960, a dual purpose project was conceived that focused on generating power for the District from the waters of the Sultan River, and increasing the City's water supply system to meet growing demands. A license authorizing construction of the Project in two stages was issued on June 6, 1961. Stage 1 (water supply project) was completed in 1965 and involved the construction of Culmback Dam and the creation of a reservoir known as Spada Lake, which increased the City's water supply available from the Sultan River basin. Stage 2 (existing hydroelectric Project in place) was completed in 1984 and involved raising Culmback Dam 62 feet, which increased the size of Spada Lake four times and provided for hydroelectric generation. With completion of the Stage 2 hydroelectric Project facilities in 1984 (which included a raised Culmback Dam, a power tunnel and pipeline, a powerhouse and a Lake Chaplain pipeline from the Powerhouse to Lake Chaplain), the function of the Diversion Dam changed considerably. Prior to the completion of Stage 2, water flowed west from the Diversion

Dam through the tunnel to Lake Chaplain; post-Stage 2, water now flows east through the tunnel between Lake Chaplain and the Diversion Dam. Some of the water diverted from Spada Lake at Culmback Dam is now returned to the Sultan River at the Diversion Dam to provide minimum instream flows below that point for fishery protection and enhancement.

Under current operations, 20 cfs of water is released from Culmback Dam into Reach 3 at all times. The rest of the water diverted from Spada Lake travels through the power tunnel and power pipeline to the Powerhouse. Most of the water delivered to the Powerhouse passes through the Pelton turbines and is returned to the river. However, an amount of water necessary for municipal supply and maintenance of minimum instream flows in the reach below the Diversion Dam is routed through two Francis turbines in the Powerhouse and then through the Lake Chaplain pipeline to the "Portal 2" facilities on the shores of Lake Chaplain. At Lake Chaplain, a portion of the water in the Lake Chaplain pipeline is diverted by means of the "Portal 2" facilities to the lake for municipal water supply. The remainder is transported east via the original water diversion tunnel back to the Sultan River at the Diversion Dam to provide minimum instream flows in the reach between the Diversion Dam and the Powerhouse (Reach 2). As noted above, prior to the Stage 2 raising of Culmback Dam and construction of the hydroelectric facilities completed in 1984, Sultan River flows were diverted by the City's Diversion Dam in a westerly direction through the tunnel into Lake Chaplain to meet the City of Everett's municipal water supply needs. Under existing normal project operations, flows through the diversion tunnel are now reversed. Water from Spada Lake can generate power and be transported by pipeline back up to Lake Chaplain and the Diversion Dam because Spada Lake is approximately 700 feet higher in elevation than Lake Chaplain and the Diversion Dam.

Occasionally, when storm events cause natural inflows within the reach between Culmback Dam and the City's Diversion Dam to exceed the combined total flows needed to meet both the City's water supply requirements and established minimum instream flows below the Diversion Dam, the Diversion Dam will be made to operate in its original manner. At these times, water for municipal supply will be diverted from the Sultan River by the Diversion Dam and routed westerly through the tunnel to Lake Chaplain. Remaining flows in the river are allowed to pass over the Diversion Dam to provide required instream flows into Reach 2. The Powerhouse then routes water diverted from Spada Lake through only the larger Pelton units for more efficient power generation, and then immediately returns the water to the river (Figure 2-5).

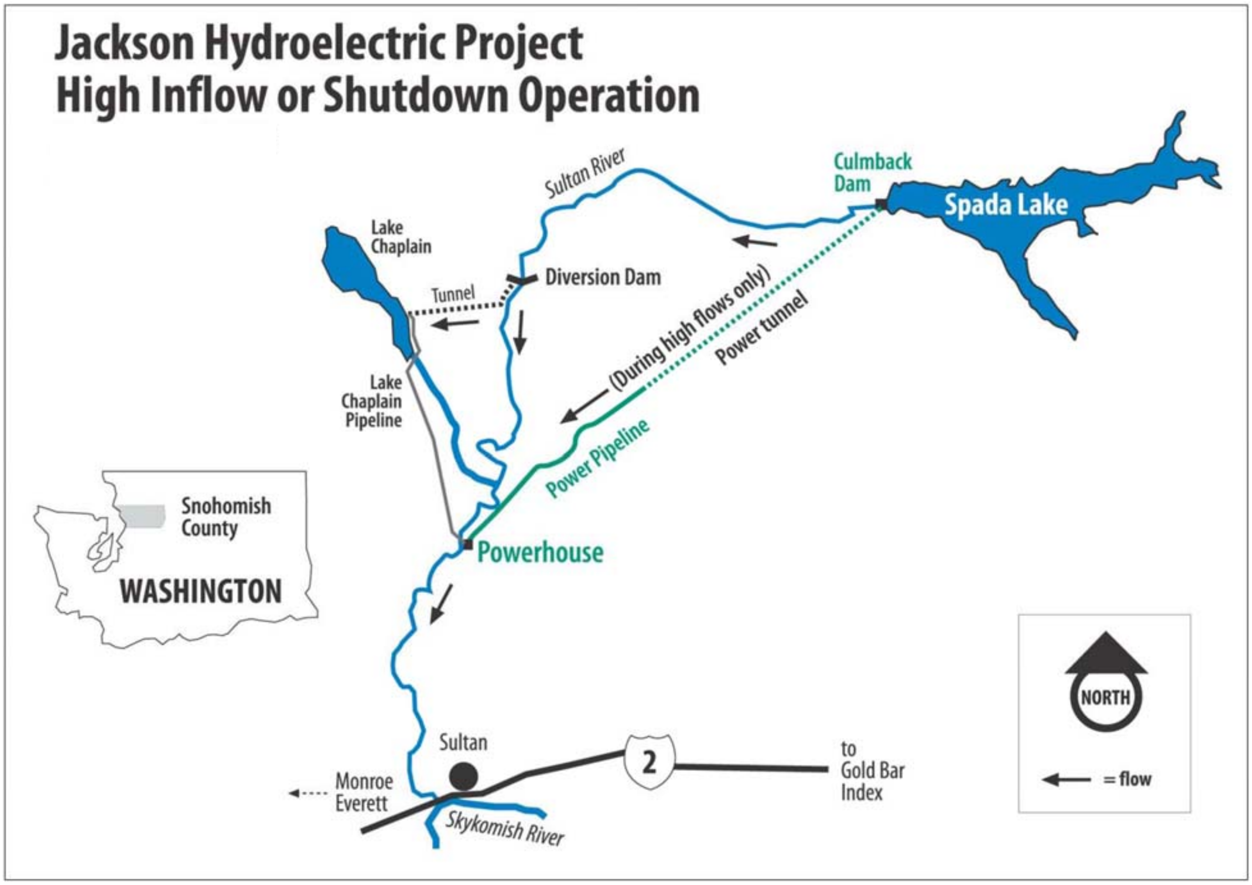


Figure 2-5. Schematic of Jackson Hydroelectric Project depicting flow directions during high flow or shutdown operations. Figure from PAD (2005).

Should the Project power pipeline, power tunnel, or Powerhouse be shut down for any reason, the Diversion Dam and tunnel can be operated in their traditional (Stage 1) manner to divert and carry flows from the Sultan River to Lake Chaplain. During this shutdown operation, sufficient flows are released from Culmback Dam to supply the required instream flows at the Powerhouse and water flows to Lake Chaplain.

Project operations have altered the seasonal flow pattern in the Sultan River as depicted in Figure 2-6). The reservoir rule curves (Figure 2-7) are shaped to minimize spill (uncontrolled release of water via the spillway) and provide storage of spring runoff for municipal water supply and instream flow augmentation later in the year during the driest months. With the same total volume of runoff from basin rainfall and snow melt, the historically higher peak flows in the lower Sultan River that occurred previously in late fall, early winter, and spring have been reduced in both amplitude and frequency. Total volume of flow below the Diversion Dam is

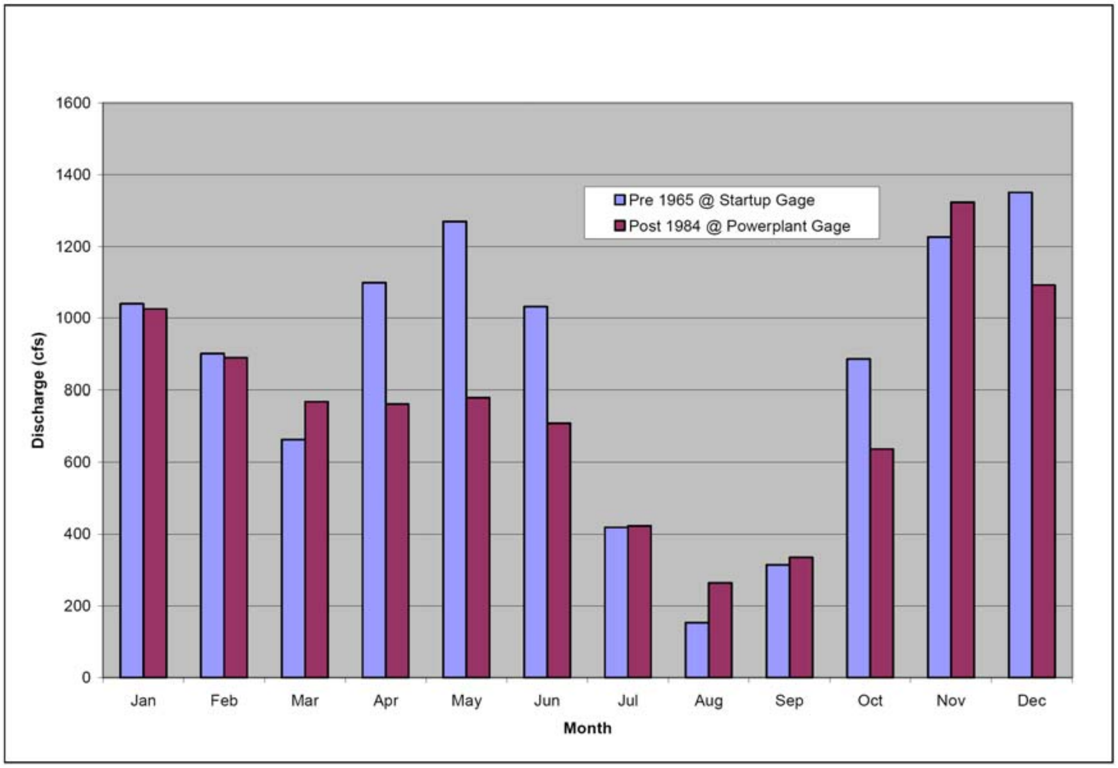


Figure 2-6. Sultan River average monthly flows, Stage 1 vs. Stage 2 (data have been standardized by drainage area and adjusted for withdrawals). Figure from the PAD (2005).

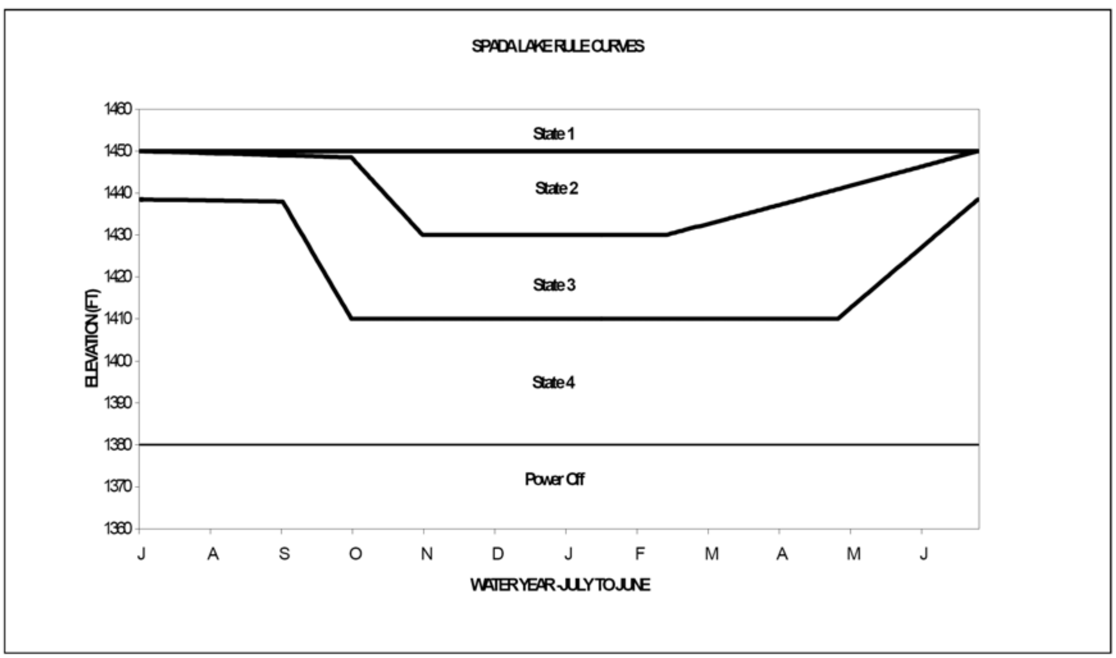


Figure 2-7. Spada Lake operational rule curves. Figure from the PAD (2005).

reduced by withdrawals for municipal water supply, which averaged 129 cfs in water year 2004. This pre-existing right for municipal water withdrawals is not an impact of the existing Project operations.

The rule curves divide Spada Lake into four states that shift throughout the water year (July through June). This operational water year is used to minimize reservoir storage changes from one year to the next. The rule curves allow the Project to provide incidental winter flood storage, municipal water supply, instream flows, and higher summer lake levels for recreation. In States 1 and 2, the Project is required to discharge 1,300 cfs into the Sultan River. In State 4, the Project is operated to maintain Lake Chaplain within a specified range of elevations and to provide required minimum fishery flows below the Diversion Dam and Powerhouse. State 3 is a "discretionary" zone where the Project may be operated between the extremes of States 2 and 4, depending on the needs for power generation and subject to limitations on ramping rates and frequency.

In the context of relicensing the hydroelectric Project and for purposes of this study, the two project stages noted above represent Stage 1 or baseline conditions, and Stage 2 conditions. Specifically, Stage 1 conditions represent flow conditions absent the hydroelectric Project but with operation of the water supply; project conditions (also termed "Stage 2 Conditions") represent those existing with the hydroelectric Project.

2.2.3 Instream Flow Studies and Flow Releases

There have been three previous instream flow studies conducted in the Sultan River commencing with the earliest in 1967 completed in Reach 1, followed by a 1978-1979 study in Reach 2, and a 1980 study completed in Reach 3. The 1967 study in Reach 1 was conducted by the Washington Department of Fisheries (WDF, now WDFW) mainly to determine fishery needs in the lower three miles of the river below the canyon section (Magee 1967). The method used was developed by WDF in the 1950s, and consisted of making discharge measurements at typical spawning sections in the river selected by biologists, and relating these discharge measurements to the depth and mean column velocities with optimum depth range and optimum velocity range criteria as determined for various species. The results of that study indicated that a minimum of 200 cfs and 165 cfs were needed for salmon spawning and rearing, respectively. Because of this, minimum flows below the Powerhouse during Chinook salmon spawning (September 15 to November 1) are maintained at or above 200 cfs. During the remainder of the year, instream flows are maintained at or above 165 cfs.

The Reach 2 instream flow study that was completed in 1978 and 1979 was conducted by WDF, Washington Department of Game, and Eicher Associates, Inc. The study employed a "useable width" methodology in the reach of river between RM 4.3 and 9.7 (Easterbrooks and Gerke 1978). The primary objective of this study was to determine the spawning and rearing flows needed to protect Chinook and coho salmon and winter-run steelhead trout downstream of the Diversion Dam. Stream depth, velocity, and substrate data were collected along six transects at known Chinook, coho, and steelhead spawning locations (at four different target flows – 200, 150, 100, and 50 cfs). Based on the results of this analysis, WDF determined the optimum Chinook salmon spawning flow to be 175 cfs, and the optimum coho salmon spawning flow to be 108 cfs (as measured at the Chaplain Creek USGS gage) (Easterbrooks and Gerke 1978). Rearing flows were determined to be adequate at 100 cfs. Steelhead spawning flows were determined to be adequate at 175 cfs and steelhead rearing flows were determined adequate at 100 cfs.

During the summer of 1980, the District completed a cooperative instream flow study within Reach 3 of the Sultan River (R.W. Beck 1980). The objective of the study was to evaluate habitat availability for resident trout and steelhead life stages in response to incremental changes in river discharge, and to compare historic river discharges to those expected under proposed operations of the Project. The study was completed using the USFWS's Instream Flow Incremental Methodology (IFIM) (Bovee and Milhous 1978).

Based in part on the results of these three studies, as well as a fish production simulation model, a river water temperature study conducted below Culmback Dam by the District, and a power generation model developed by the District, a Settlement Agreement was made in 1982 with the WDFW, NMFS, and Tulalip Tribes (the "Joint Agencies"). This agreement established three controlled flow discharge points for fish flow releases on the Sultan River, which coincidentally correspond to the upstream most points of each of the three operational reaches of this study: Culmback Dam (RM 16.5), the Diversion Dam (RM 9.7) and at the Powerhouse (RM 4.3). Under current operations, a constant minimum flow of 20 cfs is released from *Culmback Dam into the reach of the Sultan River extending to the Diversion Dam (Reach 3)* (Table 2-1). Accretion flows within this reach can be quite variable ranging from about 10 to 1,200 cfs, depending on precipitation. Big Four Creek is the principal tributary in this reach. Between the *Diversion Dam and the Project Powerhouse (Reach 2)*, a minimum flow of from 95 to 175 cfs is required to support fishery resources as determined by the Joint Agencies. This level varies seasonally (see Section 2.3), with flows supplied primarily by return flow using the Lake Chaplain pipeline. The principal tributaries in this reach are Marsh Creek and Chaplain Creek. From the *Powerhouse to the Sultan's confluence with the Skykomish River (Reach 1)*, minimum flow requirements range from 165 to 200 cfs. Three principal tributaries, Woods Creek, Ames Creek, and Winters Creek, contribute flow to this reach.

2.2.4 Downramping Rates

The District has evaluated the effects of the Project's related downramping rates on juvenile salmonids in Reach 2 (below the Diversion Dam) and Reach 1 (below the Powerhouse) and has implemented specific downramping rates below all facilities to minimize potential fish stranding within the respective reaches. These rates are displayed in Tables 2-2 and 2-3 for Reaches 1 and 2 respectively. Although no studies were specifically conducted for Reach 3, the District regulates any Project associated flow releases in a manner consistent with these downramping rates. The District does not plan to modify operations of the Project that would result in changes to these downramping rates, and therefore no ramping rates studies were completed as part of this study.

Table 2-1. Existing Sultan River instream flow requirements.

Dates	Point of Discharge	Minimum Flow (cfs)
All Year	Culmback Dam[a]	20
11/1 – 1/15	Diversion Dam[b]	95
1/16 – 2/28	Diversion Dam[b]	150
3/1 – 6/15	Diversion Dam[b]	175
6/16 – 9/14	Diversion Dam[b]	95
9/15 – 9/21	Diversion Dam[b]	145
9/22 – 10/31	Diversion Dam[b]	155
6/16 – 9/14	Powerhouse[b]	165
9/15 – 6/15	Powerhouse[b]	200[c]

[a] Cone valve discharge verified by the U.S. Geological Survey on August 28, 1990.

[b] Telemetry gages are installed immediately below the Diversion Dam and Powerhouse to monitor these flows.

[c] If flows exceed 400 cfs during the Chinook spawning period (September 15 to October 15), the District increases minimum flows during the subsequent incubation period to protect spawning redds.

Table 2-2. Jackson Hydroelectric Project Powerhouse downramping rate schedule[a] (inches/hour).

Flow Range (cfs/day)	Day	Night	Day	Night
	March 1[b] to May 31		June 1[b] to September 15	
1,500 to 750	4	4	2	1
750 to 600	2[c]	2[c]	2[c]	1[c]
600 to 300	2	4	2	1[d]
300 to minimum	2	2	2	1[d]
	September 16 to October 31		November 1 to February 28	
1,500 to 750	2	1	4	4
750 to 600	2[c]	1[c]	2[c]	2[c]
600 to 300	2	2	4	4
300 to minimum	2	2	4	4

[a] For normal operation; not for power generation equipment failures or forced outages. Values are in inches-per-hour at the Powerhouse. Rates are tracked on a 15 minute basis by USGS for compliance. No one 15 minute downramping value will exceed half the hourly rate shown in the table. No four consecutive downramping rates shall exceed the hourly rates shown in the table.
[b] This date may be adjusted annually by determining time of fry emergence with cumulative water temperature information. Upon notification to the District from WDFW that either salmon or steelhead trout fry are expected to emerge from the river gravel, based on water temperature unit calculations, the District will shift to the designated slower downramping rates.
[c] If river flow prior to downramping has exceeded 1,000 cfs for more than 72 hours, downramping through this flow range (750 to 600 cfs) occurs only after holding flow constant between 750 and 850 cfs for at least 6 hours of daylight and one overnight period.
[d] Avoid any scheduled flow reduction.

Table 2-3. Diversion Dam downramping rate schedule[a].

	Day	Night	Day	Night
	January 1[b] to May 31		June 1 to September 15	
Ramp Rate (in/hr) [d]	3	3	3	1.5[c]
	September 16 to October 31		November 1 to December 31	
Ramp Rate (in/hr)	3	3	6	6

[a] For normal operations in the flow range between 95 cfs (minimum flow) and 300 cfs, not during power-generating equipment failures, forced outages, or gravel flushing/enhancement actions requiring manual operation of the sluice gate at the Diversion Dam.
[b] Chinook salmon fry emergence schedule will be determined yearly in consultation with WDFW.
[c] Avoid any scheduled flow reduction.
[d] Units are in inches per hour as measured at the USGS gage downstream from the Diversion Dam. Rates are tracked on a 15-minute basis. No single 15-minute downramping value will exceed one half the hourly value shown in the table. The average of four consecutive 15-minute downramping rates shall not exceed the hourly rate shown in the table.

2.3 FISH OF THE SULTAN RIVER

The Sultan River currently supports over 15 species of fish, including eight anadromous Pacific salmonid species. These species include Chinook, coho, chum and pink salmon, steelhead and sea-run cutthroat trout, and native char (bull trout and/or Dolly Varden). Native resident salmonid species include rainbow and cutthroat trout and mountain whitefish (*Prosopium williamsoni*). Many other native resident fish species are also present in the Sultan River including lamprey (*Lampetra sp*.), stickleback (*Gasterosteus sp*.), sculpin (*Cottus sp*.), and suckers (*Catostomus sp*.).

The general life history of Pacific salmon species involves constructing nests (redds) in gravel beds for spawning, followed by migration to the ocean for feeding and maturation, and returning to natal sites for spawning and completion of their life cycle. There are many variations on the timing and duration of these lifecycles both among species, and from year to year for the same species (Figure 2-8). However, all salmonids share a need for the following habitat conditions: sufficient food supply; cool, high quality flowing water; high dissolved oxygen concentrations; and unimpeded migratory access to and from spawning and rearing areas (Spence et al. 1996). Additional specific information on the life-history requirements and stock statuses for select Sultan River fish species are discussed in the following sections.

2.3.1 CHINOOK SALMON (*Oncorhynchus tshawytscha*)

Chinook salmon are the largest species of Pacific salmon and can weigh over 100 pounds; however, a typical weight is around 20 pounds. Chinook salmon were historically found from the Ventura River, California to Point Hope, Alaska (Myers et al. 1998). The current, contracted distribution of Chinook salmon extends from the San Joaquin River to the Kotzebue Sound, Alaska (Healey 1991). Chinook are the least abundant of the Pacific salmon species, but over one thousand individual populations of Chinook are estimated to exist on the North American coast (Atkinson, et al. 1967; Aro and Shepard 1967).

Chinook salmon populations are distinguished by their distinct migration and spawn timing (spring, summer, fall). Spring, summer and fall Chinook runs exist throughout the geographic range, but the majority of Chinook migrate and spawn as summer and/or fall runs. Chinook salmon in the Sultan River are considered by the Washington Department of Fish and Wildlife (WDFW) as part of the Snohomish fall Chinook stock (WDFW and WWTIT 1994). The timing of Chinook migration and spawning tends to occur progressively later further south in their geographic range, but varies somewhat between river systems. Northern populations typically

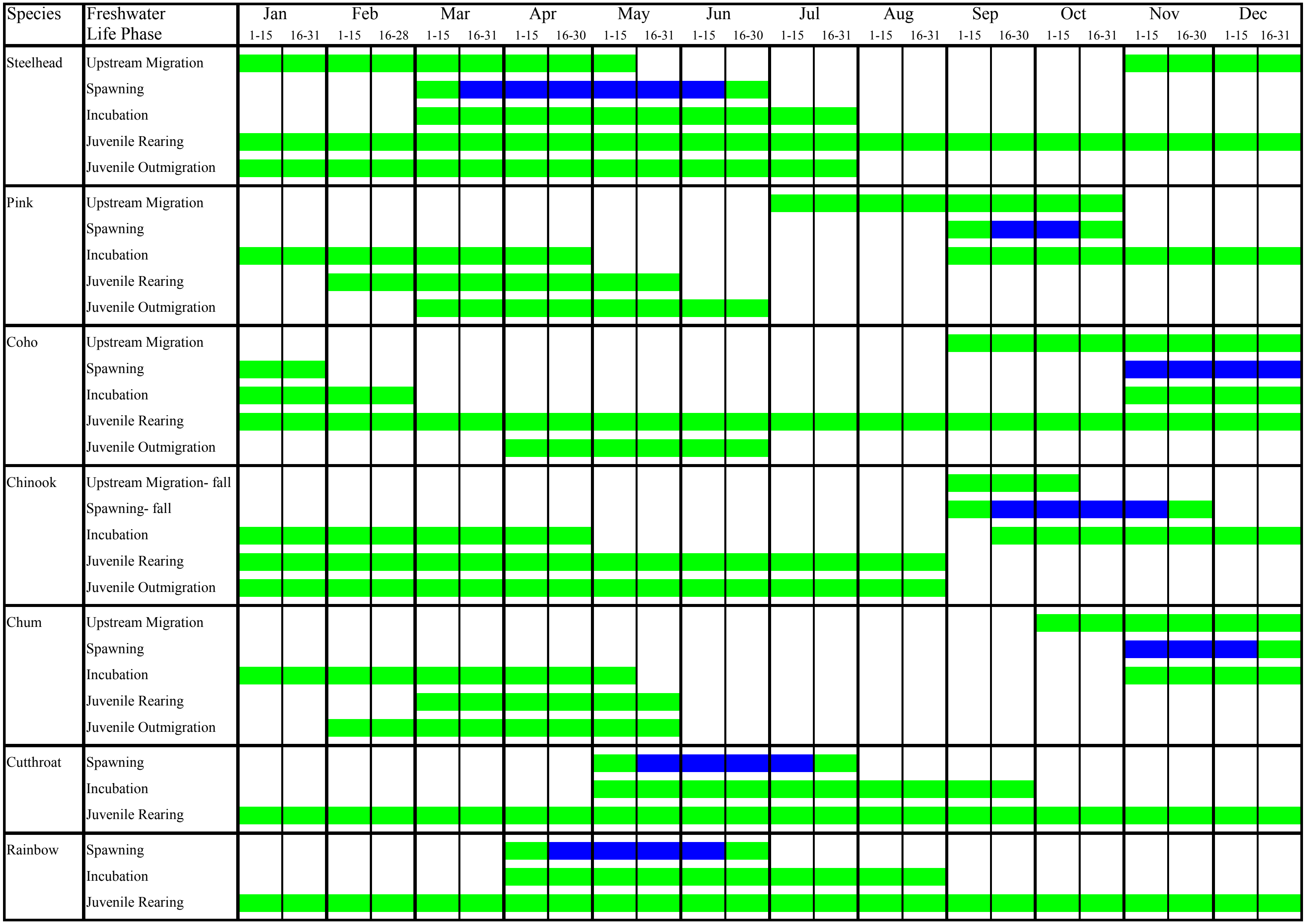


Figure 2-8. Life stage periodicities of salmonid species present within the Sultan River Basin, Washington.

spawn July to September while southern Chinook populations tend to spawn November to January. Sultan River Chinook spawn from mid-September through November.

Chinook typically spawn in the mainstem habitats, in areas defined by flow and substrate conditions. As the largest of the Pacific salmon species, Chinook tend to spawn in higher water velocities (1 to 3 feet per second) and in larger gravel (> 6 inches) than other salmon (Burner 1951). Chinook spawning areas can typically be found at the head of a riffle, prior to the crest of the rapid. Sultan River Chinook spawn from the mouth of the river upstream to the City of Everett Diversion Dam at RM 9.7, which is the upstream limit of anadromous salmon migration (CH2M HILL 2005). Chinook eggs require 882 to 991 temperature units on average before hatching (1 temperature unit = 1 degree C above freezing for 24 h) (Beauchamp et al. 1983). The length of incubation in the Sultan River varies depending on redd location, but is generally completed by the end of March. The young remain in the gravel for 2 to 3 weeks after hatching (Wydoski and Whitney 2003).

Many variations in juvenile Chinook life history are possible within this distinct fall run. The distinctions result from variability in the pattern of juvenile freshwater rearing (Reimers 1973). Some examples of juvenile Chinook salmon life histories suggested by Reimers (1973) are as follows:

- emergent fry move directly downstream and into the ocean within a few weeks;
- juveniles rear in the main river or remain in tributaries until early summer, then emigrate into the estuary for a short period of rearing, and enter the ocean in late summer; and
- juveniles rear in the main river or tributaries until early summer, then emigrate into the estuary for extended rearing during the period of improved growth in late summer, and enter the ocean in autumn.

Proportions of individuals present in the Sultan River corresponding to these listed variations are dictated by genetic and environmental factors. Environmental cues such as streamflow reductions, food supply, changes in photo-period, and temperature increases are all factors that lead to the evolution and expression of particular juvenile outmigration timing (Myers et al. 1998). Evidence in the Sultan River suggests that the majority of fry rear in the stream margins for several months, and migrate downstream predominantly by June (CH2M HILL 2005). Further information on the spatial and temporal distribution of Chinook salmon in the Sultan River is being collected as part of RSP5 and will be presented in a forthcoming report.

Population Status and Status under the ESA

Chinook salmon are included by NOAA Fisheries in the Puget Sound Evolutionarily Significant Unit (ESU). Overall, abundance of Chinook salmon in this ESU has declined substantially; both long- and short-term abundance trends are predominantly downward. These factors have led to this ESU as being listed as threatened (50 CFR 223 and 224). Puget Sound Chinook salmon are a WDFW State Candidate species under review for listing as a State Endangered, Threatened, or Sensitive species. In 2002, WDFW listed the Skykomish Chinook stock as "depressed," primarily due to low stock escapement (CH2M HILL 2005).

2.3.2 COHO SALMON (*Oncorhynchus kisutch*)

Coho salmon are of moderate size for a Pacific salmon, typically weighing 8 to 10 pounds. The geographic distribution of coho is similar to that of Chinook extending from the San Lorenzo River in Monterey Bay, California in the south to Point Hope, Alaska in the north (Wahle and Pearson 1987). Coho are generally less abundant in the northern and southern extremes of their range, and typically less abundant than some other Pacific salmon species.

Adult coho salmon generally return to their natal streams to spawn at age 3, after spending 18 to 24 months (up to 3 years) in the marine environment. Coho migrate and spawn in the fall and winter, with timing generally earlier in higher latitudes, becoming progressively later moving south through its range. Coho in the Sultan River begin upstream migration in September and continue through December with spawning generally taking place from November through mid-January (Figure 2-8) (WDFW and WWTIT 1994). Spawning habitat suitable for coho is limited in the Sultan River with steep gradients and incised channel in most of the preferred spawning habitat (CH2M HILL 2005). Incubation periods for coho salmon are reported to last from 35 to 101 days (Laufle et al. 1986). After hatching, larvae typically spend 2 to 3 weeks (depending on food stored in the yolk sac) absorbing the yolk sac in the gravels of the redd before they emerge in April and May.

Juvenile coho salmon rear in freshwater for approximately 15 months prior to migrating downstream to the ocean, but may extend their rearing time for up to 2 years (Sandercock 1991). Newly-emerged fry usually congregate in schools in pools of their natal stream. As juveniles grow, they move into more riffle habitat and aggressively defend their territory, resulting in displacing excess juveniles downstream to less favorable habitat (Wydoski and Whitney 2003). This aggressive behavior may be an important factor maintaining the numbers of juveniles within the carrying capacity of the stream, and distributing juveniles more widely downstream. Once territories are established, individuals may rear in selected areas of the stream feeding on drifting benthic organisms and terrestrial insects until the following spring (Hart 1973).

Complex woody debris structures and side channels are important habitat elements for coho salmon. Suitable overwintering habitat exists in the lower 3 miles of the Sultan River, primarily in side and off-channel complexes. Studies suggest that the abundance of juvenile coho is often determined by the combination of limited space, food and temperature interaction. The outmigration of coho smolts in the Sultan River occurs between April and early June (CH2M HILL 2005).

Population Status and Status under the ESA

Snohomish coho stocks belong to the Puget Sound/Strait of Georgia ESU. Continued loss of habitat, extremely high harvest rates, and a severe recent decline in average spawner size are substantial threats to remaining native coho populations in this ESU. Currently, this ESU is not listed as threatened or endangered; however, if present trends continue, this ESU is likely to become listed in the future (Weitkamp et al. 1995). In 1993, WDFW ranked the Sultan River coho, part of the Snohomish – Skykomish stock, as “Healthy” based on trends in spawning escapement (WDFW and WWTIT 1994). Escapement in the Sultan River has continued to increase since then with an estimated annual escapement of 300 to 500 adults (CH2M HILL 2005).

2.3.3 PINK SALMON (*Oncorhynchus gorbuscha*)

Pink salmon are the smallest of the five salmon species, and typically weigh from 2 to 6 pounds. The geographic range of pink salmon extends from the Sacramento River of central California in the south, to Point Barrow, Alaska in the North (Hallock and Fry 1967; Craig 1984). Pink are the most abundant of the Pacific salmon species.

Pink salmon are distinguished from other Pacific salmon by having a fixed two-year life span, such that fish returning to their natal stream in only odd or even years are reproductively isolated from one another. The Snohomish River and its major tributaries (including the Sultan River) support both even-year and odd-year runs. Mature adult pink salmon may grow to a length of 30 inches, and weigh on average, between 3 and 5 pounds. After 18 months at sea, adult pink salmon will return to spawn. Inshore migration starts in July and continues through October. Spawning of the odd-year stock generally takes place from mid-September through October (Figure 2-8), while spawning of the even year stock occurs primarily in September (WDFW and WWTIT 1994). The odd-year run is much larger, generally measuring more than 100,000 fish compared to only about 5,000 for the even year run in the Snohomish river system (CH2M HILL 2005). In the Sultan River, only the odd-year run has been observed spawning, primarily in the lower 3 miles of the river (CH2M HILL 2005).

Incubation of fertilized eggs lasts between 5 and 8 months in the gravel interstices (Heard 1991). Water quality, desiccation, predators and scour are some of the major environmental factors influencing egg survival to emergence. Pink salmon eggs hatch in late February, and the young emerge from the gravel in April and May, depending on water temperatures. Pink salmon fry spend less time on average in freshwater than most other salmon species. Upon reaching the mouth of the stream, increased schooling takes place. After leaving freshwater, the young salmon tend to remain close to nearshore nursery areas until approximately September (Emmett et al. 1991). Juvenile pink salmon residency in the Sultan River is minimal, utilizing the river primarily for transportation.

Population Status and Status under the ESA

Pink salmon counts in the Sultan River have increased since the start of operation of the Project in 1983. Stage 1 (1971 through 1983) escapement averaged 3,000 fish in odd years. Stage 2 escapement has averaged 51,563 fish per year (CH2M HILL 2005). A record run of pink salmon was observed in 2001 totaling 151,800 fish (CH2M HILL 2005).

The status of the Snohomish River odd-year pink stock is considered "Healthy" by WDFW and overall abundance was estimated by NOAA Fisheries to be "close to historic levels." Therefore there are no plans in the near future for listing of this species under the ESA (Hard et al. 1996; WDFW 1994). Even-year pink in the Snohomish River were determined by NOAA Fisheries to not be at risk of imminent extinction or endangerment, but merited close monitoring to determine if this population may be at risk in the future (Hard et al. 1996).

2.3.4 CHUM SALMON (*Oncorhynchus keta*)

Among the Pacific salmon species, chum are second only to Chinook in size. Chum salmon can weigh up to 45 pounds, but typically are around 10 to 15 pounds. Chum has the broadest geographic distribution of the Pacific salmon, ranging from the San Lorenzo River in Monterey Bay, California in the south to the Mackenzie River on the north coast of Canada. The largest runs of Chum salmon range from Tillamook Bay, Oregon in the south to Kotzebue Sound, Alaska in the north (Henry 1953).

Chum salmon migration up the Snohomish River begins in early September and continues through December. Upstream migration can be fast, with rates of 30 miles per day recorded (Groot and Margolis 1991). Spawning in the Sultan River takes place in November and December (Figure 2-8). Preferred spawning areas are in groundwater-fed streams or at the head of riffles (Grette and Salo 1986). However, chum salmon will utilize many different spawning areas including mainstem rivers, side channels and sloughs. Spawning in the Sultan River occurs primarily in the mainstem and side channels of the lower 2.7 river miles (CH2M HILL 2005).

The length of incubation of the eggs is influenced primarily by water temperature. For example, eggs at 15ºC hatch approximately 100 days before eggs incubated at 4ºC. Health of the emergent fry is also dependent on dissolved oxygen, gravel composition, spawner density, stream discharge, and genetic characteristics (Groot and Margolis 1991). Fry emergence in the Sultan River is generally completed by May. Juvenile chum salmon have an ocean-type early life history similar to pink salmon: rearing in freshwater for only a few days to weeks before migrating downstream to saltwater (Grette and Salo 1986). Juvenile outmigration occurs in early spring, March through May. Chum salmon mature in the ocean for 1 to 5 years before returning to spawn (Groot and Margolis 1991).

Population Status and Status under the ESA

Information from early spawning surveys indicates that very few chum salmon historically spawned in the Sultan River prior to operation of the Project. However, from 1992 to 2004 chum salmon escapement in the Sultan River has averaged 2,500 fish (CH2M HILL 2005). Currently, WDFW considers the Sultan River chum stock to be part of the Skykomish fall chum stock, and is separated geographically from other chum stocks (WDFW and WWTIT 1994). This stock is considered “Healthy” based on escapement trends. Sultan River chum salmon are considered by NOAA Fisheries to be part of the Puget Sound / Strait of Georgia ESU. NOAA Fisheries concluded that this ESU is not presently at risk of extinction, nor is likely to become endangered in the near future (63 Fed. Reg. 11778).

2.3.5 STEELHEAD TROUT (*Oncorhynchus mykiss*)

Steelhead trout occupy a geographic range similar to Pacific salmon stocks. Steelhead trout historically inhabited regions as far south as Baja California. The current contracted range of steelhead extends from the Malibu River, California in the south to southeastern Alaska (50 CFR Part 222 and 227). Many populations of steelhead in streams throughout their range are believed to be in decline.

Steelhead trout are iteroparous, and are capable of spawning more than once, unlike Pacific salmon species. Steelhead is generally classified into two races, summer and winter, based on timing of spawning migration. Winter run steelhead enter streams between early November and late April, while summer steelhead are typified by a run timing of early May to late October. Regardless of the timing of river entry, most steelhead generally spawn between December and June. Summer steelhead usually spawn between December and March in upstream reaches of their natal streams. Winter runs, like those in the Sultan River, typically spawn later than summer steelhead, from March through June in lower reaches of streams (Figure 2-8). In general, steelhead differ from spawning Chinook and coho salmon by their use of faster, shallower, and higher gradient locations in mainstem or tributary streams (Everest and Chapman 1972). Steelhead have been observed to spawn above and below the Powerhouse upstream to the Diversion Dam (RM 9.7) (CH2M HILL 2005).

Incubation rates vary with water temperature, with fry emergence occurring 40 to 80 days after spawning. Dissolved oxygen levels at or near saturation with no temporary reductions in concentration below 5 parts per million are most suitable for incubation (Stolz and Schnell 1991). Depending on the time of spawning and the water temperature during incubation, fry emerge from the gravel in spring or early summer, 3 or more weeks after hatching (Barnhardt 1986). Juvenile steelhead will utilize stream margins and submerged rootwads, debris and logs to provide shelter and cover while rearing (Bustard and Narver 1975). Both winter and summer juvenile steelhead rear in freshwater for 1 or more years before migrating to the ocean. Migrating smolts are typically age 2 in the Snohomish River (Busby et al. 1996). A positive relationship between migration speed of active migrants and fish size has been seen in studies (Busby et al. 1996). Juvenile surveys in the Sultan River (WDG 1986), showed rapid steelhead fry growth. Mean length doubled from June to November and weights (estimated from published length/weight relationships) increased nearly tenfold. Juvenile downstream migration for steelhead smolts in the Sultan River occurs from April through May (CH2M HILL 2005). Snohomish County PUD provides funding for an annual plant of 30,000 hatchery steelhead smolts (winter and summer run combined) in the Sultan River (CH2M HILL 2005).

Population Status and Status under the ESA

Sultan River steelhead have been classified by NOAA Fisheries as part of the Puget Sound ESU (1 of 15 west coast steelhead ESUs). After initial review, this ESU was determined to not warrant listing under the Endangered Species Act on 9 August 1996. In response to a petition, NOAA announced on 29 March 2006 it was proposing to list this ESU as “threatened.” On 7 May 2007 NOAA announced that Puget Sound steelhead warrant protection under the ESA, and that all naturally spawned winter-run and summer-run populations are now listed as “threatened,” meaning likely to become an endangered species in the future.

2.3.6 BULL TROUT (*Salvelinus confluentus*)

The taxonomic status of the bull trout has been confused with that of Dolly Varden. Both species are native salmonids and members of the char family. The species are similar in coloration, morphology and life history, making distinction between the two species difficult without the use of electrophoretic samples or exact measurements of specific external characteristics (Beak 1996). Furthermore, morphological and genetic samples taken from populations in Washington show a degree of overlap and genetic introgression. The State of Washington has indicated that protective measures and management for the two species are identical. Therefore, the following description of status and life history for the two species has been combined; they will be referenced as native char in the remainder of this life history description.

Native char life history expressions include anadromous and freshwater migratory and resident forms (Goetz et al. 2004). Adfluvial stocks rear in lakes or reservoirs before returning to tributary streams to spawn, whereas riverine forms spend their entire life cycle in streams. Bull trout populations that exhibit different life history forms may be present within a river system. In some river systems that are known through genetic testing to contain both species of char (Dolly Varden and bull trout) and their hybrids, it appears that Dolly Varden mature at a smaller size and exhibit a riverine life history, whereas bull trout are generally adfluvial and larger-bodied (McPhail and Taylor 1995; Baxter et al. 1997; Hagen and Taylor 2001; Taylor et al. 2001).

All lifestages of native char can be found throughout the Snohomish River basin. However, they have only been observed sporadically in the Sultan River, and always below RM 9.7 (CH2M HILL 2005). These fish are presumed to be sub-adult or adult foraging fish as it is doubtful that the Sultan River contains any habitat suitable for native char spawning, based on temperature and elevation data (CH2M HILL 2005).

Foraging native char would most likely be present in association with salmon fry emergence during late winter and spring. They may also feed on eggs during salmon spawning time in September through December.

Population Status and Status under the ESA

The Sultan River native char population is considered by the USFWS to be part of the Puget Sound bull trout Distinct Population Segment (DPS). This DPS is a geographically isolated segment, encompassing all Pacific coast drainages within the contiguous United States north of the Columbia River in Washington (63 Fed. Reg. 31695). Due to several detrimental factors (including disease, predation, increased stream temperatures and loss of habitat) this DPS has been listed as threatened by the USFWS under the ESA (50 CFR Part 17). Bull trout are a WDFW State Candidate Species under review for listing as a State Endangered, Threatened, or

Sensitive species. However, WDFW considers the Snohomish / Skykomish bull trout population to be "Healthy" (WDFW 1998).

2.3.7 COASTAL CUTTHROAT TROUT (*Oncorhynchus clarki clarki*)

Coastal cutthroat trout are similar in appearance to steelhead. Coastal cutthroat trout inhabit coastal streams from Humboldt Bay, California in the south to Gore Point on the Kenai Peninsula, Alaska in the north (Stolz and Schnell 1991). Considerable information exists for Puget Sound cutthroat trout, though little of that has been collected in a standardized manner and over a long enough time period to establish trends in populations (Leider 1997). However, the relative abundance of cutthroat trout is assumed to have generally declined throughout its range.

Cutthroat trout life history is complex, as multiple forms exist, often within the same river system. Anadromous, freshwater migratory, and freshwater non-migratory are three cutthroat life history forms that are known to occur in the same river system, and presumably could occur in the Sultan River, although documentation of such is lacking. Indeed, recent fish surveys completed in Reach 3 in which the non-migratory form would likely have existed failed to detect or capture any cutthroat trout. Non-migratory cutthroat trout will typically inhabit a small stream section throughout their lifecycle, whereas freshwater migratory cutthroat will migrate within the river system, typically moving to smaller tributaries to spawn. Like steelhead, adult sea-run cutthroat trout are repeat spawners, but unlike steelhead, sea-run cutthroat trout recover quickly to pre-spawn condition (Trotter 1997). They may live to an age of 7 or 8 years, spawning three, four, or even as many as five times during their life (Trotter 1997). Although anadromy exists, there is evidence that this trait is not strongly developed; fish generally remain close inshore or in areas of reduced salinity while in salt water (Trotter 1997). They will rarely, if ever, overwinter in saltwater, indicating that some of the returning fish may not spawn during their first or second migrations back into freshwater. Sea-run cutthroat trout are usually smaller than other anadromous salmonids, and rarely exceed 50 cm in length. This size appears to be adaptive for entering small tributaries where interspecific competition for habitat with other, larger, salmonids is reduced (Pearcy 1997).

Cutthroat trout spawning in the Sultan River occurs from May through July (Figure 2-8). Sea-run cutthroat trout spawn in low gradient reaches of small tributaries, or in the lower regions of streams (Trotter 1997). This appears to be an adaptation to isolate their nursery/rearing ground from other, more competitive, species such as steelhead (Stolz and Schnell 1991). The preferred spawning substrate is pea to walnut sized gravel, in 15-45 cm of water, with pools nearby for escape cover. Actual spawning may extend over a period of 2 to 3 days (Trotter 1997).

Juvenile coastal cutthroat trout exhibit early life history characteristics similar to coho and steelhead, whereby juveniles spend time rearing in freshwater before outmigrating as smolts (Leider 1997). Juvenile sea-run cutthroat will generally rear in streams for two or more years, seeking pools and other slow water habitats with root wads and large wood for cover (Trotter 1997). Often coho fry are present in the same habitat, and the larger coho will drive the cutthroat into riffles, where they will remain until fall and winter (Stolz and Schnell 1991). Puget Sound cutthroat trout will feed and migrate along beaches, often in waters less than 10 feet deep (Johnston 1982). Many stocks are thought to stay within estuarine habitats for their entire marine life (Leider 1997). Most cutthroat return to freshwater the same year they migrate to sea.

Population Status and Status under the ESA

Sultan River coastal cutthroat trout have been classified as part of the Puget Sound ESU by NOAA Fisheries (64 Fed. Reg. 16397). This ESU includes populations of coastal cutthroat trout from streams in Puget Sound and the Strait of San Juan de Fuca west to, and including, the Elwha River. The southern boundaries of the Puget Sound ESU extend to Nisqually River, while the northern boundaries include coastal cutthroat trout populations in Canada (64 Fed. Reg. 16397). NOAA Fisheries has concluded that Puget Sound coastal cutthroat trout do not warrant listing under ESA at this time as populations have been relatively stable over the past 10-15 years (64 Fed. Reg. 16397). WDFW has included the Sultan River coastal cutthroat as part of the Snohomish stock complex. The status of this stock is "Unknown," but may be healthy (WDFW 2000). There is little information available concerning the abundance or survival of any life history form of coastal cutthroat in the Snohomish River basin.

3. METHODS

The Sultan River Instream Flow Study was completed in accordance with Revised Study Plan 3 and following procedures outlined by the WDFW and WDOE (2004) in the Instream Flow Guidelines. Chronologically, the study involved completion of the following six steps:

- Step 1 – Planning and Site Reconnaissance, to familiarize technical personnel with site characteristics and operations of the Project, to select target flows, and to make a preliminary selection of transect locations;
- Step 2 – Study Reach Delineation and Transect Selection, that included mainstem areas in Reach 3, Reach 2, and Reach 1, and side channel areas in Reach 1;
- Step 3 – Field Data Collection, that included three trips to collect detailed depth and water velocity data from all transects under a low, mid- and high target flow condition, and two additional trips to collect supplemental water surface elevation (WSE) measurements at two higher flows;
- Step 4 – Habitat Suitability Criteria Curve Development, that involved development and submittal of an HSC plan for review by stakeholders and agencies, collection of microhabitat data, data analysis, and derivation of modified curves for selected species;
- Step 5 – Data Analysis and Modeling, that included hydraulic model calibrations for all transects, and subsequent derivation of species and life stage specific habitat indices (expressed as Weighted Useable Area – WUA) versus flow relationships for each site, and, based on channel widths, an estimation of the total habitat area of each species and life stage for each reach under different flow conditions; and
- Step 6 – Time Series Analysis that linked habitat-flow relationships with hydrologic conditions involving three different flow scenarios (wet, average, and dry years), under Stage 1 and Stage 2 operations. The time series analysis and resulting habitat duration curves provide a means to compare effects of different Project operations on the frequency and availability of habitats within the three reaches of the river.

3.1 PLANNING AND SITE RECONNAISSANCE

Planning for the instream flow study involved an initial review of background information related to Project operations, hydrology, and fishery resources that was provided in the PAD and other documents cited therein, as well as a review of previous instream flow studies, including those by R.W. Beck (1980), Easterbrooks and Gerke (1978), and Magee (1967). R2 also carefully reviewed the aerial digital videotape that was taken during a June 17, 2004[3] helicopter flyover of the entire reach of the Sultan River, from its confluence with the Skykomish River to Culmback Dam. This video was used to assess habitat types and features in each of the reaches and to select candidate study sites and transect locations within.

R2 also completed two preliminary field reconnaissance surveys within the Sultan River watershed designed to familiarize personnel with Project facilities and operations, channel characteristics and access points to channel reaches. The first, completed on April 11, 2007 represented a joint survey to assess access and sampling locations for both the Sultan River Instream Flow study (RSP3) and the Juvenile Fish Occurrence, Life History and Distribution study (RSP5) within the lower two reaches (Reach 2 and Reach 1). The second survey was a two-day effort (April 18 and 19, 2007) that entailed first a helicopter flyover of the entire length of river from the confluence with the Skykomish River to Culmback Dam, followed by an on-the-ground survey of several segments of Reach 3.

Two subsequent more detailed surveys were completed to identify candidate sites and potential transect locations within each reach. The first survey involved a two-day effort (May 4 and 5, 2007) and focused on Reaches 3 and 2; the second on May 9, 2007 included a combined foot and float survey of Reach 1. During these surveys, candidate transects were flagged and GPS coordinates taken. These candidate transect locations were subsequently marked on copies of still images captured from the digital video and provided to the stakeholders and agencies prior to a formal transect selection meeting that was held on May 22, 2007 (see Section 3.2).

Target flows for field measurement were selected based on review of the flows measured and modeled during the previous instream flow studies (R.W. Beck 1980; Easterbrooks and Gerke 1978; and Magee 1967), an evaluation of channel characteristics and habitat types and their sensitivity to flows, and the periodicities of the target fish species and lifestages with consideration for the range of flows needed to adequately define their habitat – flow relationships (Table 3-1). A total of five flows were selected for each reach, the first three of which were used to obtain complete depth-velocity data sets and water surface elevations (WSE) at all transects, and the last two flows (the two highest) used to obtain supplemental WSE measurements.

[3] Videotaping completed by Devine Tarbell and Associates. 2004. Sultan River aerial video, 17 June, 2004. Skykomish River confluence to Culmback Dam.

Table 3-1. Target flows selected for field measurement for each study reach of the Sultan River, Washington. Actual flows measured varied by location and were influenced by tributary inflow and prevailing weather conditions.

Reach	Existing Instream Flow Requirements	Modeled Flow Range - Suggested in RSP3	Proposed Target Flows (Q) (first three flows will include depth-velocity sets)	Extrapolation Range[1] (based on Qs with D-Vel sets)
3	Year-round: 20 cfs	20 to 1,000 cfs	Q1 – 20cfs Q2 – 150 cfs Q3 – 300 cfs Q4* – 500 cfs Q5* – > 750 cfs	Conservatively – 8 cfs to 750 cfs; probably higher given additional WSEs at higher Qs
2	11/1 to 1/15: 95 cfs 1/16 to 2/28: 150 cfs 3/1 to 6/15: 175 cfs 6/16 to 9/14: 95 cfs 9/15 to 9/21: 145 cfs 9/22 to 10/31: 155 cfs	50 to 1,500 cfs	Q1 – 95 cfs Q2 – 200 cfs Q3 – 400 cfs Q4* – 600 cfs Q5* – > 800 cfs	Conservatively – 38 cfs to 1000 cfs; probably higher given additional WSEs at higher Qs
1	6/16 to 9/14: 165 cfs 9/15 to 6/15: 200 cfs	100 to 1,500 cfs	Q1 – 165 cfs Q2 – 300 cfs Q3 – 500 cfs Q4* - 700 cfs Q5* – > 800 cfs	Conservatively – 66 cfs to 1250 cfs; probably higher given additional WSEs at higher Qs

[1] The range of flow extrapolation will adhere to Washington State Guidelines (WDFW and WDOE 2004) that specify limiting the range of extrapolation to flows at which all Velocity Adjustment Factors (VAFs) are between 0.80 and 1.20, and for which no simulated velocities exceed 10 fps.

* Estimated target flows - only Water Surface Elevations measured at these flows.

Safety was also considered in the selection of the highest flow for which a complete velocity set would be measured. A more detailed discussion regarding the selection of target flows is provided in Appendix B, which contains a memorandum circulated to agencies and stakeholders describing the rationale and basis for the proposed flows.

3.2 STUDY REACH DELINEATION AND TRANSECT SELECTION

A total of six mainstem study sites were established on the Sultan River from Culmback Dam to the confluence with the Skykomish River: two sites in Reach 3, two sites in Reach 2, and two in Reach 1 (one each in Sub-Reaches 1A and 1B) (Figure 3-1). Study site locations were selected based on known fish use, and to emphasize stream channel/habitat areas most sensitive to Project operations. River access and safety were also considered in the selection of sites, especially in Reaches 3 and 2. As noted above, the location of potential study sites was first determined from a review of aerial photography, topographic maps, and low elevation video. An initial review of potential site locations was made (R2 biologists and District staff) during a reconnaissance survey of the Project reaches completed on May 4 and 9, 2007. During this survey, potential transect locations were flagged and marked on aerial photographs. The number and initial location of proposed transects was based on a review of existing habitat composition information (PUD #1 of Snohomish County and City of Everett 2005), field scoping, and consultation with District staff.

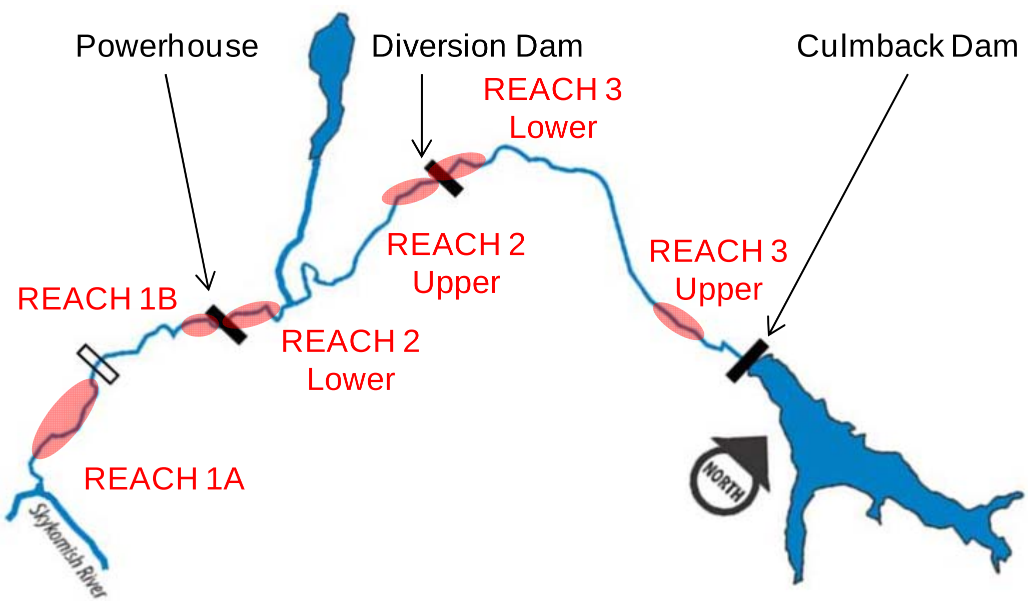


Figure 3-1. Location of mainstem study sites established for the instream flow study in each of the three operational reaches of the mainstem, Sultan River, WA.

3.2.1 Mainstem Transect Selection

Final study site and transect locations were determined collaboratively in consultation with the resource agencies/Project stakeholders (WDFW, NMFW, USFWS, USFS, and Tulalip Tribal consultant) during a field reconnaissance conducted on May 22, 2007 (Appendix A). After reviewing comments expressed by the agencies/stakeholders during the field reconnaissance, several minor adjustments to the number and location of specific transects were made (Appendix A). The most significant of the changes was the redistribution of transects within Reach 1.

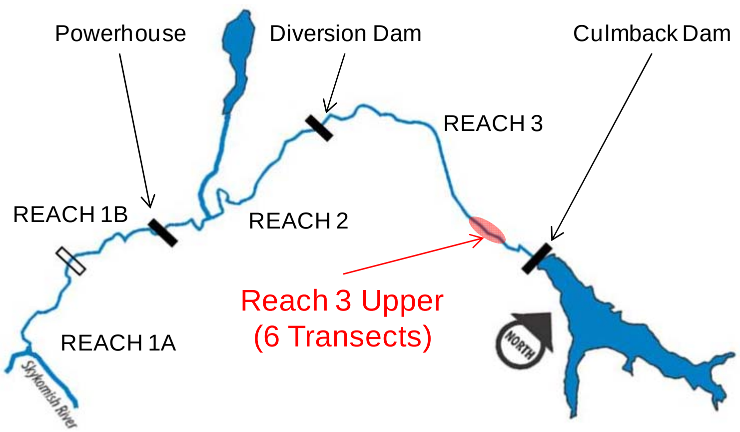
A total of 38 transects were identified as being broadly representative of channel characteristics and the overall composition of habitat within the mainstem Sultan River. Transects were arranged and numbered within each study site from downstream to upstream. Based on the results of detailed habitat surveys (RSP-18) and channel type classification (RSP-22), each transect was considered to be representative of a certain length of the river. River segment lengths were assigned to the nearest transect with similar channel morphology type[4]. Some revisions to habitat type designations were required after review of RSP 18 habitat surveys Habitat representations and locations of transects are depicted in (Figures 3-2 to 3-7 progressing from the upper reach (Reach 3) to the lower reach (Reach 1).

3.2.2 Side Channel Transect Selection

Side channels can provide important rearing and spawning habitats for salmonids and other aquatic species. For this study, side channels were defined as channels that are physically connected at both the upper and lower ends to the mainstem, that transmit flowing water from the mainstem at a relatively frequent mainstem flow level (i.e., annually or more often), and that have a well-defined and sorted channel substrate (i.e., exposed sand or gravel) (Figure 3-8). In the Sultan River, side channels are predominately found in Reach 1, where the river channel is less confined, and hence has been able to meander, form and use side channel areas for flow conveyance (Figure 3-9). The assessment of side channel habitats in this study focused on determining; a) the relationship of habitat quantity within the side-channel to flow in the side-channel; and b) relationship of flow in mainstem river to flow in the side-channel; i.e., connectivity. A PHABSIM type analysis involving transect placement and measurement conducted in concert with the mainstem study was completed to address the flow-habitat quantity component; surveying of water surface and bed elevations at the inlets of each side channel was used to determine mainstem connectivity.

Potential side channel habitat sites within Reach 1 were initially identified using color orthophotographs and USGS topographic maps. A total of 10 potential side channels were identified (Figure 3-9). Side channels were then verified and selected for sampling during a field visit conducted on May 9, 2007. Three of the identified 10 side channels were found to meet the criteria used in this study to define side channels, while also supporting fish use and unrestricted physical access.

[4] Some revisions to habitat type designations used in RSP 18 (Stillwater Sciences and Meridian Environmental (S008a) were made to ensure compatibility with habitat type designations used in this study.



Revised Transect Number	Habitat Type	Revised Habitat Type	Location (U/S to D/S)
TR-6	Pool/Riffle	Low Gradient Riffle	Transition u/s of TR-5
TR-5	Pool	Pool	Body of pool
TR-4	Riffle/Pool Tailout	Glide	Large pool u/s of LWD jam
TR-3	Riffle	Low Gradient Riffle	~20m u/s of LWD jam
TR-2	Riffle	Low Gradient Riffle	d/s of LWD jam
TR-1	Cascade	Rapid	~50m u/s of bridge

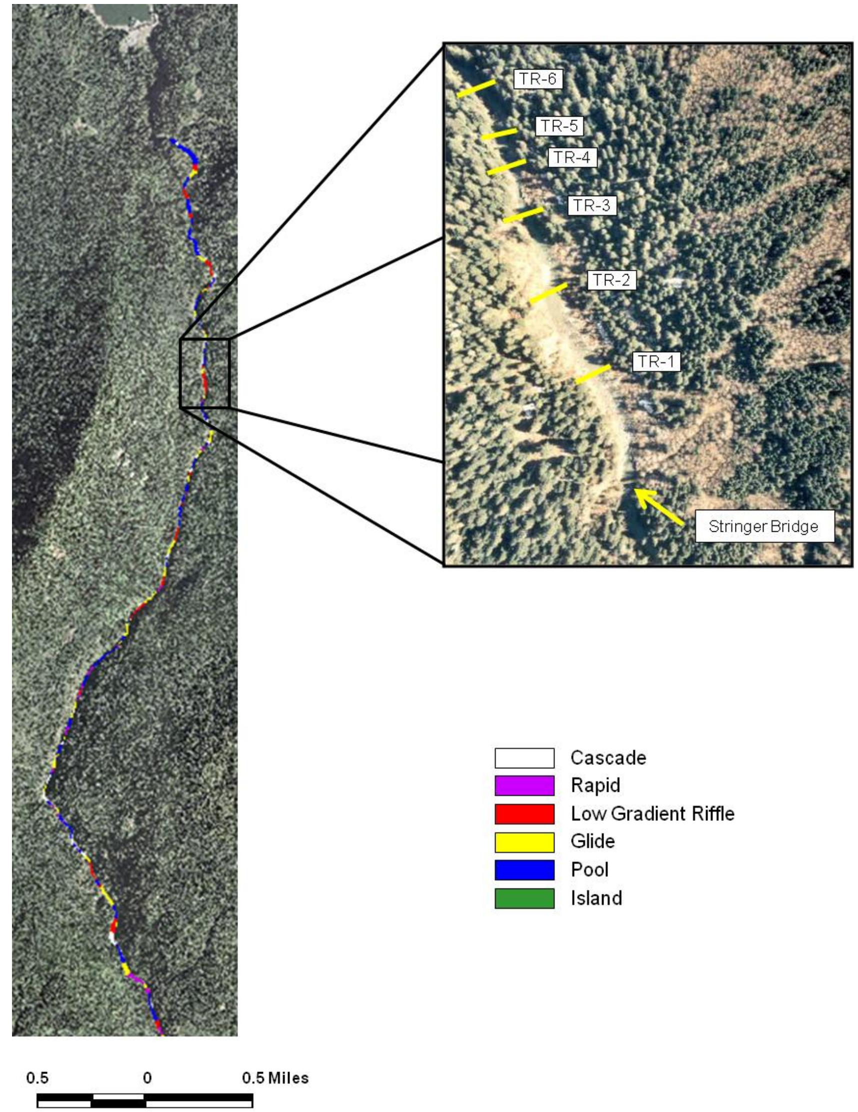
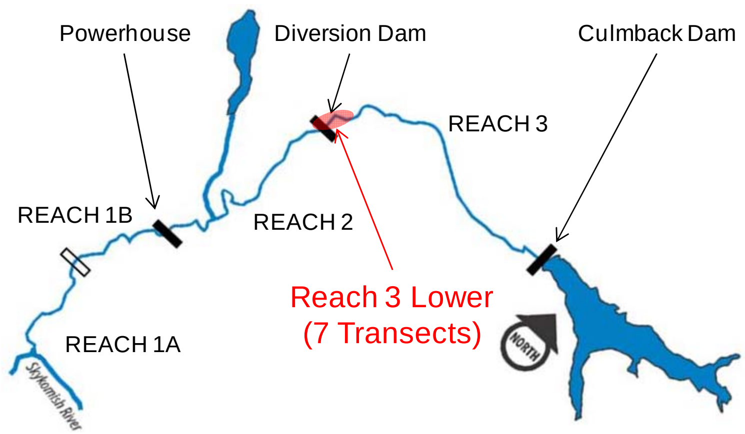


Figure 3-2. Reach 3 upper study site location, habitat composition (Stillwater Science and Meridian Environmental 2008a) and habitat types represented by each instream transect on the Sultan River, WA.



Transect Number	Habitat Type	Revised Habitat Type	Location (U/S to D/S)
TR-7	Pool/Riffle	Glide	u/s of Diversion Dam
TR-6	Riffle	Low Gradient Riffle	u/s of Diversion Dam
TR-5	Pool	Pool	u/s of Diversion Dam
TR-4	Glide	Glide	u/s of Diversion Dam
TR-3	Riffle	Rapid	u/s of Diversion Dam
TR-2	Riffle	Low Gradient Riffle	u/s of Diversion Dam
TR-1	Riffle	Glide	u/s of Diversion Dam

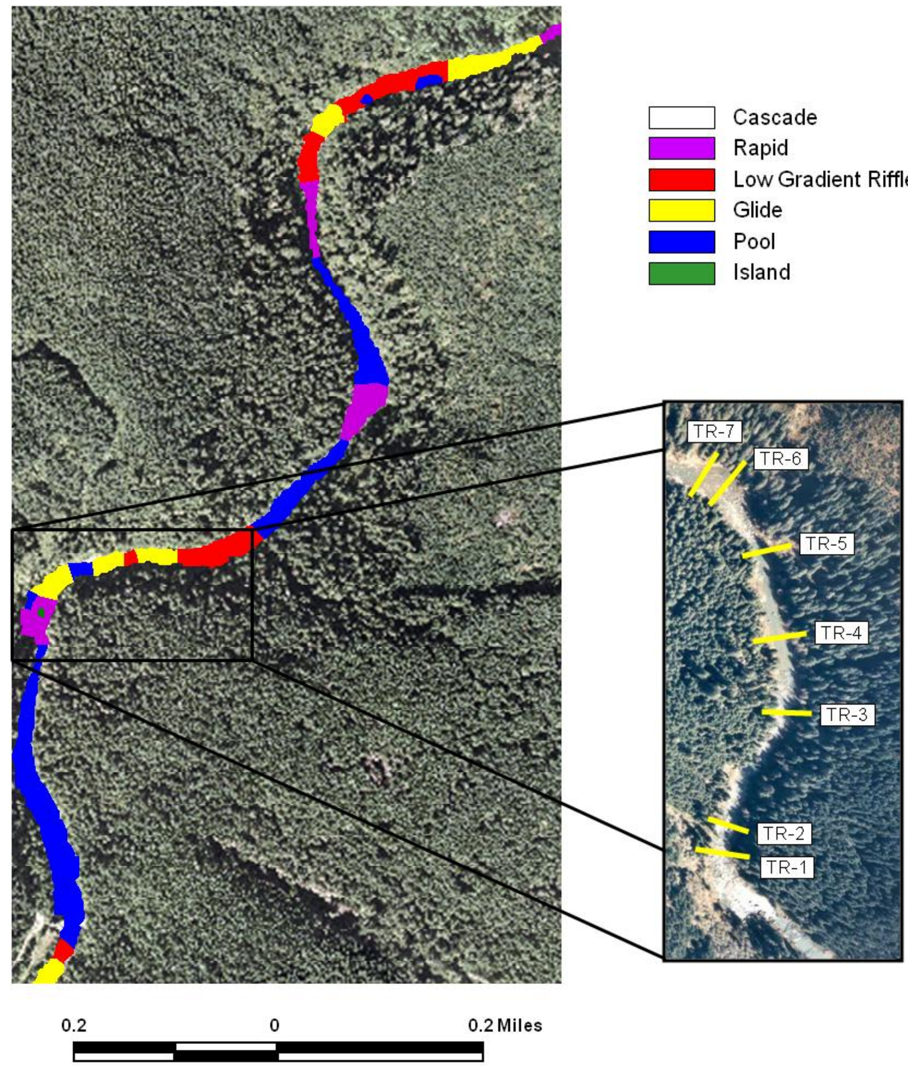
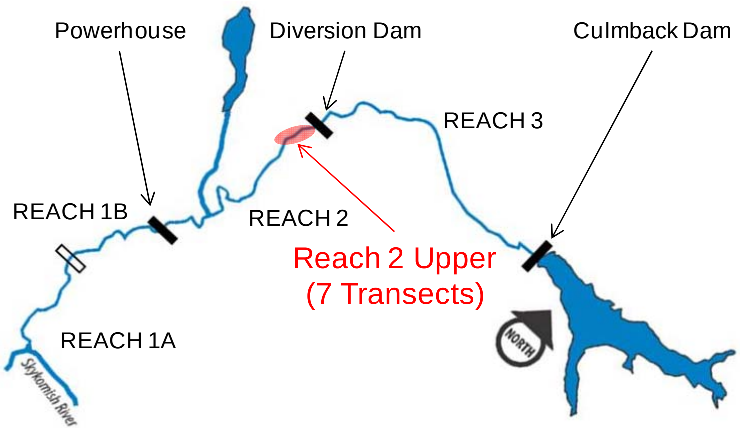


Figure 3-3. Reach 3 lower study site location, habitat composition (Stillwater Science and Meridian Environmental 2008a) and habitat types represented by each instream transect on the Sultan River, WA.



Transect Number	Habitat Type	Revised Habitat Type	Location (U/S to D/S)
TR-7	Riffle	Low Gradient Riffle	u/s of USGS trolley line
TR-6	Riffle	Low Gradient Riffle	d/s of USGS trolley line
TR-5	Cascade	Rapid	
TR-4	Riffle	Low Gradient Riffle	
TR-3	Riffle	Low Gradient Riffle	Gauging station stairs
TR-2	Pool	Glide	
TR-1	Pool/Cascade	Pool	Transition

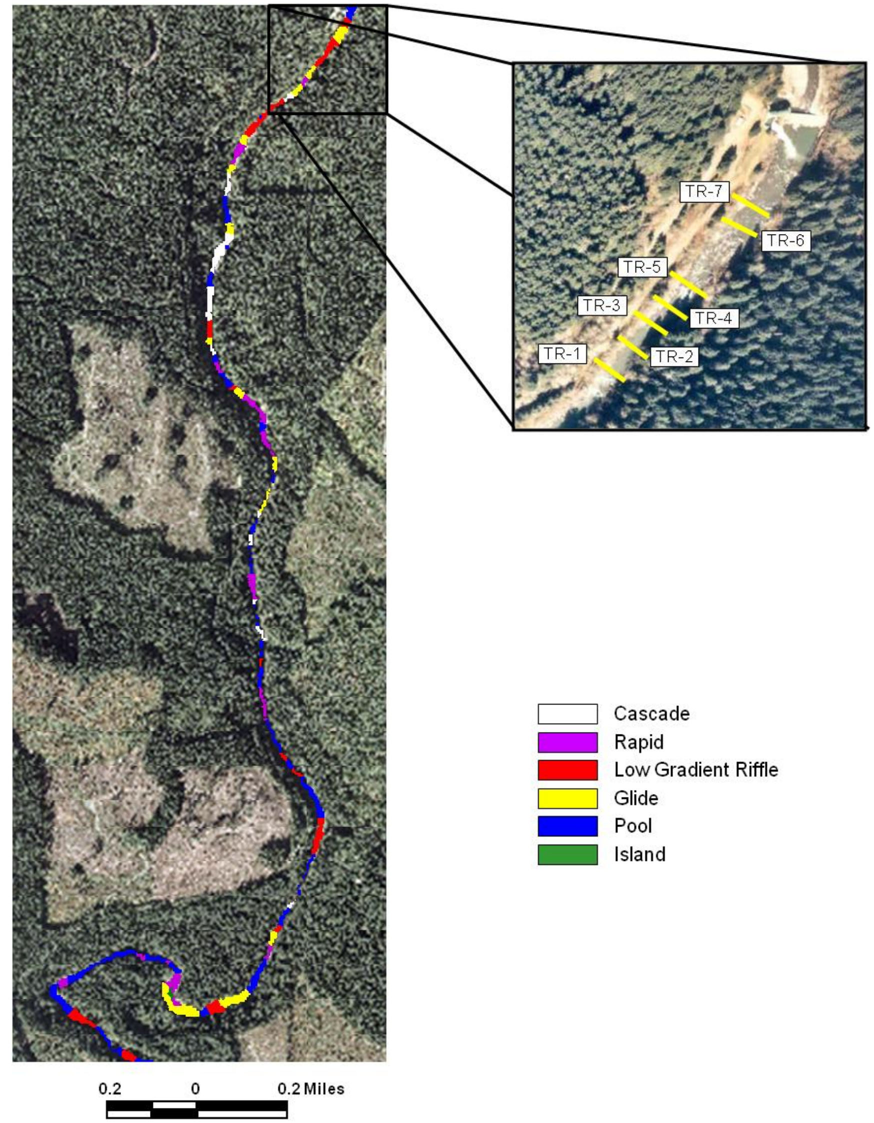
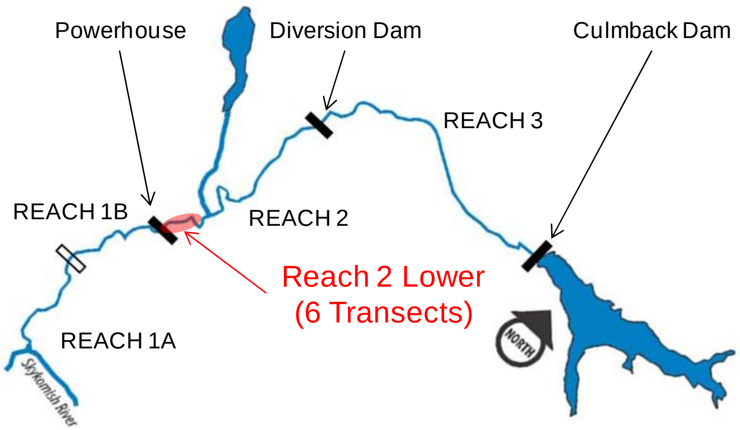


Figure 3-4. Reach 2 upper study site location, habitat composition (Stillwater Science and Meridian Environmental 2008a) and habitat types represented by each instream transect on the Sultan River, WA.



Transect Number	Habitat Type	Revised Habitat Type	Location (U/S to D/S)
TR-6	Pool Tailout	Pool	u/s of Powerhouse
TR-5	Cascade/Riffle	Low Gradient Riffle	u/s of Powerhouse
TR-4	Pool	Pool	u/s of Powerhouse
TR-3	Pool Tailout	Glide	u/s of Powerhouse
TR-2	Riffle	Rapid	u/s of Powerhouse
TR-1	Riffle	Glide	u/s of Powerhouse

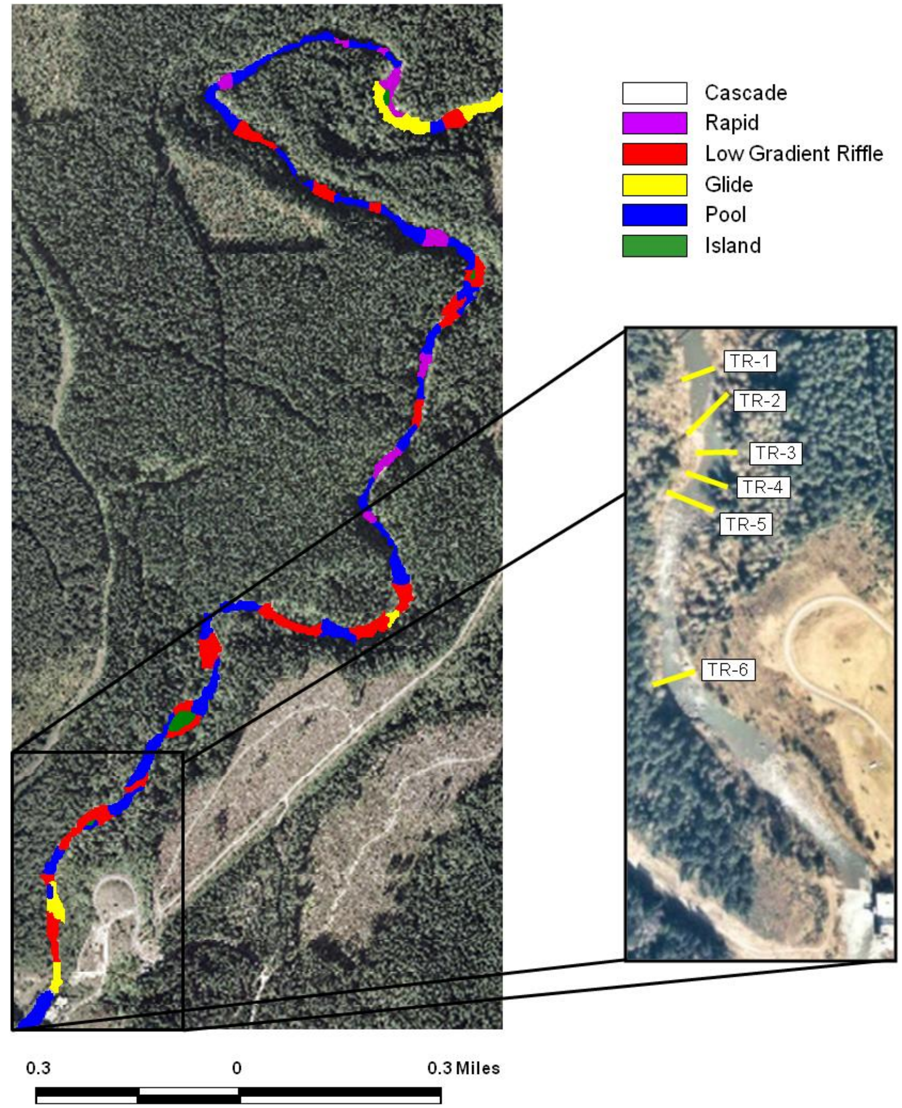
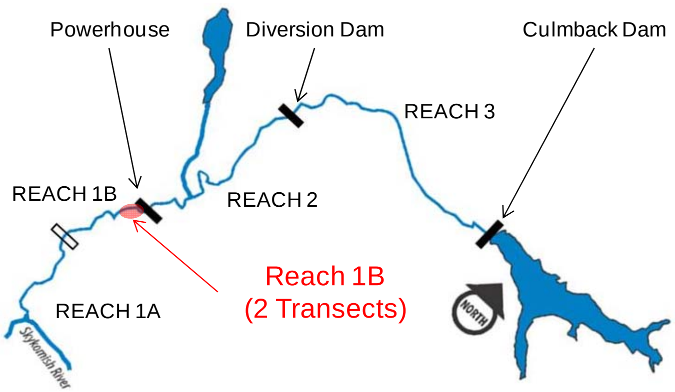


Figure 3-5. Reach 2 lower study site location, habitat composition (Stillwater Science and Meridian Environmental 2008a) and habitat types represented by each instream transect on the Sultan River, WA.



Transect Number	Habitat Type	Revised Habitat Type	Location (U/S to D/S)
TR-2	Run	Glide	d/s of Powerhouse
TR-1	Riffle	Low Gradient Riffle	d/s of Powerhouse

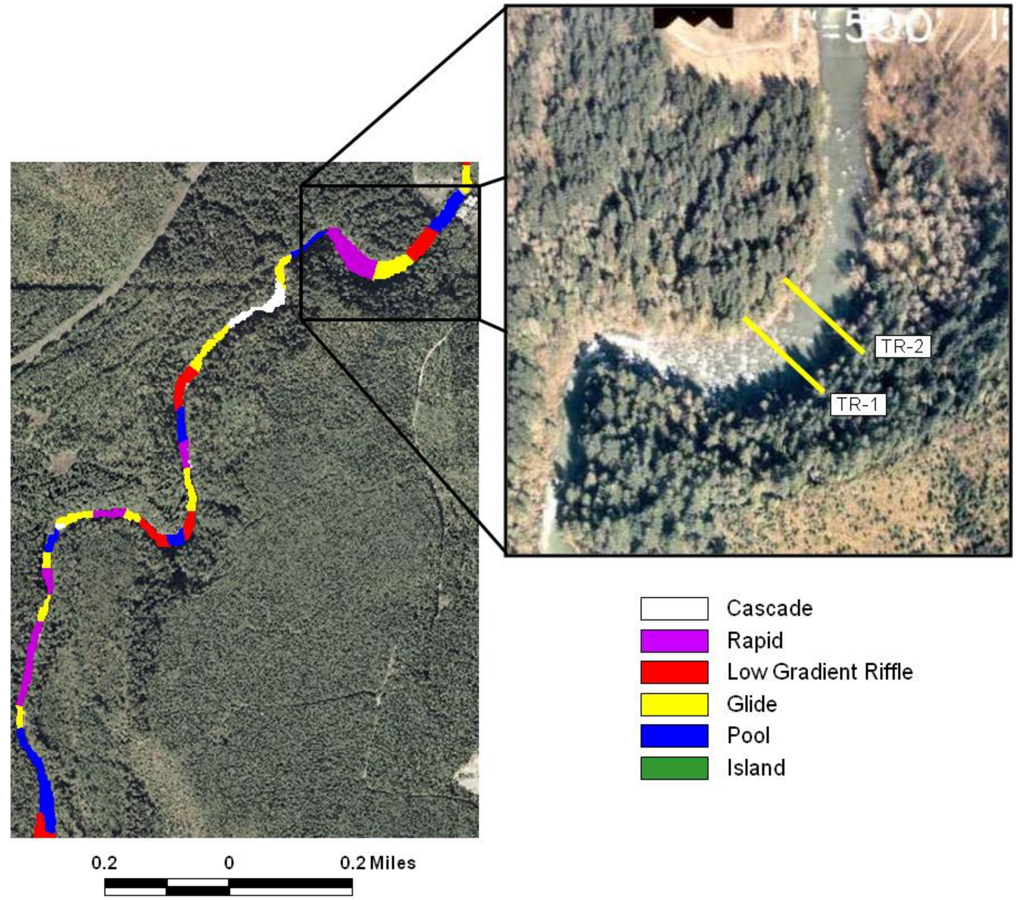
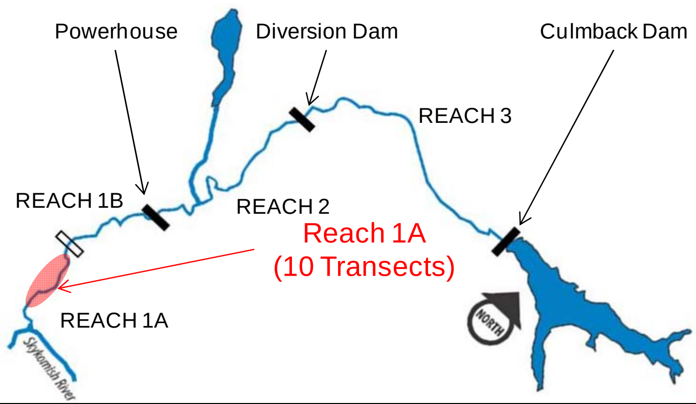


Figure 3-6. Reach 1B study site location, habitat composition (Stillwater Science and Meridian Environmental 2008a) and habitat types represented by each instream flow transect on Sultan River, WA.



Revised Transect Number	Habitat Type	Revised Habitat Type	Location (U/S to D/S)
TR-10	Riffle	Rapid	Head of Mike's Island
TR-9	Pool	Pool	
TR-8	Pool Tailout/Riffle	Glide	
TR-7	Riffle	Low Gradient Riffle	
TR-6	Run/Pool	Glide	u/s of Keenes Island
TR-5	Riffle	Low Gradient Riffle	Top of Rose Bar
TR-4	Riffle	Low Gradient Riffle	Bisects Rose Bar
TR-3	Run/Pool	Glide	
TR-2	Riffle	Low Gradient Riffle	Right side of Osprey Island
TR-1	Glide/Run	Glide	

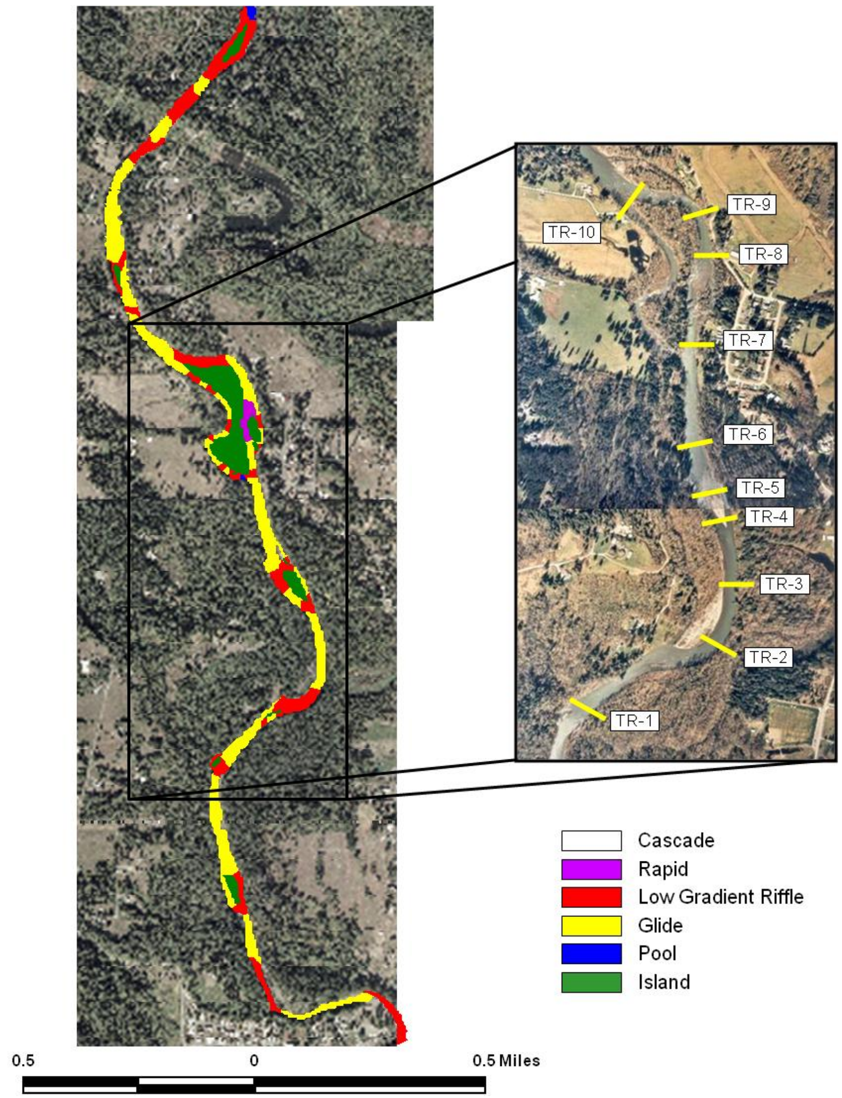


Figure 3-7. Reach 1A study site location, habitat composition (Stillwater Science and Meridian Environmental 2008a) and habitat types represented by each instream flow transect on the Sultan River, WA.

Figure 3-8. Downstream view within Side Channel #1 of the Sultan River, Washington under relatively high flow conditions. Photo taken on April 12; main channel flow approximately 3000 cfs. Tripod sits on exposed gravel and cobble substrates.

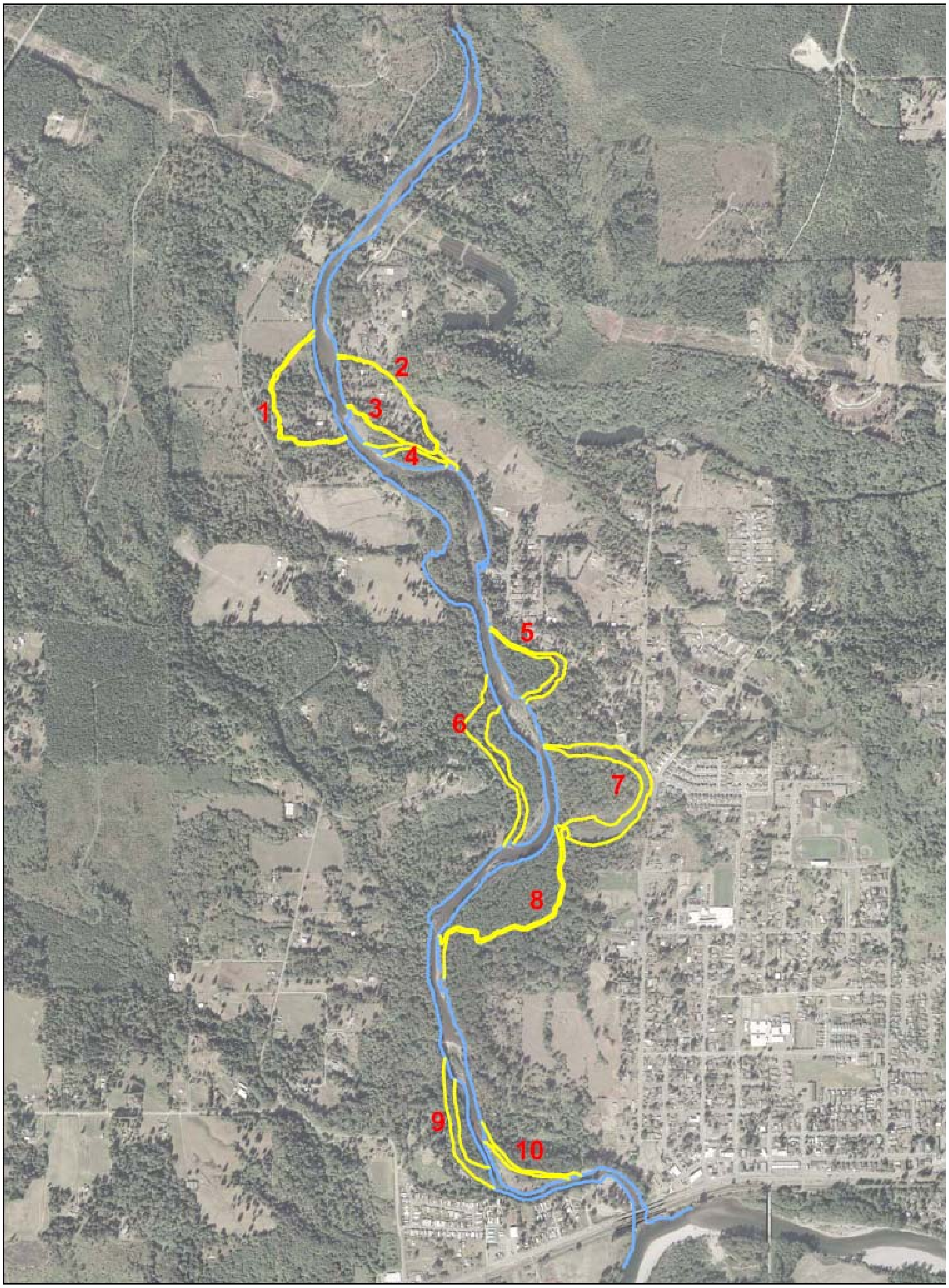


Figure 3-9. Location of mapped side channel areas within Reach 1A (PUD #1 of Snohomish County and City of Everett 2005) of the lower Sultan River, WA. Side channels 1, 6 and 8 were selected for detailed analysis in this study, and correspondingly re-numbered Side Channels 3, 2, and 1, respectively).

A total of 18 transects, were established within the three side channels. Because detailed habitat mapping information was not available during transect selection, transects were equally distributed between the three side channels, with six transects placed within each. Individual transects were located to capture riffle, pool, and run/glide habitat types within each channel (Figures 3-10, 3-11, 3-12). Special emphasis was placed on locating the upstream most transect within each side channel near the inlet so that a stage-discharge relationship could be developed between flow in the mainstem Sultan River and within each side channel.

3.3 FIELD DATA COLLECTION

Field data were collected at mainstem and side channel transects between June 2007 and December 2007. Mainstem cross-sectional profiles and water surface elevations, and flow depths and velocities across the wetted channel width, were measured at three to five flow conditions ranging from a low of approximately 38.1 cfs in Reach 3 to a high of 1,400 cfs[5] in Reach 1 (Table 3-2). Figures 3-13 through 3-18 depict views of representative transects within each of the two sites for each reach as measured during two flow conditions. Side channel habitat width, depth, and velocities were measured over several flow conditions ranging from a low of <1 cfs to a high of >90 cfs. Field data collection methods were the same for mainstem and side channel transects.

3.3.1 Hydraulic and Habitat Measurements

R2 collected hydraulic and habitat measurements consistent with methods described for the Physical Habitat Simulation System (PHABSIM) as noted in Bovee (1982), Milhous et al. (1984). PHABSIM relies on cross sections to define the channel shape and characterize the hydraulic properties over a range of flow conditions. At each of the Sultan River sampling sites, cross sections (transects) were established within representative habitat types (except cascade habitat as defined by RSP-18) to characterize the channel bathymetry, water surface elevations, and velocity profiles at several different discharges. Figure 3-19 illustrates the general set-up and locations of hydraulic and habitat measurements for a given transect. The percentages of the dominant and subdominant substrate surface layers were visually estimated at each transect station using the nine substrate classifications listed in Table 3-3.

The collection of physical and hydraulic measurements at each transect was completed following the general procedures outlined by Bovee and Milhous (1978), Bovee (1982), and Trihey and Wegner (1983). Depending on flow conditions, field data were collected by a field crew (2-4 individuals) having expertise in PHABSIM field methods as well as hydraulic and habitat simulation modeling procedures. Copies of the raw field notes are presented in Appendix F.

[5] High flow discharge obtained from USGS gage 12138160 15 minute flow data

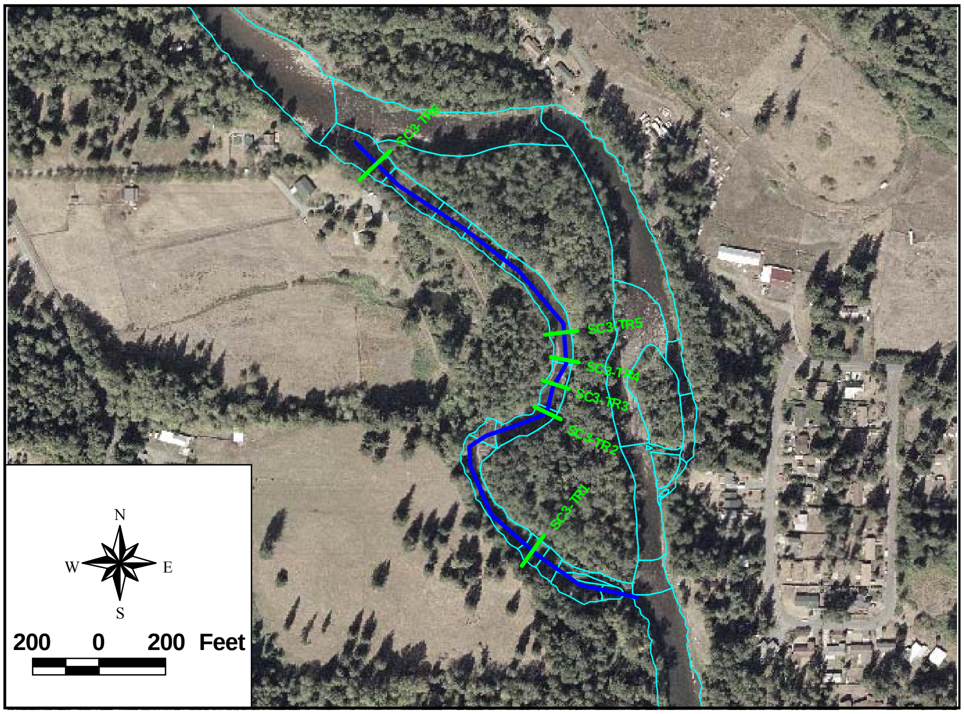


Figure 3-10. Distribution of transects within Side Channel 3 (upper most side channel), Reach 1A, Sultan River, WA.

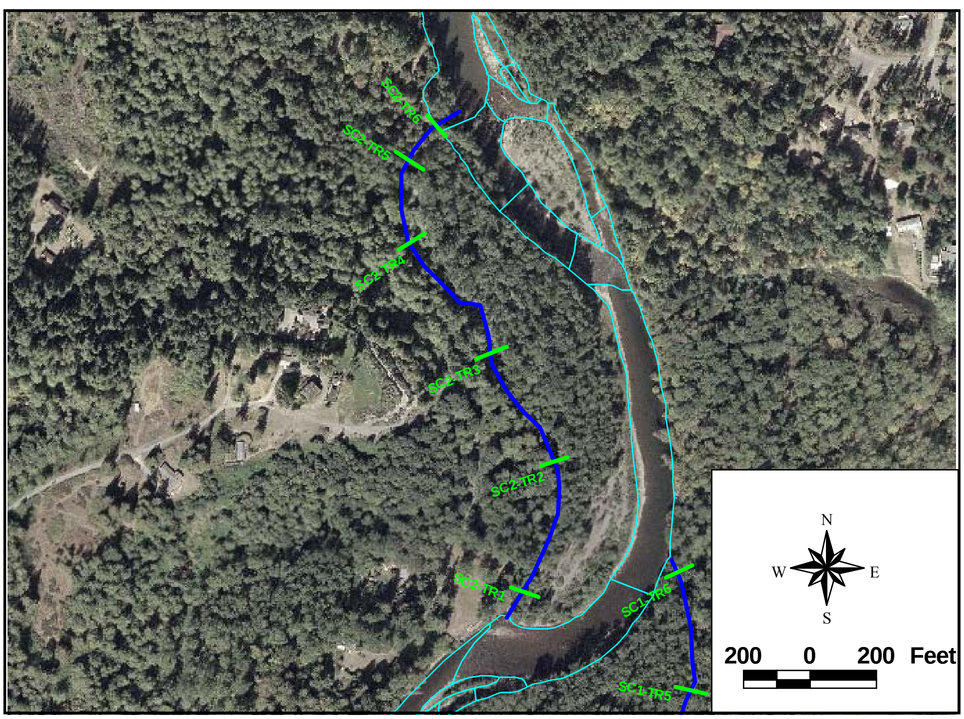


Figure 3-11. Distribution of transects within Side Channel 2, Reach 1A, Sultan River, WA.

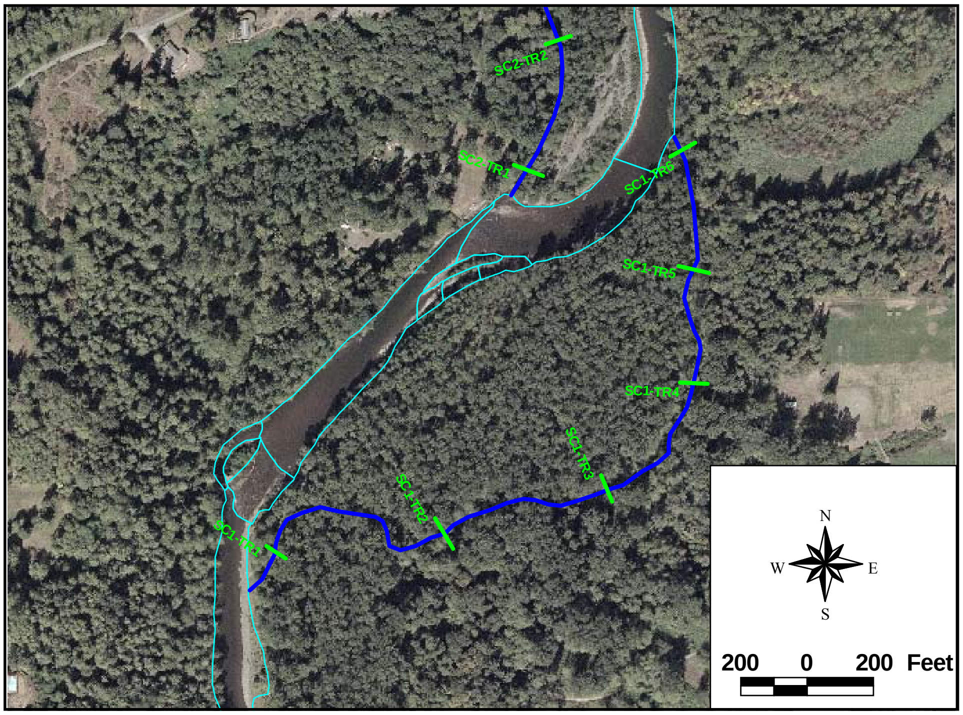


Figure 3-12. Distribution of transects within Side Channel 1 (lower most side channel), Reach 1A, Sultan River, WA.

Table 3-2. Dates and flows (cubic feet/sec, cfs) measured in the mainstem Sultan River, 2007, during the instream flow study.

	Sample Date and Flow									
Reach	**Date**	**Flow (cfs)**	**Date**	**Flow (cfs)**	**Date**	**Flow (cfs)**	**Date**	**Flow (cfs)**	**Date**	**Flow (cfs)**
1A	07/18/07	495	07/19/07	296	07/20/07	180	10/21/07	1400	12/20/07	900
1B	07/18/07	495	07/19/07	296	07/20/07	180	10/21/07	1400	12/20/07	900
2 Lower	07/11/07	123	07/12/07	240	07/13/07	430	10/19/07	724	10/20/07	1282
2 Upper	07/11/07	116	07/12/07	236	07/13/07	398	10/19/07	523	10/20/07	928
3 Lower	06/27/07	55	06/28/07	176	06/29/07	350	10/19/07	510	NS	NS
3 Upper	06/27/07	38	06/28/07	168	06/29/07	320	10/19/07	370	NS	NS

NS=not sampled

Figure 3-13. Upstream views to Transect 3 within the Upper Site of Reach 3 during high flow (320 cfs; June 29, 2007) (upper photo) and low flow (38 cfs; June 27, 2007) measurements.

Figure 3-14. Side views of Transect 1 within the Lower Site of Reach 3 during high flow (350 cfs; June 29, 2007) (upper photo) and low flow (55 cfs; June 27, 2007) (lower photo) measurements.

Figure 3-15. Upstream views to Transect 4 within the Upper Site of Reach 2 during high flow (398 cfs; July 13, 2007) (upper photo) and low flow (116 cfs; July 11, 2007) (lower photo) measurements.

Figure 3-16. Side views of Transect 1 within the Lower Site of Reach 2 during high flow (430 cfs; July 13, 2007) (upper photo) and low flow (123 cfs; July 11, 2007) (lower photo) measurements.

Figure 3-17. Side views of Transect 1 within Reach 1B during high flow (495 cfs; July 18, 2007) (upper photo) and low flow (180 cfs; July 20, 2007) (lower photo) measurements.

Figure 3-18. Upstream view to Transect 7 within Reach 1A during high flow (495 cfs; July 18, 2007) (upper photo) and low flow (180 cfs; July 20, 2007) (lower photo) measurements.

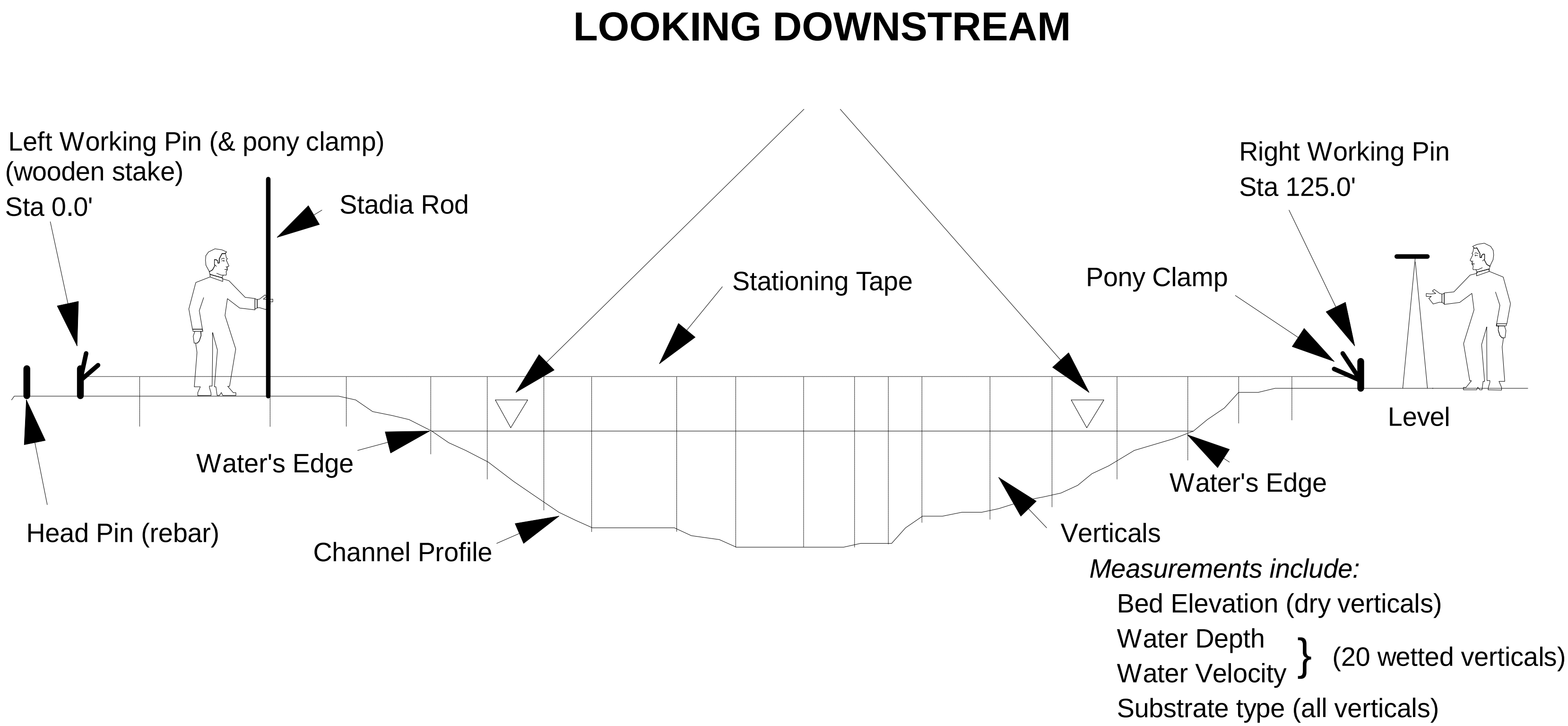


Figure 3-19. Example PHABSIM cross channel transect illustrating typical transect setup and data collection points across each transect.

Table 3-3. Channel substrate grain size classifications, used for the Sultan River instream flow study.

Code	Type of Substrate	Code	Type of Substrate	Code	Type of Substrate
1	Silt, clay, or organic	4	Medium gravel (0.5–1.5")	7	Large cobble (6–12")
2	Sand	5	Large gravel (1.5–3")	8	Boulder (> 12")
3	Small gravel (0.1–0.5")	6	Small cobble (3–6")	9	Bedrock

The establishment of transects occurred during initial field measurements conducted during June and July 2007. The set-up of transects at each location was completed as follows:

- Locations of Transects – Transect locations were determined as latitude and longitude using a satellite based Global Positioning system (GPS). Transect positions were recorded into a field book and then marked on a topographic map.

- Establishment of Site Benchmark – Permanent benchmarks (BMs) were established at each transect; this benchmark was given an arbitrary elevation datum of 100.00 ft. All survey measurements, including headpin and water surface elevations, were referenced to this arbitrary benchmark elevation.

- Installation of Head Pins – Head pins (rebar) were installed on one side of the river near the start or end point of each transect. The head pins and BMs served as vertical reference for water surface and bed elevation measurements. The head pins were left in place for future reference.

- Establishment of Working Pins – Working pins (wooden stake, tree, fencepost) were established on both sides of a transect. The working pins were established in such a way that the line connecting these points would be perpendicular to the main flow of the river (or side channel) channel. A surveying tape was then tied to the working pins and stretched across the river channel and connected to these points.

- Survey of Headpin Elevations and Completion of Level Loop – Subsequent to the installation of the head pins, a level loop survey was conducted to establish head pin elevations. The elevation data were obtained using a Nikon 32x Automatic Level and 25-ft stadia rod with increments in 0.01 ft intervals. The level loop was considered "closed" if the head pin and BM elevations were within 0.02 ft.

Transect measurements were obtained under three to five different flow conditions. The following data were recorded at each transect:

- Reach Location, Study Site Location, and Transect Number – corresponding to the Operational reach, site location, transect;

- Habitat Type – classified as run/glide, low gradient riffle, steep riffle/rapid, or pool (as previously noted – no cascade habitat units were sampled);
- Sampling Date/Time/Field Crew/Flow – information regarding when data were collected, who collected the data, and what flow condition/target estimated;
- Water Surface Elevations (WSEs) – measured to the nearest 0.01 ft. at three locations in the channel: near left water edge, center of channel, and near right water edge (note: in some high flow conditions, only one side of the channel was surveyed due to high velocities and safety concerns);
- Photographs – representative photographs were taken of each transect under each of the sampled flow conditions (Appendix E).

Velocity and depth measurements were collected during separate flow events for all transects except those representing pool habitat. Only one set of velocity and depth measurements were made in pool habitat units due to the small amount of variability or change in pool velocity and depth in response to changes in flow level. Velocity and depth data were collected at specified intervals (verticals) across each transect, with the number and spacing of the vertical measurements dependent on transect width and flow. The verticals were spaced in such a way that no more than 10% of the channel flow was located between any two verticals. If the channel was flowing (only applicable to side channel habitats), depth and velocity profiles were measured at each transect. The following data were collected at measurement points across each transect:

- Bed Elevations (to nearest 0.01 ft) – determined indirectly from water depth measurements (bed elevation = WSE - water depth);
- Water Depth (to nearest 0.01 ft) – measured using either a 4-ft or 6-ft top setting rod or depth sounder;
- Mean Column Water Velocity (to nearest 0.01 ft/sec) – measured using a Swoffer Model 2100 velocity meter; velocities were measured at 6/10ths depth in the water column for depths less than 2.5 ft, and 2/10ths and 8/10ths depths in the water column for depths greater than 2.5 ft;
- Substrate (dominant and subdominant) – see classifications in Table 3-3; and
- Cover – the presence of bank cover, object cover (e.g., boulder, large woody debris), and overhead vegetation.

3.4 HABITAT SUITABILITY CRITERIA

Biological input into PHABSIM modeling is provided in the form of Habitat Suitability Criteria (HSC) curves that represent the use/preference of a given species and life stage for certain water depths, velocities, and substrate characteristics. When the HSC are linked with the hydraulic models developed for each transect and site, PHABSIM can then estimate the amount of habitat, termed Weighted Useable Area (WUA), over a range of flows. For this study, R2 followed the Washington State Instream Flow Study Guidelines (WDFW and WDOE 2008) that suggested either the development of site-specific HSC curves or the use of agency fallback criteria (State Fallback Curves) when conducting PHABSIM studies.

Because the shape of HSC curves can dramatically influence the shape of the resulting WUA-flow curves, the District requested R2 to collect site specific HSC data for selected target species. Given their importance in the basin and their listing status, R2 focused data collection on Chinook salmon (spawning and juvenile), steelhead trout (spawning and juvenile), and coho salmon (juvenile). For other salmonid species and life stages in the basin, R2 relied on the State Fallback Curves.

This section summarizes the methods used in collecting microhabitat data and developing site specific HSC criteria for the Sultan River. A detailed description and discussion of the HSC development process is provided in Appendix C.

3.4.1 Snorkel Surveys

Snorkel observations were selected as the primary survey technique to determine microhabitat use (depth, velocity, and substrate) of juvenile and adult salmonids in the lower Sultan River. Fish observations specific to the habitat being utilized provide information needed to construct site specific HSC curves. Observational surveys of juvenile and adult salmonids were completed during the summer (July/August) of 2007. Snorkel surveys were conducted by a team of two or three fish biologists with extensive experience in salmonid species identification. In general, the steps used in completing these surveys included: assessment of water visibility using a secchi disk; identification of fish species, size class, location in the water column, and proximity to habitat structure; and microhabitat measurements of water depth, mean column velocity and substrate classification (see Appendix C).

3.4.2 Redd Surveys

Redd surveys were conducted as part of a larger monitoring program conducted by District fish biologists to monitor spawning activities in the Sultan River basin. Active spawning locations were identified by District staff during pedestrian and helicopter surveys of the river completed as part of their annual spawner surveys. Redd surveys were conducted on-foot during three time periods: Fall (September – November) 2006 and 2007; Summer (June and July) 2007; and Spring 2008 (April and May).

All surveys were conducted by walking the stream channel in an upstream direction and identifying the location of newly constructed redds. For each identified redd, the following measurements were made: 1) redd dimensions (length and width in ft); 2) water depth (nearest 0.1 ft); 3) mean water column velocity (fps); and 4) substrate size (dominant, sub-dominant, and percent dominant) characterized in accordance with the size classifications described in WDFW (2008).

3.4.3 Data Analysis

Site specific microhabitat utilization measurements were collected for four distinct species and life stages of fish in the Sultan River: steelhead/rainbow trout fry (n observations = 431), juvenile coho salmon (n observations = 459), spawning steelhead trout (n observations = 68), and spawning Chinook salmon (n observations = 133). Prior to computation of HSC curves, the habitat data were entered into commercially available spreadsheets and subsequently checked for data entry accuracy. Data were sorted according to species type and life-history stage. Frequency distributions were then generated for mean velocity, depth, and substrate type for each species. Frequency bin widths of 0.1 were initially used to evaluate the mean velocity and depth utilization distributions. Histogram plots of depth and mean column velocity utilization were produced using slightly larger bin widths to ensure a sufficient number of observations per bin.

Draft HSC curves (depth and velocity) were subsequently developed using the site specific observations normalized to a suitability of 1.0. The resulting curves for juvenile coho salmon as well as steelhead/rainbow trout fry were similar to the State Fallback curves and no modifications were suggested (R2 2008a). However, the spawning curves for Chinook and steelhead differed from the Fallback curves suggesting these site specific curves may be more applicable for determining the habitat-flow relationships for the Sultan River.

3.4.4 Review and Adoption of HSC Criteria

R2 subsequently prepared a report that described the overall process used in collecting and analyzing the HSC data, and presented the proposed modified HSC curves (based on utilization data) for Chinook and steelhead spawning (R2 2008a). The report was distributed to the Aquatic Resources Working Group (ARWG) for review, and was discussed during a technical meeting on July 22, 2008. Based on written comments on the report and comments received during the meeting, R2 completed additional analysis of the utilization data to account for availability. This analysis resulted in the development of preference curves for both Chinook and steelhead spawning. R2 prepared a Technical Memorandum (TM) (R2 2008b) describing the methods and results of the analysis, along with the two proposed HSC curves for Chinook and steelhead spawning. The District submitted the TM to the ARWG for review and comment on August 4, 2008, and subsequently received concurrence from the WDFW on the curves on August 7, contingent on a minor change to the depth curve for steelhead (see Appendix C). Because either no site specific data were collected, or the data collected did not suggest modification, R2 relied on and used Fallback Curves for the species and life stages noted in Table 3-4; HSC curves for these species and life stages are presented in Appendix C. The Sultan River site specific HSC curves and Fallback curves noted below were adopted and used in deriving all of the habitat-flow relationships presented and discussed in the remainder of this report.

Table 3-4. Species and life stages for which State Fallback Curves were applied for the Sultan River instream flow study, and rationale for use.

Species	Life Stage	Rationale for Using State Fallback Curves
Chinook salmon	Juvenile	Insufficient observations to develop site specific criteria
Steelhead trout	Juvenile	No data collected; observations only made of fry life stage
Coho salmon	Juvenile	Site specific data collected but Utilization Curve did not indicate modification warranted
Chum salmon	Spawning	No data collected
Chum salmon	Juvenile	No data collected
Pink salmon	Spawning	No data collected
Rainbow trout	Spawning	No data collected
Rainbow trout	Adult	No data collected
Rainbow trout	Juvenile	No data collected
Cutthroat trout	Spawning	No data collected
Cutthroat trout	Adult	No data collected
Cutthroat trout	Juvenile	No data collected

3.5 MODELING

3.5.1 Hydraulic Modeling

The cross sectional field data collected from each transect were analyzed using hydraulic models within PHABSIM (i.e., IFG4, MANSQ, WSP). Based on transect/channel morphologies, a hydraulic model was selected to develop stage-discharge relationships for each of the mainstem and side channel transects. Details of all calibration steps were documented and are presented in Appendix E.

Hydraulic simulation modeling included the following steps:

- Raw field data were entered into Excel spreadsheets, reviewed, and reduced into a form ready for creation of hydraulic data decks (Appendix E).
- Data entry errors were identified, noted in a copy of the field notebook, and corrected. These computer spreadsheets were then used to generate hydraulic data input files for the PHABSIM hydraulic simulation program, IFG4 (Appendix E).
- The IFG4 data files were checked for any errors and erroneous field measurements using the REVI4 and CKI4 computer programs.
- Stage:discharge relationships were developed using one or more hydraulic simulation procedures, depending upon the hydraulic characteristics of individual transects. An initial stage:discharge calibration was conducted using the PHABSIM program IFG4. Depending upon the hydraulic characteristics of a given transect, a final stage:discharge relationship was developed using one or more of three methods: a log-log regression method (rating curve developed using the program STGQS4), a channel geometry and roughness method (rating curve developed using the Manning's Equation based program MANSQ), or a step-backwater method (rating curve developed using the program WSP) (Appendix E).
- Velocities across each transect were calibrated to provide a realistic distribution of mean column velocities across the river channel for the entire range of flows employed in habitat simulations. As recommended under the Washington State Instream Flow Study Guidelines (2008), a standard "three velocity set" regression model was used on all transects except for special circumstances, such as a pool habitat in which only one velocity set was measured.

The range of extrapolation of hydraulic modeling results to unmeasured flows depends greatly on the spread between the calibration/measured flows and the Velocity Adjustment Factors

(VAF). VAF is a measure of how well a three-flow regression model simulates or predicts velocities at measured flows. Washington State Instream Flow Study Guidelines (2008) recommend that extrapolation of measured flows/velocities be limited to flows at which all VAFs are between 0.80 and 1.20. A summary of VAFs and calibration details are presented in Appendix E.

3.5.2 Habitat Modeling

Habitat simulations were completed using the HABTAV habitat simulation modeling program. HABTAV uses velocities obtained directly from the hydraulic model (IFG4) output files for habitat area calculations (Milhous et al. 1989). Output from the hydraulic simulation modeling was used in conjunction with the appropriate modified and Fallback HSC criteria to simulate habitat conditions for each target species and life stage over a wide range of flows. Habitat quantification is expressed as an index called Weighted Useable Area (WUA) and is given in square feet of habitat per 1,000 feet of stream. The determination of habitat-flow relationships progressed initially from the individual transect level, to the site/sub-reach level in which a composited habitat –flow curve was developed based on transect weightings within the site/sub-reach (i.e., 2 sites per reach), and finally to the reach level, in which a single habitat-flow relationship was derived for each reach based on reach specific habitat mapping and corresponding transect weightings. The steps in this analysis are described below.

3.5.2.1 Transect Weighting and Habitat Mapping

The results of the mainstem transect WUA calculations for each transect were weighted based on the amount of habitat each transect represented within their respective operational reaches. During the site selection process, transect groupings (as represented by a site) were generally positioned in both the upper and lower portion (i.e., sub-reach) of each Operational Reach in part to help capture geomorphological differences within a reach. As such, each grouping of transects at a site can be viewed as representing a sub-reach within each Operational Reach. Sub-reaches were defined based primarily on break points between the Process Reaches as determined in Stillwater Sciences and Meridian Environmental (2008b). However, because Operational Reach 2 falls entirely within a single process reach, the delineation between Reach 2 Lower and Reach 2 Upper was defined as the longitudinal midpoint of Operational Reach 2. A complete description of sub-reach definitions is provided in Table 3-5.

Once the sub-reaches were defined, the habitat composition (by length) of each sub-reach was calculated using the results of the habitat mapping study completed by Stillwater Sciences and Meridian Environmental (2008a). To ensure that each habitat unit was assigned to the appropriate sub-reach, this step required making a slight adjustment to the length of each unit measured during the RSP18 study, such that the measured river-miles were consistent with the Operational Reach breaks (i.e., Powerhouse = RM 4.3; Diversion Dam = RM 9.7). In addition, because the habitat surrounding islands was typically divided into separate units, the habitat composition of each sub-reach was calculated using only mainstem units to avoid overestimating the contribution of split channel sections of river (i.e., parallel units).

Table 3-5. Description of sub-reaches used for weighting of transects for the Sultan River instream flow study.

Transect Group Sub-Reach	Operational Reach (OR)	Process Reach (PR)	River-Miles Represented
Reach 1A	OR 1	PR 1	Skykomish R. confluence (RM 0.0) upstream to upper bound of Process Reach 1 (RM 3.0)
Reach 1B	OR 1	PR 2	Lower bound of Process Reach 2 (RM 3.0) upstream to Powerhouse (RM 4.3)
Reach 2 Lower	OR 2	PR 2	Powerhouse (RM 4.3) upstream to midpoint of Operational Reach 2 (RM 7.0)
Reach 2 Upper	OR 2	PR 2	Midpoint of Operational Reach 2 (RM 7.0) upstream to Diversion Dam (RM 9.7)
Reach 3 Lower	OR 3	PR 2	Diversion Dam (RM 9.7) upstream to upper bound of Process Reach 2 (RM 11.0)
Reach 3 Upper	OR 3	PR 3	Lower bound of Process Reach 3 (RM 11.0) upstream to terminus of 2007 habitat survey (RM 16.2)

The next step in weighting the instream flow transects required reclassifying the habitat type initially assigned to each transect to be consistent with the habitat classifications used in RSP18. This was followed by assigning a number of river miles to each transect based on the transect habitat type and the amount of that habitat type within the corresponding sub-reach. Where multiple transects with the same habitat type were located within the same sub-reach, the amount of that habitat was divided equally among each transect. For example, Reach 1A contained 1.97 river-miles of glide habitat and four transects classified as glides. Thus, each of these glide transects were assigned to represent 0.46 miles of river (Table 3-6).

At the reach level, transect weighting was calculated as a percentage by dividing the number of miles represented by each transect by the total number of miles within each Operational Reach (rather than sub-reach). This approach was slightly modified for sub-reaches where surveyed habitat types were not represented by any transects. Specifically, there were no transects in any sub-reach that qualified as cascades, as defined in RSP 18. In addition, because only two

Table 3-6. Transect-weighting factors used to derive reach specific habitat results from the PHABSIM analysis for the Sultan River instream flow study. GLD = glide; LGR = low gradient riffle; RPD = rapid; POOL = pool.

Reach	Sub Reach	Transect	Habitat Type	River Miles Assigned	Transect Weighting Factor*
1	1A	1	GLD	0.46	13.1%
1	1A	2	LGR	0.26	7.5%
1	1A	3	GLD	0.46	13.1%
1	1A	4	LGR	0.26	7.5%
1	1A	5	LGR	0.26	7.5%
1	1A	6	GLD	0.46	13.1%
1	1A	7	LGR	0.26	7.5%
1	1A	8	GLD	0.46	13.1%
1	1A	9	POOL	0.00	0.0%
1	1A	10	RPD	0.09	2.5%
1	1B	1	LGR	0.16	4.6%
1	1B	2	GLD	0.37	10.3%
2	2 Lower	1	GLD	0.07	1.3%
2	2 Lower	2	RPD	0.29	5.9%
2	2 Lower	3	GLD	0.07	1.3%
2	2 Lower	4	POOL	0.76	15.3%
2	2 Lower	5	LGR	0.74	14.8%
2	2 Lower	6	POOL	0.76	15.3%
2	2 Upper	1	POOL	0.96	19.2%
2	2 Upper	2	GLD	0.51	10.3%
2	2 Upper	3	LGR	0.12	2.4%
2	2 Upper	4	LGR	0.12	2.4%
2	2 Upper	5	RPD	0.35	7.0%
2	2 Upper	6	LGR	0.12	2.4%
2	2 Upper	7	LGR	0.12	2.4%
3	3 Lower	1	GLD	0.09	1.4%
3	3 Lower	2	LGR	0.14	2.3%
3	3 Lower	3	RPD	0.18	2.9%
3	3 Lower	4	GLD	0.09	1.4%
3	3 Lower	5	POOL	0.61	10.0%
3	3 Lower	6	LGR	0.14	2.3%
3	3 Lower	7	GLD	0.09	1.4%
3	3 Upper	1	RPD	0.53	8.7%
3	3 Upper	2	LGR	0.30	4.9%
3	3 Upper	3	LGR	0.30	4.9%
3	3 Upper	4	GLD	1.16	19.1%
3	3 Upper	5	POOL	2.18	35.8%
3	3 Upper	6	LGR	0.30	4.9%

* The total percentages by reach may not equal 100% due to rounding.

transects were placed in Reach 1B (one glide and one riffle), none of the rapid or pool habitats in this sub-reach were represented by transects. To address this issue, the total length of each operational reach (i.e., the denominator) excluded all cascade habitat. In addition, the total length of Operational Reach 1 excluded all of the rapid and pool habitat in sub-reach 1B.

The WUA values for each transect were subsequently weighted according to the values noted in Table 3-6 and the total length of habitat represented by the habitat type which the transect(s) represents computed. The WUA versus habitat curves were then used to estimate the relationship of total habitat area (HAs) for each operational reach, expressed in acres, to streamflow. The computation process followed the procedures noted by Bovee (1982). HA combines the amount of WUA provided among the different instream flow transects and sites weighted according to habitat types to provide an overall habitat – flow relationship for each operational reach.

3.5.3 Flow and Habitat Time Series

In a previously completed study (R2 2008a), impacts of the Project on basin hydrology were assessed by comparing flow differences between Stage 1 and Stage 2 conditions. Based on that assessment, the habitat-flow relationships for each reach were linked with the hydrographs defined for wet, average and dry water years to develop reach-specific flow and habitat time series for both Stage 1 and Stage 2 conditions. A common period was selected to perform the hydrologic analysis, from July 1 1984 to June 30 2004. This 20-year period is considered representative of current Project operations. From this 20-year period, representative wet, average, and dry years were selected to assess impacts of Project operations on fish habitat, based on a time-series analysis in this study. Flow records from the nearby gage on the Skykomish River near Gold Bar (USGS Gage 12134500) were used as a guide to select appropriate wet, average, and dry years from the 20-year period used to assess the Sultan River. From the 20-year period extending from 1985 through 2004, the years 1991, 2004, and 2001 were selected as the wet, average, and dry years, respectively. The average annual flows from these three years are associated with exceedance frequencies of 6%, 52%, and 95%, respectively, based on the longer period of record. These same years were then used in deriving the time-series assessments of fish habitat. Stage 1 hydrology was synthesized using hydrologic records obtained from the US Geological Survey (USGS), the District, and the City. The selection of a common study period for comparing Stage 1 and Stage 2 conditions enabled a direct assessment of Project-related effects without the confounding factors that would be associated with different study periods with differing hydrology. The hydrologic analysis was performed at the upstream and downstream ends of each of the three study reaches.

3.5.3.1 Flows in Operational Reach 3

Daily flows at the downstream and upstream ends of Operational Reach 3 for wet (1991), average (2004), and dry (2001) years under Stage 1 and Stage 2 conditions are shown in Figures 3-20 and 3-21, respectively. Flows at the downstream end of Operational Reach 3 are higher than flows at upstream end of Operational Reach 3 because the Sultan River gains additional accretion from a drainage area of 8.8 mi^2 between Culmback Dam and the Diversion Dam. For the time series analyses performed in this study, daily flows at instream flow study sites in Operational Reach 3 were determined by applying a drainage area ratio to the accretion flows between Culmback Dam and the Diversion Dam. Flows in Operational Reach 3 have generally been reduced by the Project during all months of the year.

3.5.3.2 Flows in Operational Reach 2

Daily flows at the downstream and upstream ends of Operational Reach 2 for wet (1991), average (2004), and dry (2001) years under Stage 1 and Stage 2 conditions are shown in Figures 3-22 and 3-23, respectively. Flows at the downstream end of Operational Reach 2 are higher than flows at upstream end of Operational Reach 2 because the Sultan River gains additional accretion between the Diversion Dam and the Powerhouse. The total additional drainage area to the Sultan River between the Diversion Dam and the Powerhouse is 17.1 mi^2. Of this total, runoff from 13.7 mi^2 is unregulated, and runoff from 3.4 mi^2 is regulated by water diversion operations at Lake Chaplain. For the time series analyses performed in this study, daily flows at instream flow study sites in Operational Reach 2 were determined by applying a drainage area ratio (based on the unregulated portion of the drainage) to the accretion flows between the Diversion Dam and the Powerhouse. Low flows in Operational Reach 2 have been increased by the Project, especially during the summer months (August and September). Flows in Operational Reach 2 have generally been reduced during the remainder of the year (October through July), except for July 2004.

3.5.3.3 Flows in Operational Reach 1

Daily flows at the downstream and upstream ends of Operational Reach 1 for wet (1991), average (2004), and dry (2001) years under Stage 1 and Stage 2 conditions are shown in Figures 3-24 and 3-25, respectively. Flows at the downstream end of Operational Reach 1 are higher than flows at upstream end of Operational Reach 1 because the Sultan River gains additional accretion from a drainage area of 10.7 mi^2 between the Powerhouse and the confluence with the Skykomish River. For the time series analyses performed in this study, daily flows at instream flow study sites in Operational Reach 1 were determined by applying a drainage area ratio to the accretion flows between the Powerhouse and the confluence with the Skykomish River. Low

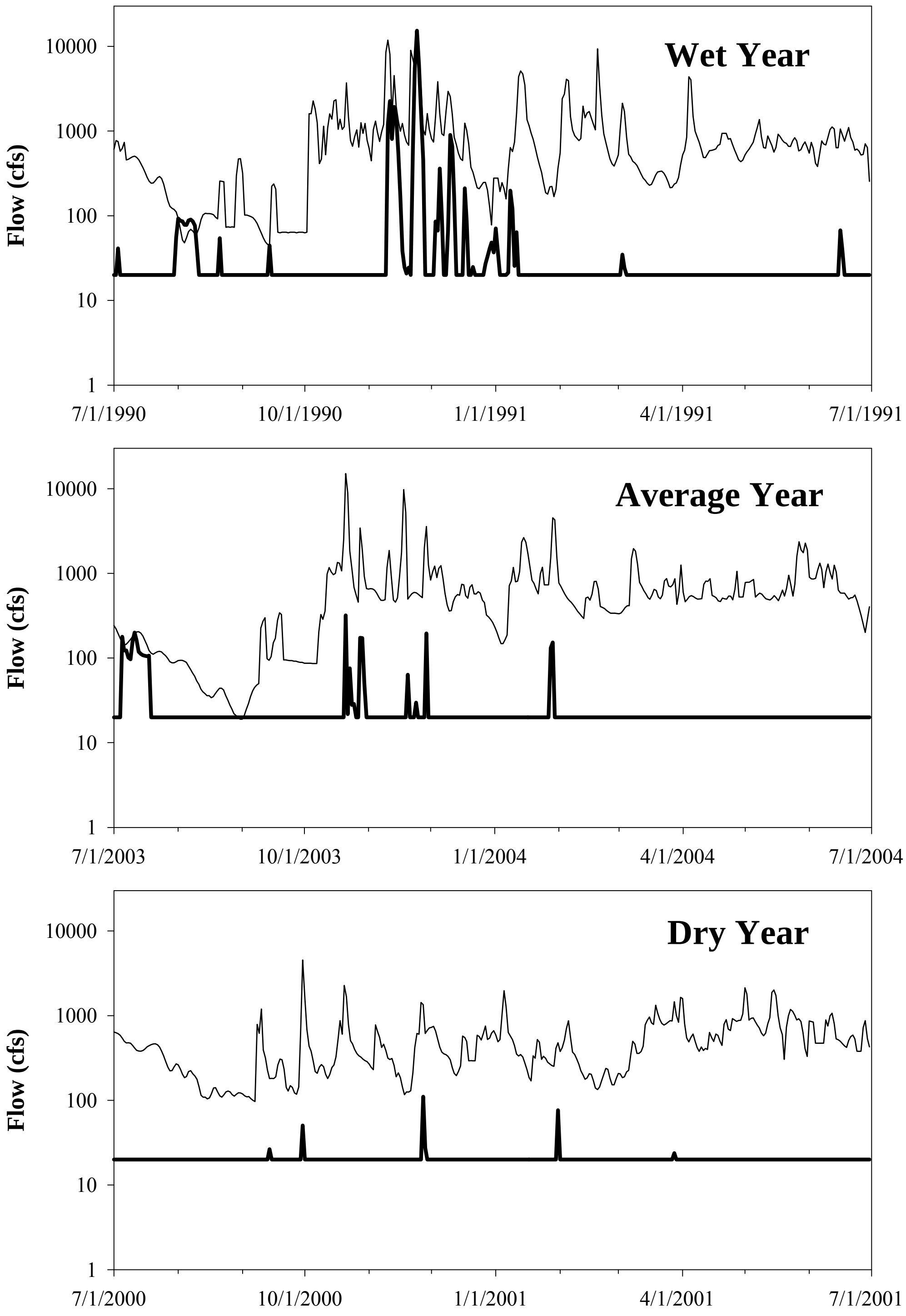


Figure 3-20. Daily flows in the Sultan River at the upstream end of Operational Reach 3 under Stage 1 (thin line) and Stage 2 (thick line) conditions during representative wet (1991), average (2004), and dry (2001) years.

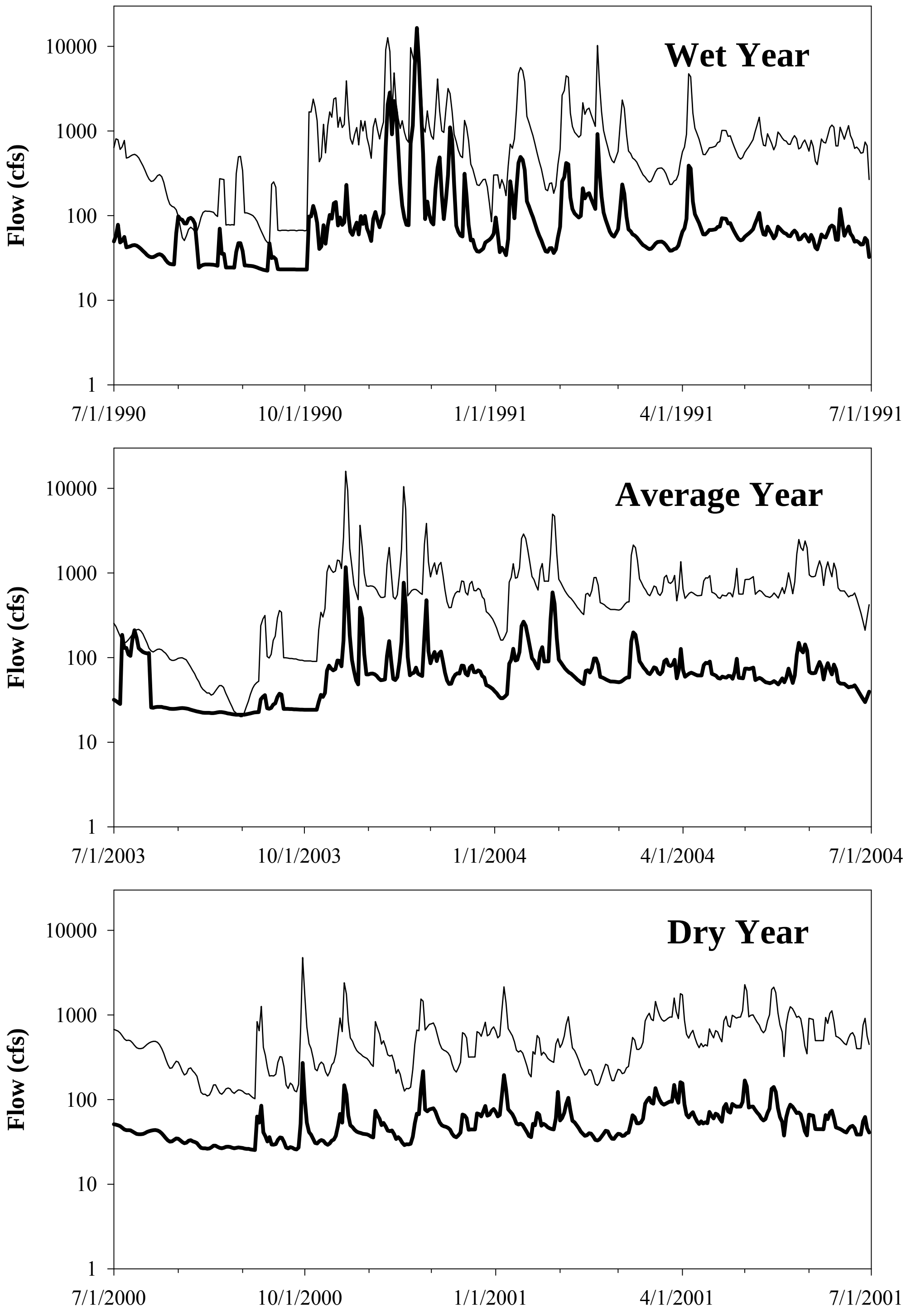


Figure 3-21. Daily flows in the Sultan River at the downstream end of Operational Reach 3 under Stage 1 (thin line) and Stage 2 (thick line) conditions during representative wet (1991), average (2004), and dry (2001) years.

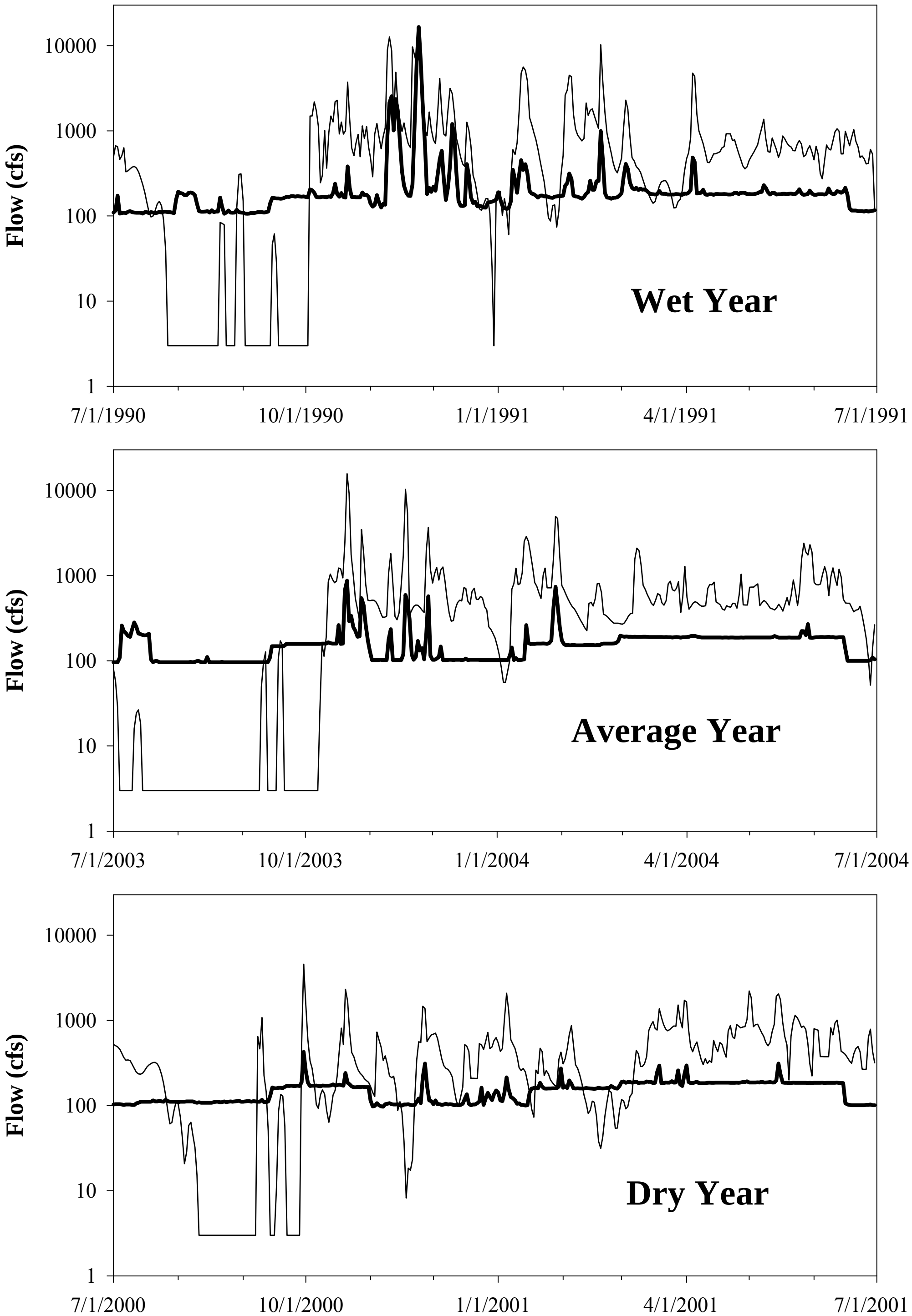


Figure 3-22. Daily flows in the Sultan River at the upstream end of Operational Reach 2 under Stage 1 (thin line) and Stage 2 (thick line) conditions during representative wet (1991), average (2004), and dry (2001) years.

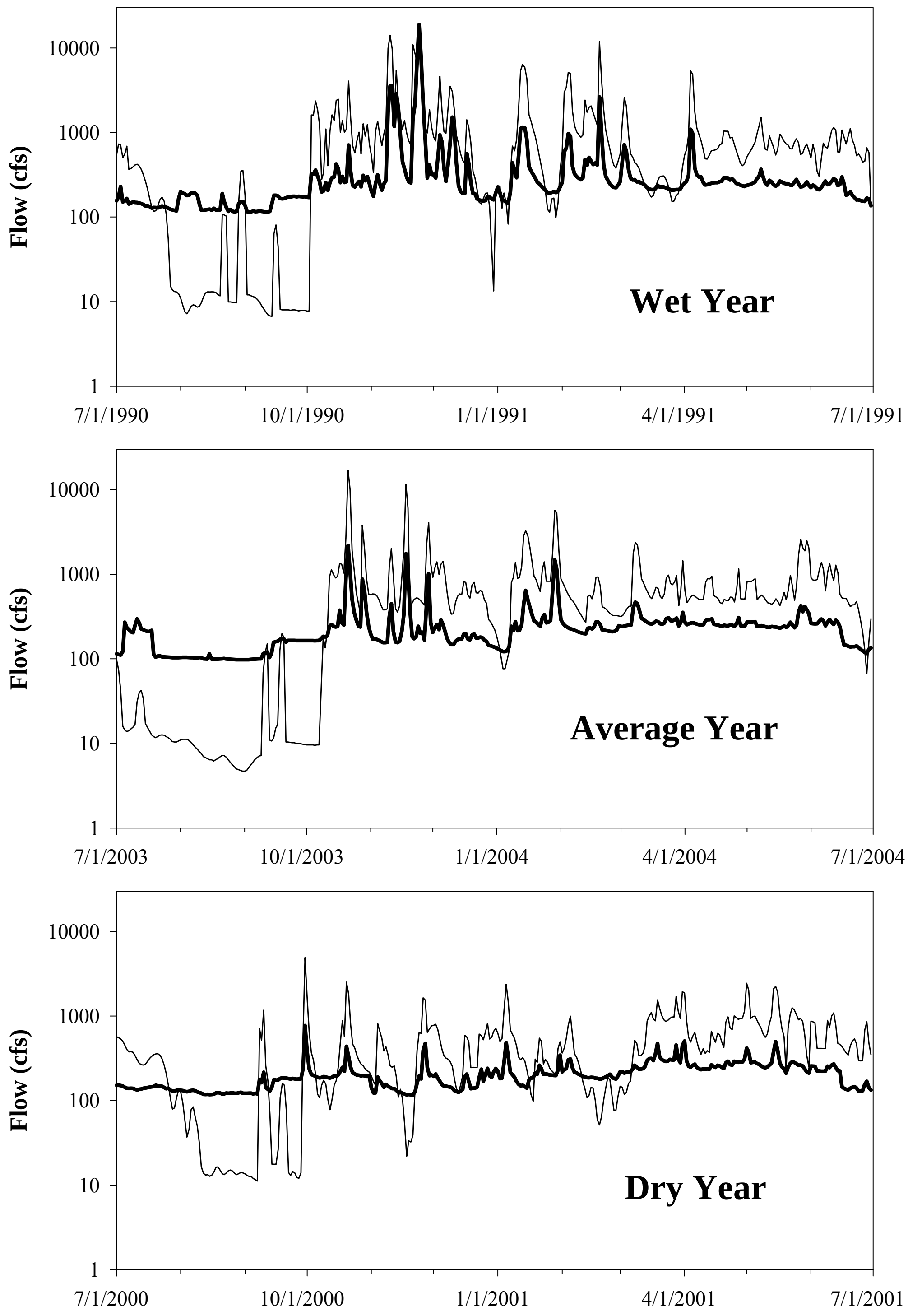


Figure 3-23. Daily flows in the Sultan River at the downstream end of Operational Reach 2 under Stage 1 (thin line) and Stage 2 (thick line) conditions during representative wet (1991), average (2004), and dry (2001) years.

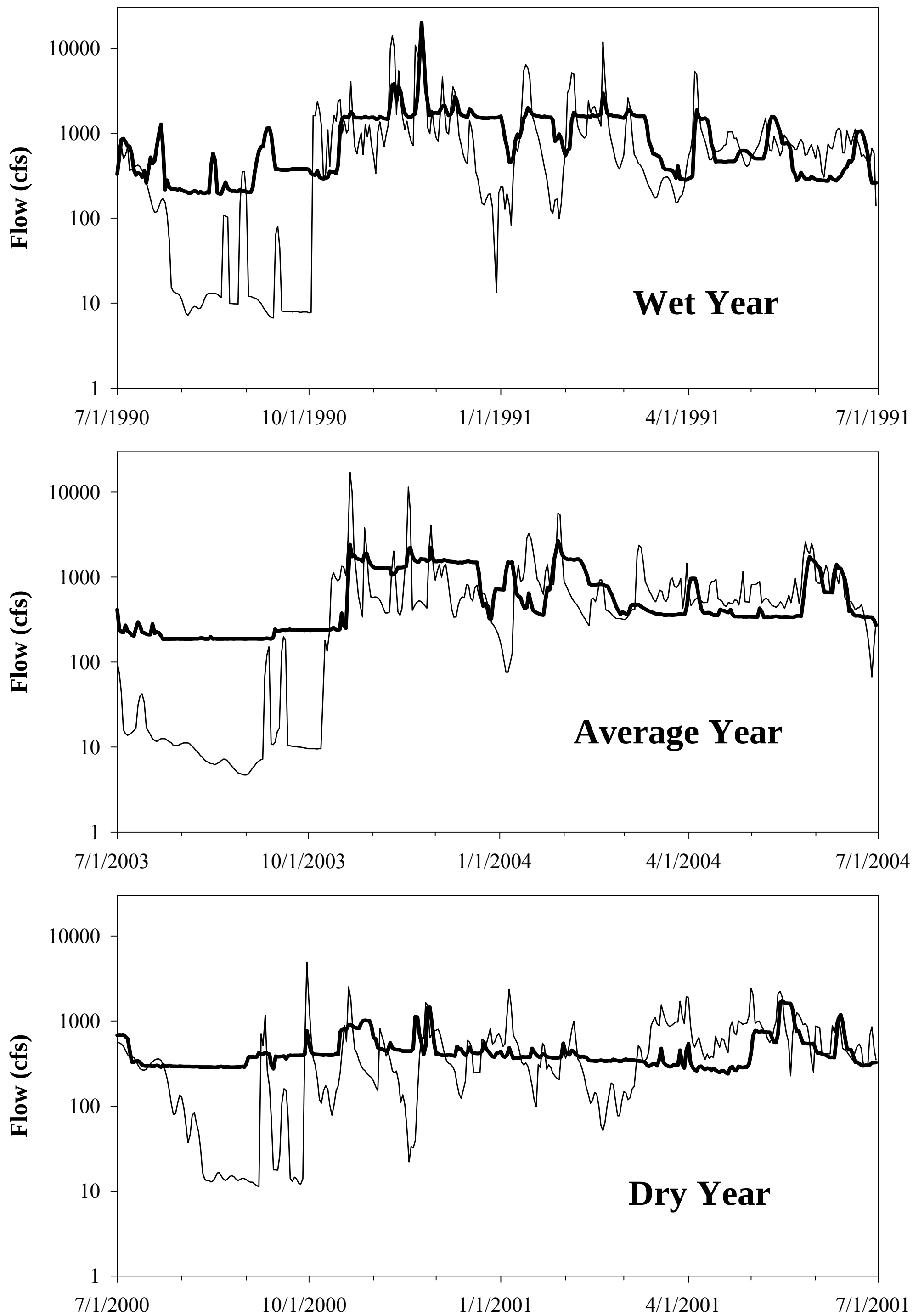


Figure 3-24. Daily flows in the Sultan River at the upstream end of Operational Reach 1 under Stage 1 (thin line) and Stage 2 (thick line) conditions during representative wet (1991), average (2004), and dry (2001) years.

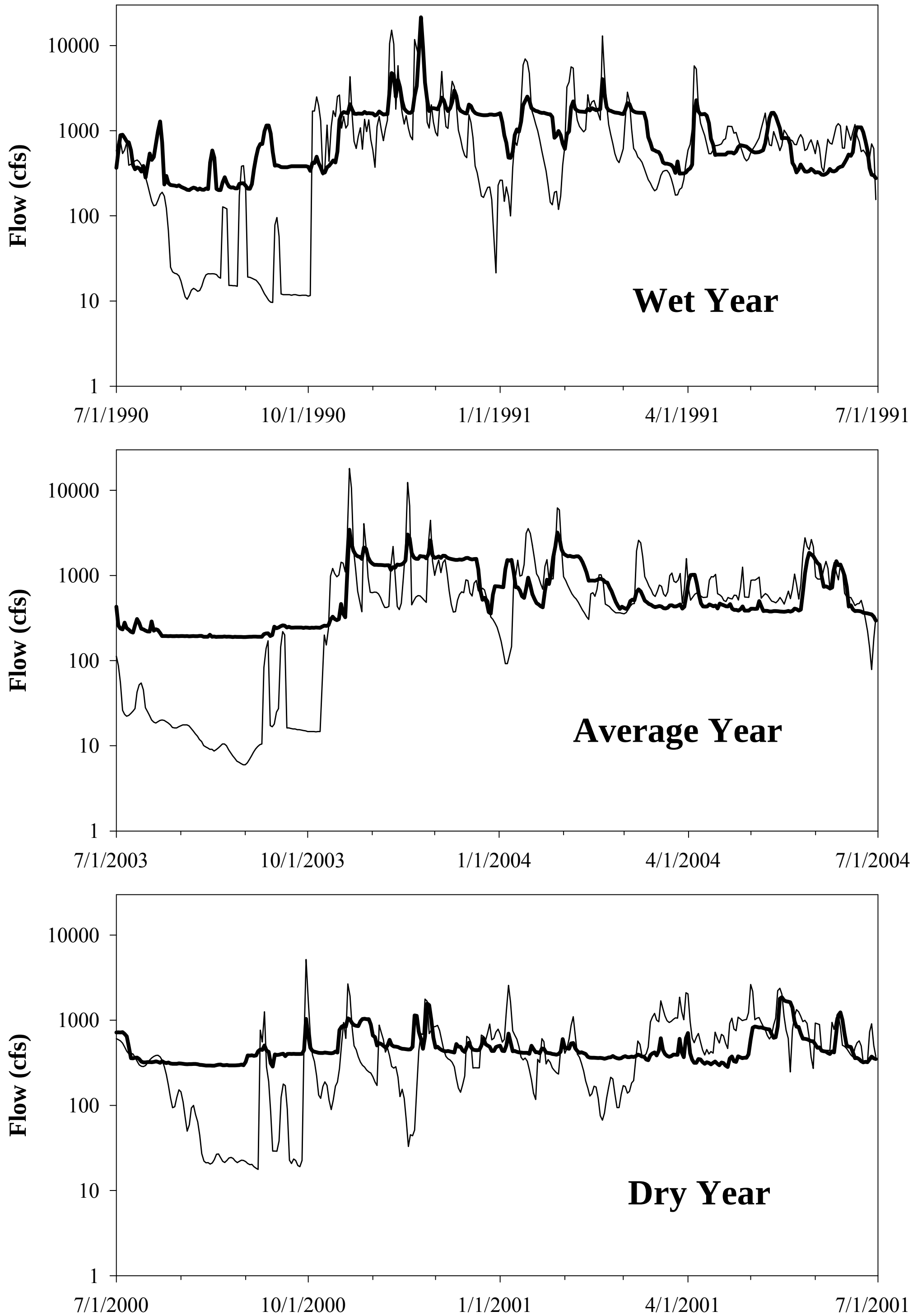


Figure 3-25. Daily flows in the Sultan River at the downstream end of Operational Reach 1 under Stage 1 (thin line) and Stage 2 (thick line) conditions during representative wet (1991), average (2004), and dry (2001) years.

flows in Operational Reach 1 have been increased by the Project, especially during the summer months (July, August, and September). The magnitudes of high flows have been reduced by the Project.

The overall time series were developed in accordance with guidelines provided in Milhous et al. (1990) for each species and spanned the period of time specific to a given life stage. R2 developed a Fortran program to link the species and life stage specific habitat-flow relationships to the appropriate hydrology as depicted in Figures 3-14 through 3-19, which then computed first, the corresponding time series (based on a daily time step) and then a habitat-duration curve. These time series and curves were compared on a Stage 1 versus Stage 2 basis to determine reach – specific Project effects.

Importantly and as previously noted, operational impacts of the Project were not assessed with respect to natural flows, but rather with respect to the flow regime associated with municipal water withdrawals (referred to in this study as Stage 1 conditions).

4. HABITAT MODELING

This section presents the results of the habitat modeling and times series analysis completed for the Sultan River, and organizationally progresses from the upper (Reach 3) to lower (Reach 1) operational reaches. The results focus on the total habitat area (HA) versus flow relationships since these provide reach–scale estimates of the total amount of habitat for a given species and life stage available under different flow conditions. For convenience, the results are presented graphically both as numerical estimates of habitat, expressed in acres, as well as normalized estimates expressed as percentages of maximum habitat area. The former are useful for comparing the relative amounts of habitat provided for a given species and life stage under different flow conditions, while the latter are useful for comparing overall habitat-flow response dynamics. The percentages of maximum habitat corresponding to specific flows are also presented in tabular format. Results of PHABSIM analysis presented for each reach on a study site basis (i.e., Reach 3 Upper Site and Reach 3 Lower Site) for all species and life stages are presented in Figures D1-1 through D1-24 contained in Appendix D1.

The time series analysis provides a comparison of the amounts of habitat that would occur on a daily basis under a Wet, Normal, and Dry year scenario for Stage 1 versus Stage 2 operations[6]. The specific time series that are presented are unique to the individual species and life stage periodicities identified in Figure 2-4. Habitat duration curves depict overall differences in the availability (presented as a percentage exceedance value) of habitat for a given species, life stage and periodicity, under Stage 1 and Stage 2 conditions.

Results of the HA versus flow relationships are presented for each of the following target fish species identified in the respective reaches: Reach 3 – Chinook and coho salmon, and steelhead, rainbow and cutthroat trout; Reach 2 and Reach 3 – Chinook, coho, pink, and chum salmon, and steelhead, rainbow and cutthroat trout. Because of their listing status and importance from a resource management perspective, the time series and habitat duration analysis presented in this section are focused primarily on Chinook salmon and steelhead trout. However, time series and habitat duration analysis are also presented for rainbow and cutthroat trout for Reach 3, since these two species are the only salmonids presently found within this reach; anadromous salmonids have not been found in Reach 3 since 1929. Appendix D contains the results of time series and habitat duration analysis for other species.

[6] The wet, average, and dry years corresponded to years 1991, 2004, and 2001 as determined from an evaluation of the 20-year period extending from 1985 through 2004. Stage 1 conditions correspond to conditions prior to operation of the hydroelectric project (i.e., prior to 1984), but with the diversion of water for municipal purposes.

Results of the side channel surveys are also provided. These include a graphical display of the relationship of side channel connectivity to mainstem flow, a depiction of cumulative side channel area versus flow, and plots of habitat (WUA) versus flow for each species and life stage.

4.1 REACH 3 – CULMBACK DAM TO DIVERSION DAM

Modeling results for this reach are presented for Chinook and coho salmon, and steelhead trout, three anadromous salmonid species that could presumably inhabit the reach if fish passage facilities were provided at the Diversion Dam. Results are also presented for rainbow trout which is currently present in the reach, and cutthroat trout which could occur within the reach.

4.1.1 PHABSIM Analysis

4.1.1.1 Spawning Habitat

Spawning habitat versus flow relationships generated for this reach indicate that the amount of habitat provided at the habitat maximizing flow would be highest for Chinook (230 cfs provides ≈ 10 acres), followed by steelhead (230-200 cfs provides ≈ 8 acres) and then coho (160 to 140 cfs provides ≈ 6.5 acres) (Figure 4-1; Table 4-1). When habitats are expressed as percentages of maximum, the relationships for Chinook and steelhead are of similar form. Habitat amounts remain relatively high (≥ 85% of maximum) for all three species even at flows as low as 140 cfs for Chinook, 160 cfs for steelhead, and 120 cfs for coho (Table 4-1; Figure 4-2).

The habitat-flow relationships for rainbow and cutthroat peak at flows of 160 cfs and 80 cfs, respectively (Figures 4-1 and 4-2; Table 4-2). For these two species, flows as low as 120 cfs for rainbow, and ≈ 50-52 cfs for cutthroat would still provide ≥ 85% of maximum habitat.

4.1.1.2 Juvenile and Adult Habitat

Habitat-flow relationships derived for juvenile and adult life stages reflected a relatively wide range of response curves for the target species. Overall, habitat maximizing flows range from the lowest to highest for coho juvenile (≈ 5.5 acres at 30 cfs), steelhead adults (≈ 8.5 acres at 55 cfs), Chinook juvenile (≈ 6.5 acres at 200 cfs), rainbow juvenile (≈ 5 acres at 230 cfs), cutthroat juvenile (≈ 4.5 acres at 290 cfs), and Chinook adults (≈ 4 acres at 680 cfs) (Figures 4-3 and 4-4; Tables 4-1 and 4-2). The shapes of the steelhead, rainbow and cutthroat trout juvenile curves were generally similar, with each characterized by a broad, gradually decreasing descending limb. Juvenile habitat would remain at levels ≥ 85% of maximum at flows of 20 cfs for coho, 230 cfs for steelhead, and 120 cfs for Chinook, rainbow and cutthroat (Table 4-2; Figure 4-4).

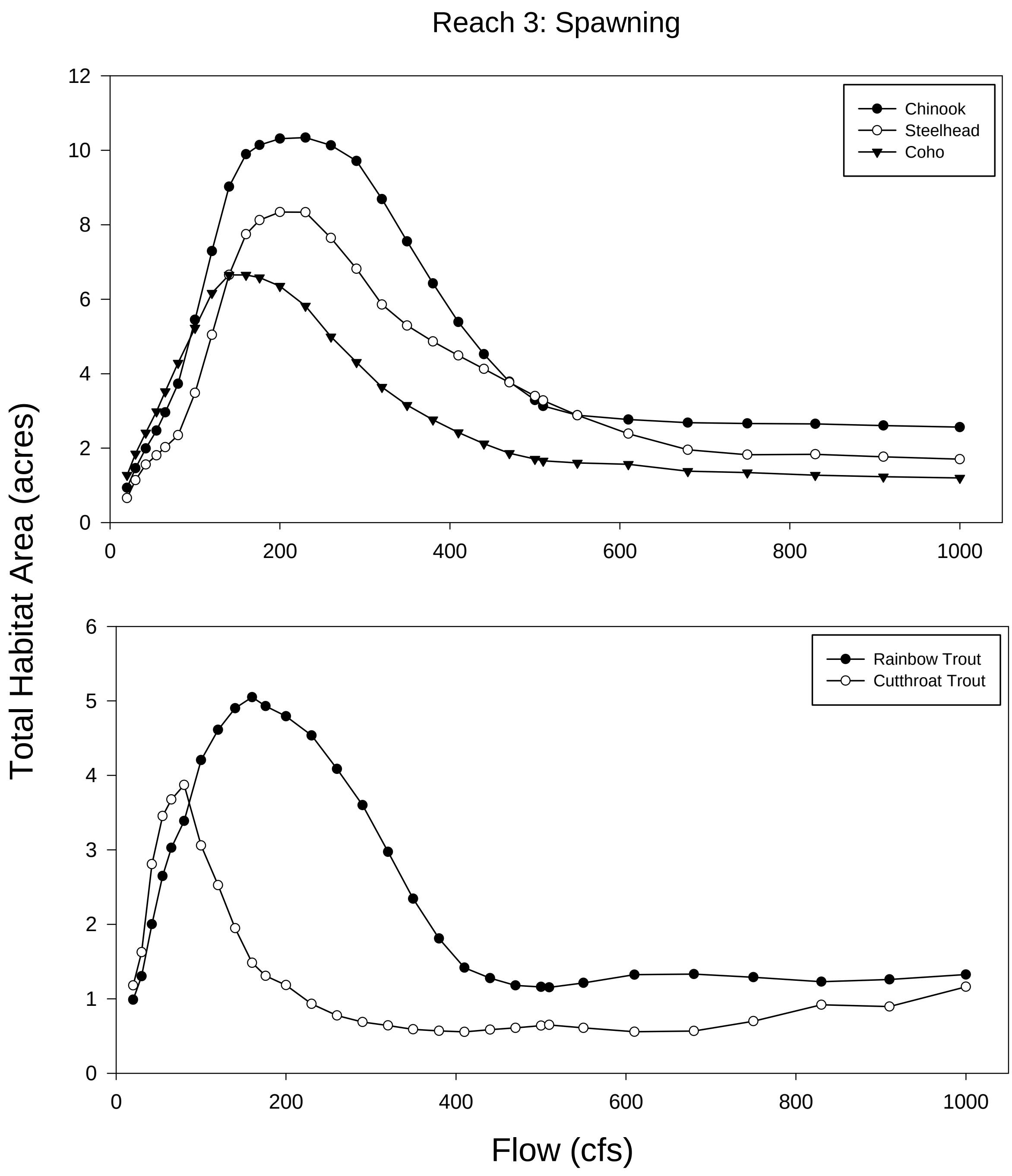


Figure 4-1. Total spawning habitat area (acres) versus flow (cfs) relationships for Chinook and coho salmon and steelhead trout (upper figure), and rainbow and cutthroat trout (lower figure) in Reach 3 of the Sultan River, Washington. * Note that anadromous salmonids have not been present since 1929 within Reach 3; for comparative purposes, all anadromous species were analyzed and results displayed.

Table 4-1. Percentages of maximum habitat area at specified flows (cfs) for Chinook, steelhead, and coho salmon life stages within Reach 3 of the Sultan River, Washington. * Note that anadromous salmonids have not been present since 1929 within Reach 3; for comparative purposes, all anadromous species were analyzed and results displayed.

	Chinook			Steelhead			Coho	
Flow (cfs)	Spawning	Juvenile	Adult	Spawning	Juvenile	Adult	Spawning	Juvenile
20	9.0	15.7	45.7	7.9	17.9	83.2	19.1	**90.9**
30	14.1	21.5	48.0	13.7	21.9	**96.1**	27.7	100.0
42	19.2	29.0	50.4	18.7	27.4	99.2	36.2	99.1
54.6	23.9	42.0	52.7	21.6	32.9	100.0	44.8	**89.1**
65.0	28.6	54.3	54.5	24.2	37.3	99.0	52.9	82.5
80	36.0	68.7	57.0	28.1	43.7	**93.6**	64.5	74.5
100	52.7	80.5	60.3	41.8	51.8	82.3	78.6	70.1
120	70.5	**88.0**	63.4	60.5	59.6	72.3	**92.6**	66.6
140	**87.2**	92.5	66.4	79.7	66.8	62.8	100.0	63.9
160	95.7	95.4	69.2	**92.8**	72.8	59.3	100.0	60.0
176	98.1	98.0	71.2	97.4	76.9	56.1	98.9	57.5
200	99.7	100.0	74.2	100.0	81.7	53.6	95.4	55.8
230	100.0	96.6	77.6	100.0	87.4	47.6	**87.5**	53.2
260	98.0	**90.9**	80.9	**91.6**	**91.5**	41.7	75.0	50.0
290	**93.9**	86.7	83.8	81.7	94.5	39.4	64.7	49.3
320	84.0	82.6	86.5	70.2	96.9	36.1	54.7	47.0
349.5	73.0	78.9	88.8	63.4	97.1	34.2	47.4	46.2
380	62.1	76.2	**91.1**	58.3	98.3	33.3	41.5	45.9
410	52.1	73.7	93.1	53.8	99.4	33.1	36.4	45.1
440	43.7	71.4	94.8	49.5	99.8	32.7	31.8	44.4
470	36.6	69.3	96.0	45.1	100.0	32.4	28.0	44.0
500	31.8	66.9	97.0	40.7	99.7	32.2	25.6	44.1
509.6	30.3	66.0	97.3	39.3	99.5	32.1	24.9	44.1
550	27.9	62.9	98.0	34.6	98.1	31.5	24.1	43.6
610	26.7	59.1	99.0	28.6	96.9	30.1	23.5	42.5
680	25.9	54.3	100.0	23.4	95.7	27.3	20.7	40.9
750	25.8	51.0	98.8	21.9	92.2	27.3	20.2	42.2
830	25.6	49.3	96.4	22.0	**90.0**	28.4	19.2	40.5
910	25.2	48.3	93.3	21.2	88.1	28.6	18.5	40.7
1000	24.8	46.9	**90.8**	20.4	84.3	27.9	18.0	40.7

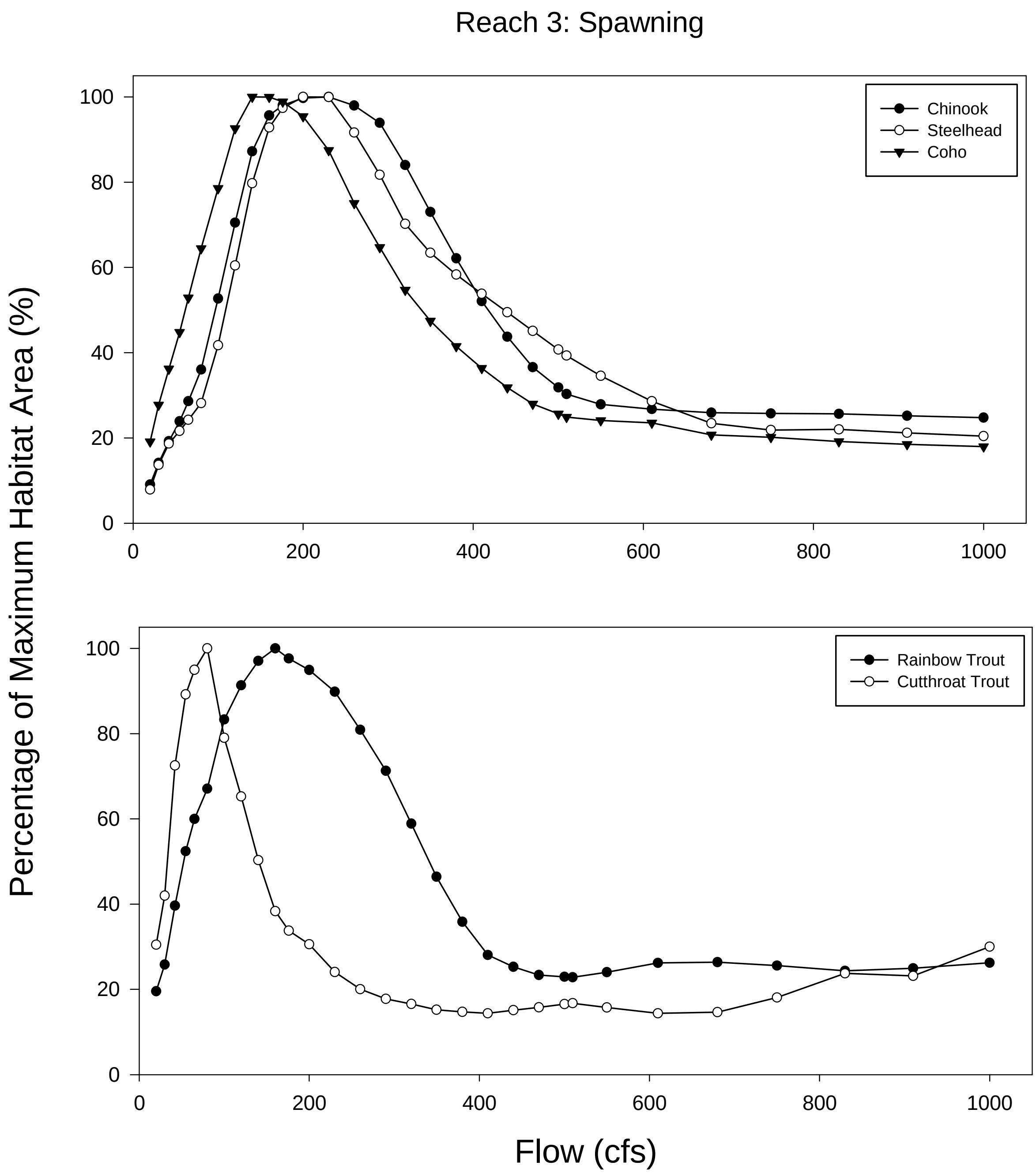


Figure 4-2. Percentage (%) of maximum spawning habitat area versus flow (cfs) relationships for Chinook and coho salmon and steelhead trout (upper figure), and rainbow and cutthroat trout (lower figure) in Reach 3 of the Sultan River, Washington.

Table 4-2. Percentages of maximum habitat area at specified flows (cfs) for rainbow and cutthroat trout life stages within Reach 3 of the Sultan River, Washington.

	Rainbow		Cutthroat	
Flow (cfs)	Spawning	Juvenile	Spawning	Juvenile
20	19.5	26.8	30.5	16.1
30	25.8	33.3	42.0	25.4
42	39.6	41.0	72.5	38.8
54.6	52.4	48.4	**89.2**	53.0
65.0	60.0	54.6	95.0	62.0
80	67.1	63.4	100.0	72.3
100	83.3	75.2	79.0	83.7
120	**91.3**	85.4	65.3	**91.4**
140	97.1	**92.6**	50.3	93.5
160	100.0	95.3	38.3	95.0
176	97.6	96.3	33.8	96.2
200	95.0	99.6	30.6	99.8
230	**89.8**	100.0	24.1	99.6
260	80.9	98.9	20.0	99.7
290	71.3	98.1	17.8	100.0
320	58.9	97.5	16.6	97.5
349.5	46.4	96.6	15.2	96.5
380	35.8	95.0	14.7	95.1
410	28.1	93.3	14.4	93.2
440	25.3	91.6	15.1	**90.8**
470	23.4	**89.9**	15.8	88.4
500	22.9	89.2	16.5	85.7
509.6	22.8	88.9	16.8	84.9
550	24.0	86.8	15.7	82.9
610	26.2	83.7	14.4	81.6
680	26.4	81.1	14.6	76.8
750	25.6	78.8	18.1	73.4
830	24.3	78.3	23.7	70.6
910	24.9	77.2	23.2	66.1
1000	26.2	75.2	30.0	61.0

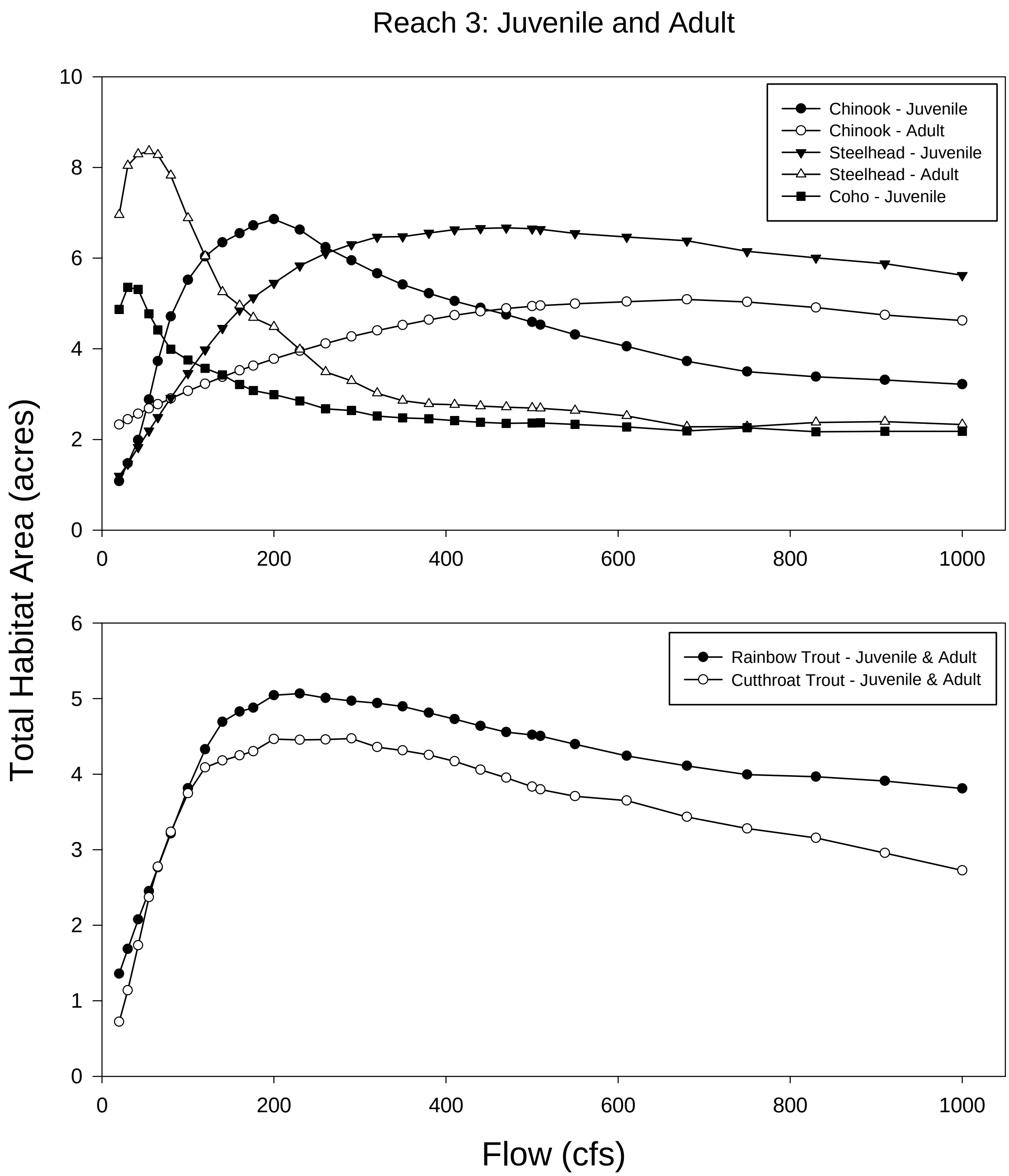


Figure 4-3. Total juvenile and adult habitat area (acres) versus flow (cfs) relationships for Chinook and coho salmon and steelhead trout (upper figure), and rainbow and cutthroat trout (lower figure) in Reach 3 of the Sultan River, Washington.

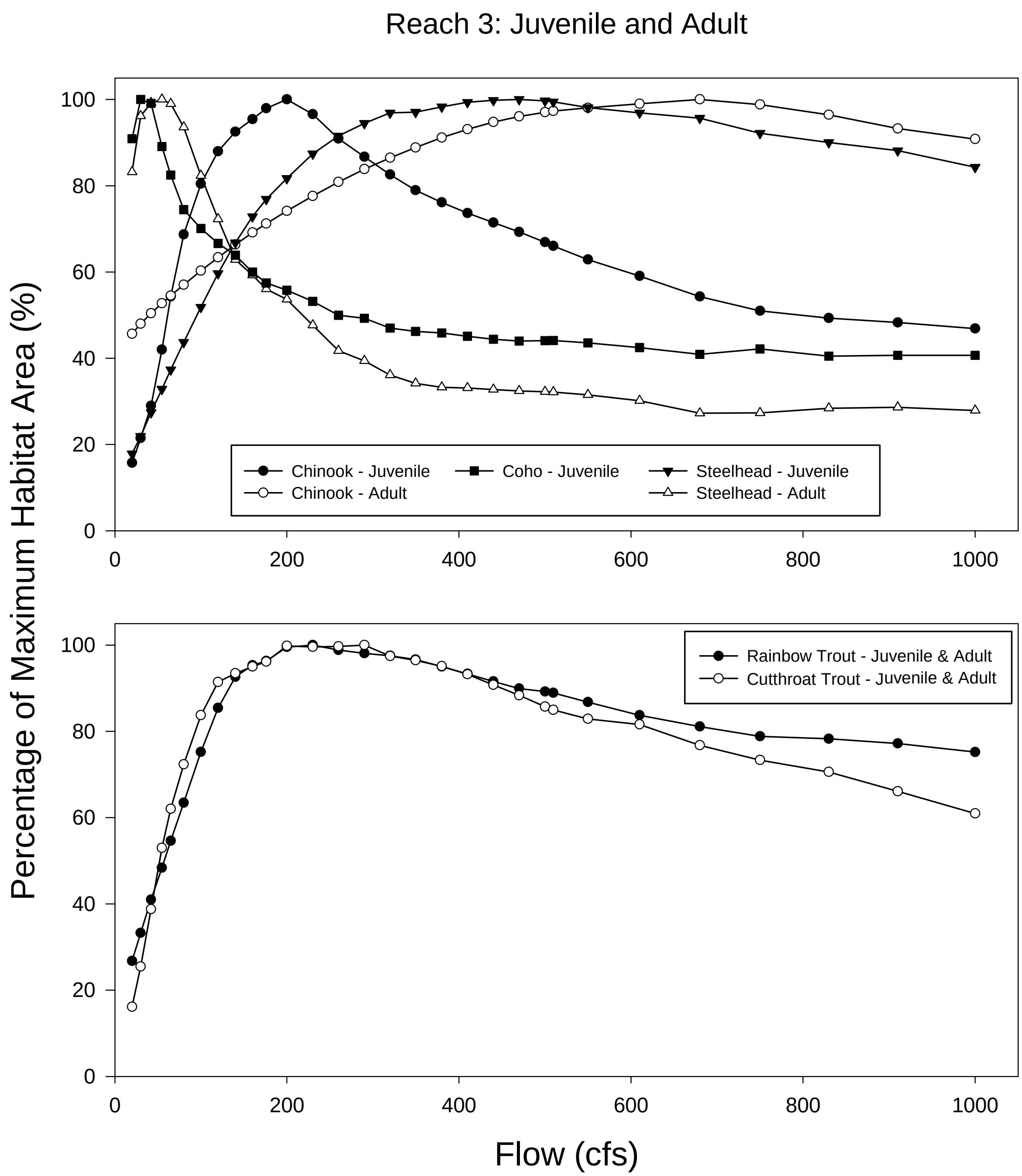


Figure 4-4. Percentage (%) of maximum juvenile and adult habitat area versus flow (cfs) relationships for Chinook and coho salmon and steelhead trout (upper figure), and rainbow and cutthroat trout (lower figure) in Reach 3 of the Sultan River, Washington.

4.1.1.3 Habitat Time Series

Habitat time series and corresponding habitat duration curves for rainbow and cutthroat trout spawning are presented in Figures 4-5 through 4-8. For Reach 3, the Stage 1 conditions represent flow conditions regulated by Culmback Dam prior to hydroelectric operations. Thus, flows would essentially reflect natural flow conditions as passed-through Culmback Dam downstream to the Diversion Dam. Under Stage 2 conditions, flows are regulated by Culmback Dam for hydroelectric generation with flow releases into this reach consisting of a 20 cfs release year-round.

Based on results of the time series analysis, Stage 2 conditions provide higher rainbow and cutthroat trout spawning habitat levels than Stage 1 conditions, a likely result of having lower velocities provided during the spawning periods than would otherwise occur. A similar trend was noted for coho spawning under the wet and average year conditions, as well as for coho juvenile rearing under all year types (Figures D2-1 to D2-4; Appendix D2). This trend is reversed for rainbow and cutthroat trout juvenile rearing; i.e., Stage 1 conditions provide higher habitat levels than Stage 2 (Figures D2-5 to D2-8; Appendix D2). A similar pattern is noted in the time series analysis for Chinook and steelhead spawning as depicted in Figures 4-9 through 4-12 and juvenile rearing (Figures D2-9 to D2-12; Appendix D2). For Chinook spawning, the difference is most pronounced under the dry year scenario (Figures 4-9 and 4-10), while for steelhead, the greatest difference occurs under the wet year scenario (Figures 4-11 and 4-12). Comparisons of the median (50%), maximum, minimum and average habitat areas and percentage differences under Stage 1 and Stage 2 operations for all target species in Reach 3 based on the time series analysis are presented in Tables 4-3 and 4-4 (exceedance values for Reach 3).

4.2. REACH 2 – DIVERSION DAM TO POWERHOUSE

Modeling results for Reach 2 are presented for Chinook, coho, chum, and pink salmon, and steelhead trout spawning. With the exception of chum salmon, all of these species are known to spawn in Reach 2. Chum salmon spawning has also been included as a primary target species/lifestage because of their potential use of this reach. Because of the short residence time of juvenile chum and pink salmon in the Sultan River following emergence, modeling results for juvenile rearing in Reach 2 are limited to Chinook and coho salmon, and steelhead trout.

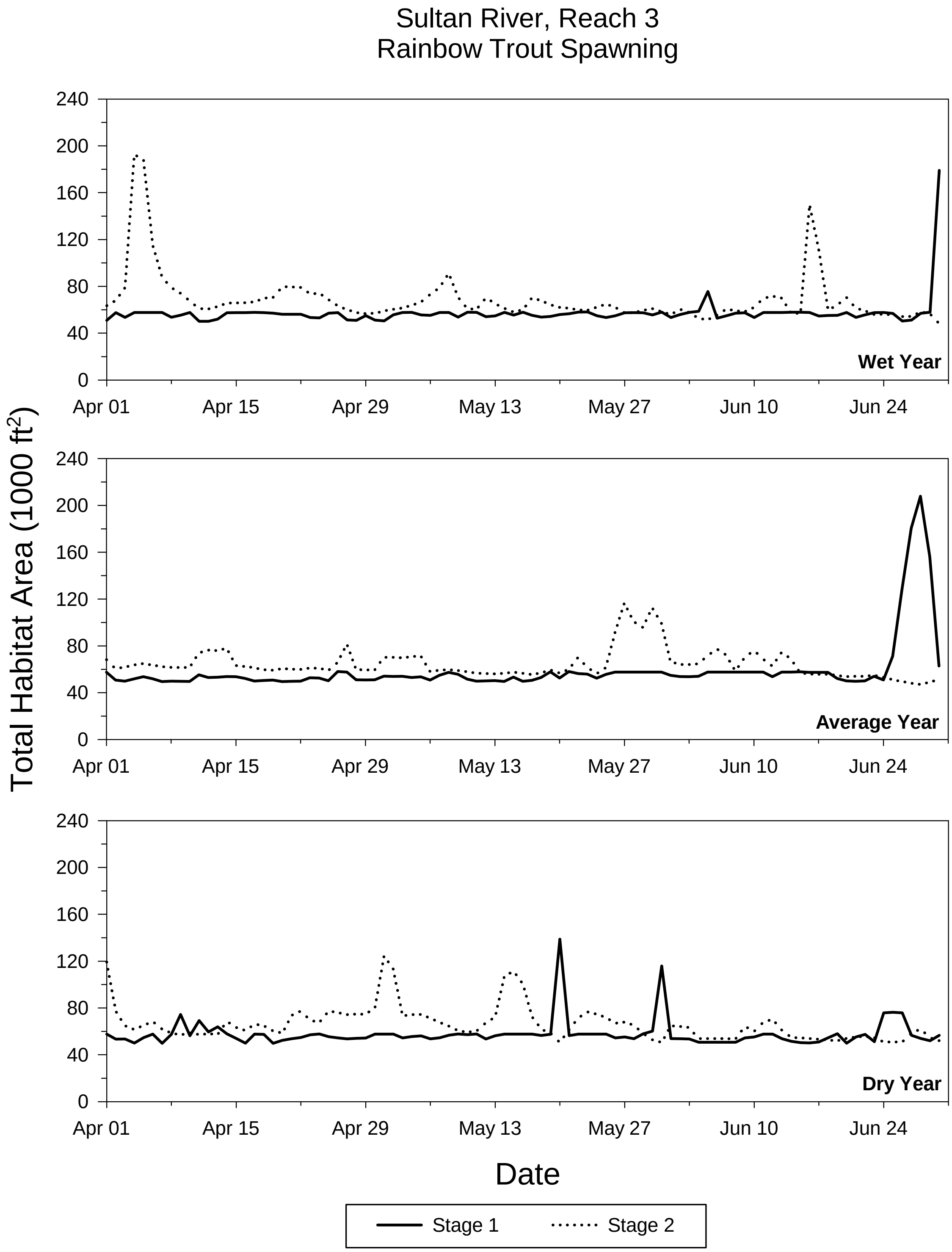


Figure 4-5. Time series analysis depicting total rainbow trout spawning habitat (1000 ft^2) available over the period of spawning under wet, average and dry year scenarios for Reach 3 of the Sultan River, Washington.

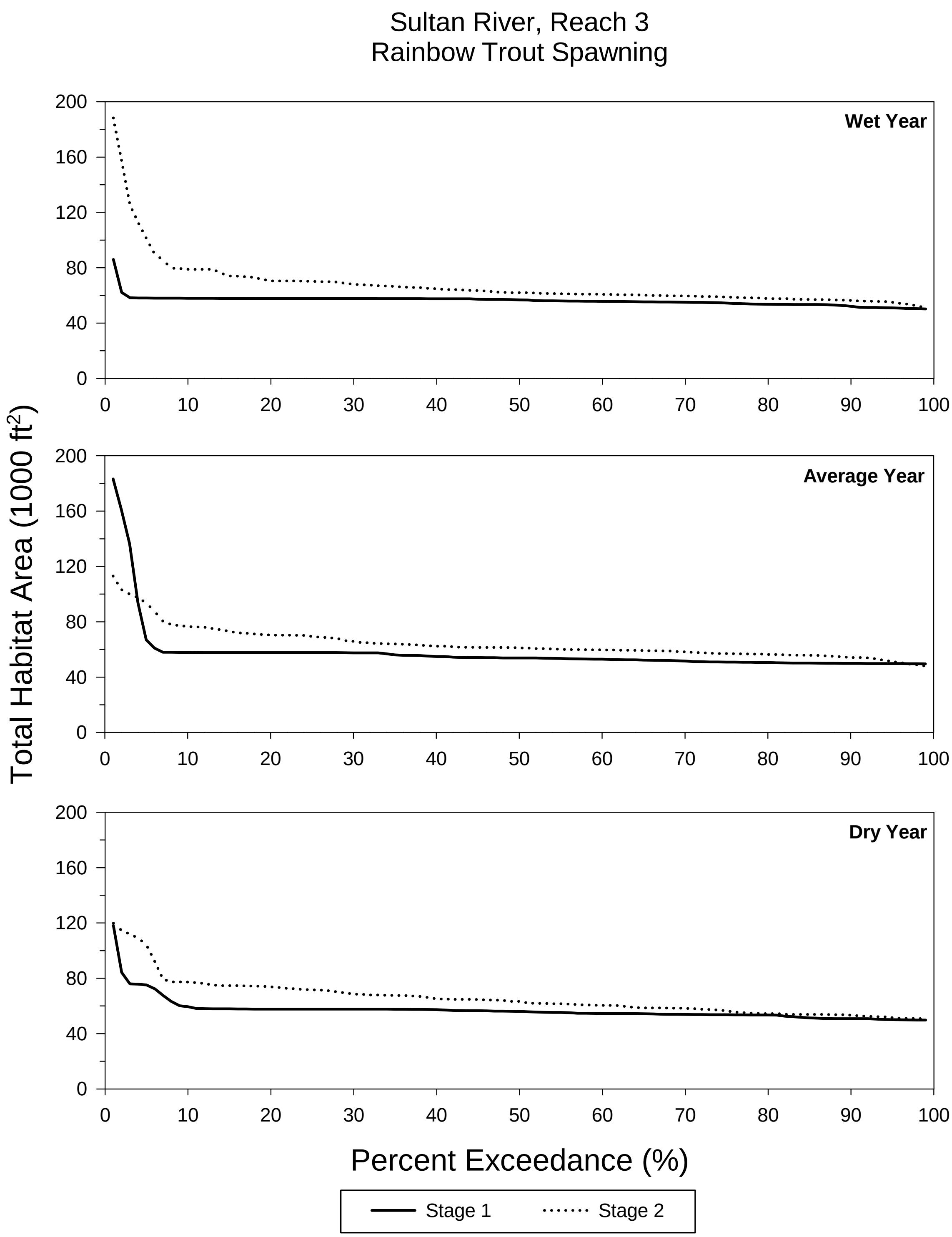


Figure 4-6. Habitat duration curves for rainbow trout spawning habitat (1000 ft^2) under wet, average, dry year scenarios for Reach 3 of the Sultan River, Washington.

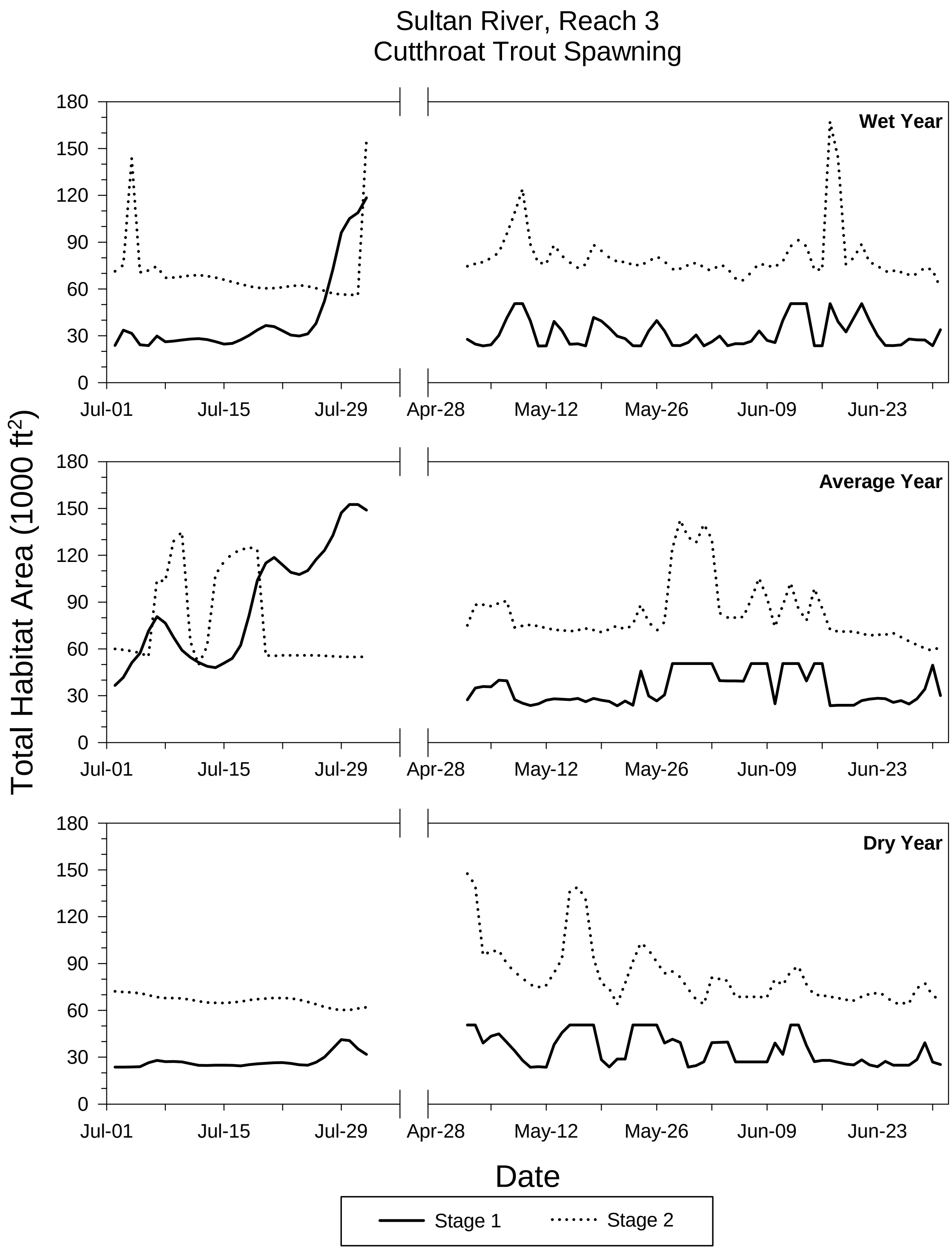


Figure 4-7. Time series analysis depicting total cutthroat trout spawning habitat (1000 ft^2) available over the period of spawning under wet, average and dry year scenarios for Reach 3 of the Sultan River, Washington.

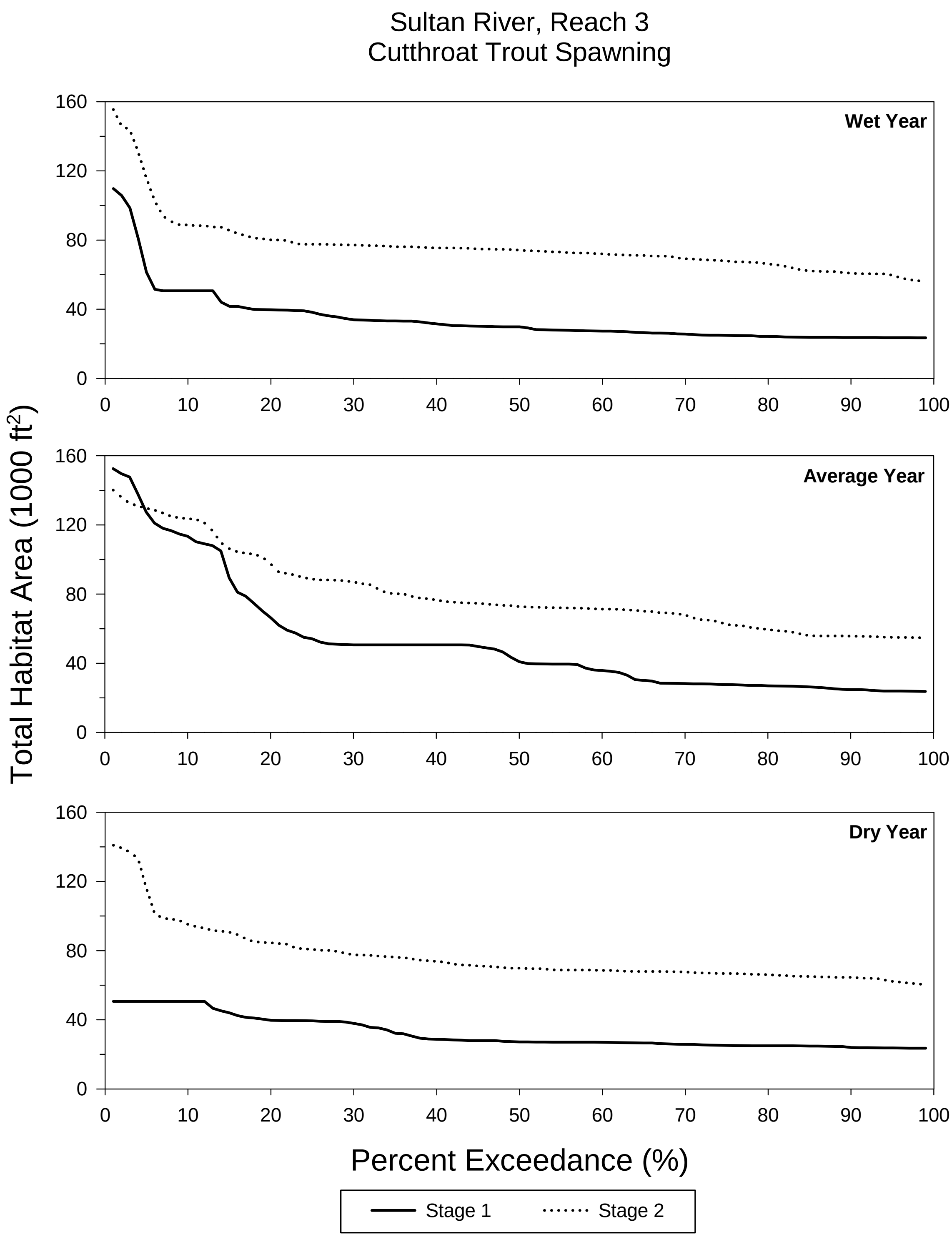


Figure 4-8. Habitat duration curves for cutthroat trout spawning habitat (1000 ft^2) under wet, average, dry year scenarios for Reach 3 of the Sultan River, Washington.

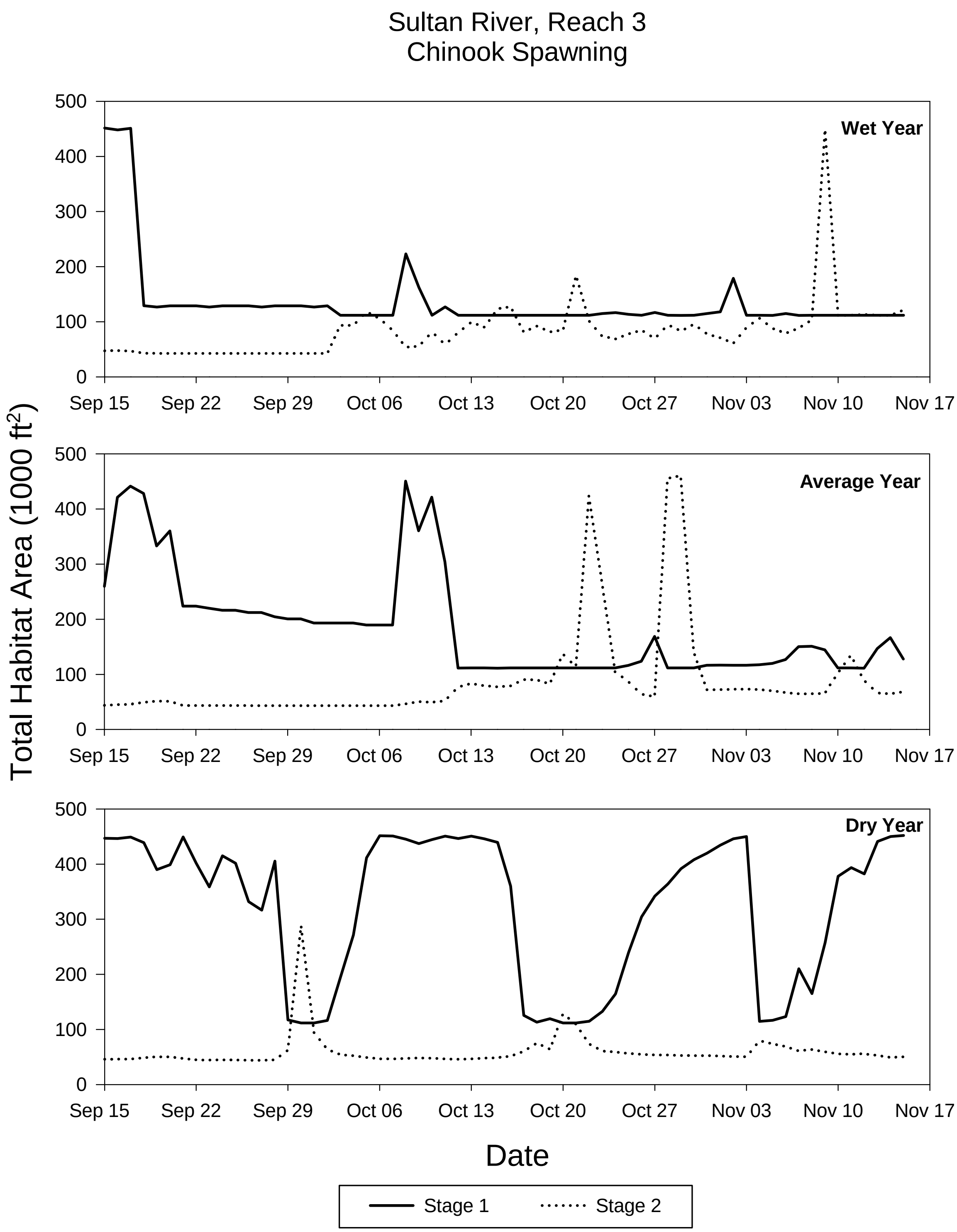


Figure 4-9. Time series analysis depicting total Chinook salmon spawning habitat (1000 ft^2) available over the period of spawning under wet, average and dry year scenarios for Reach 3 of the Sultan River, Washington.

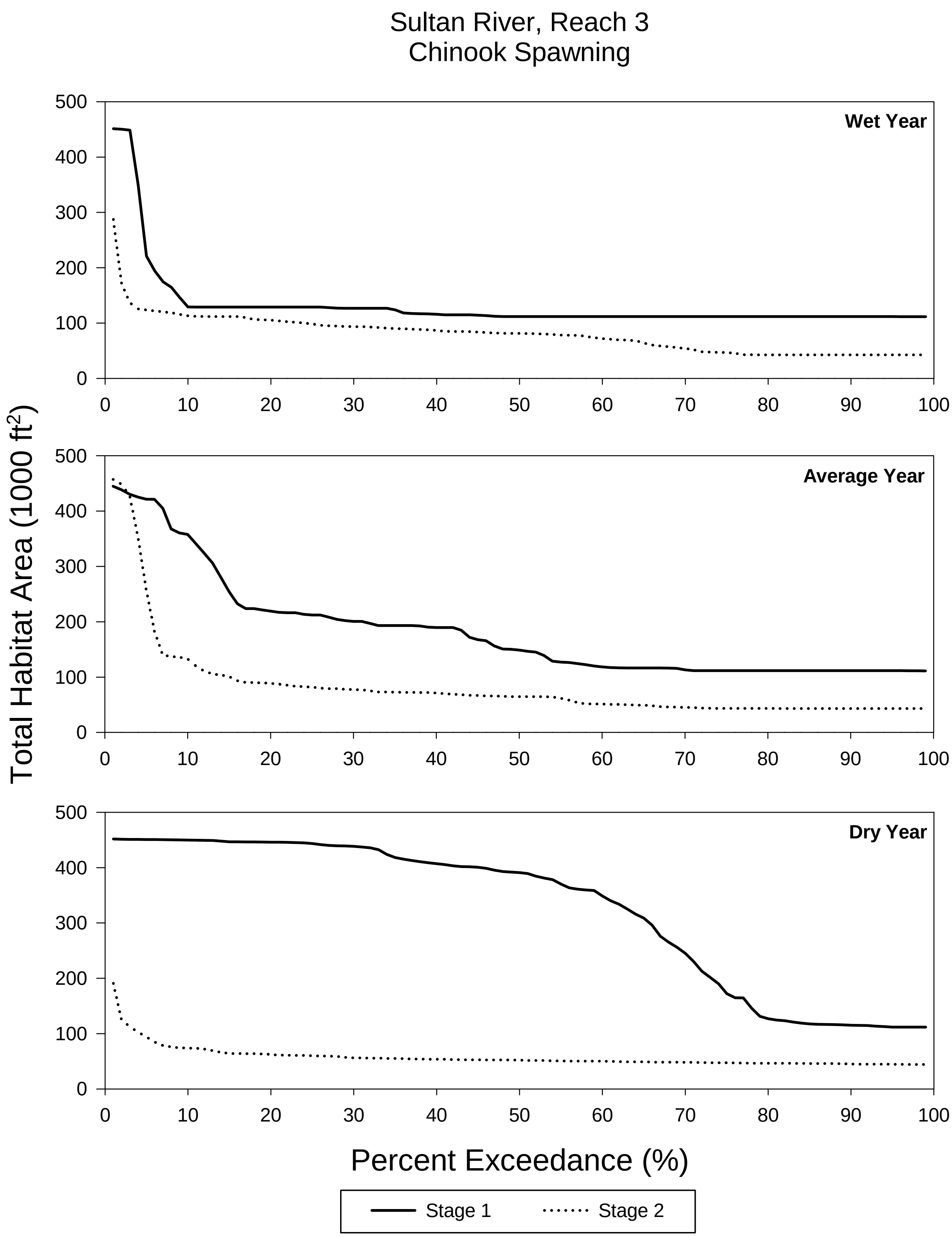


Figure 4-10. Habitat duration curves for Chinook salmon spawning habitat (1000 ft^2) under wet, average, dry year scenarios for Reach 3 of the Sultan River, Washington.

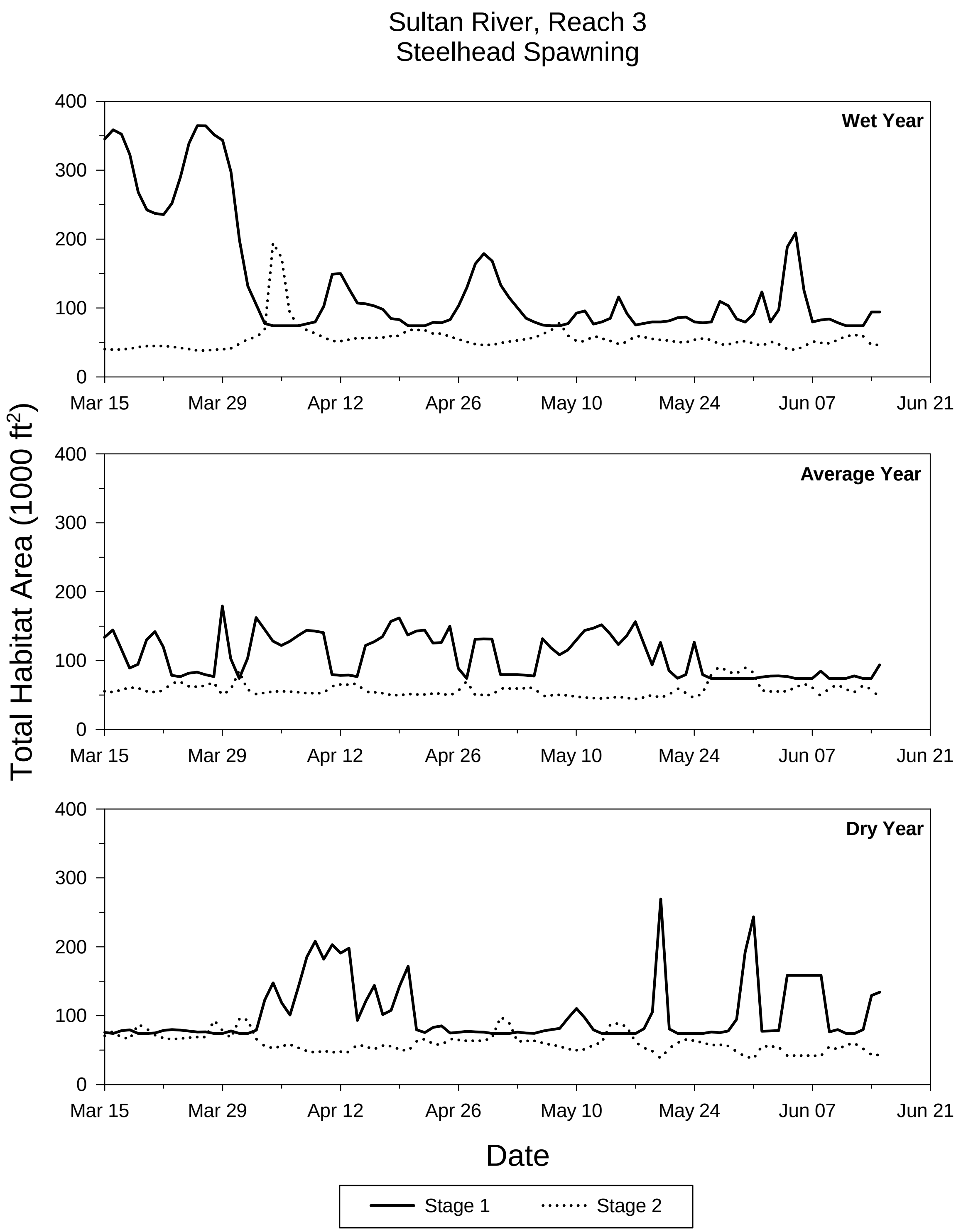


Figure 4-11. Time series analysis depicting total steelhead trout spawning habitat (1000 ft^2) available over the period of spawning under wet, average and dry year scenarios for Reach 3 of the Sultan River, Washington.

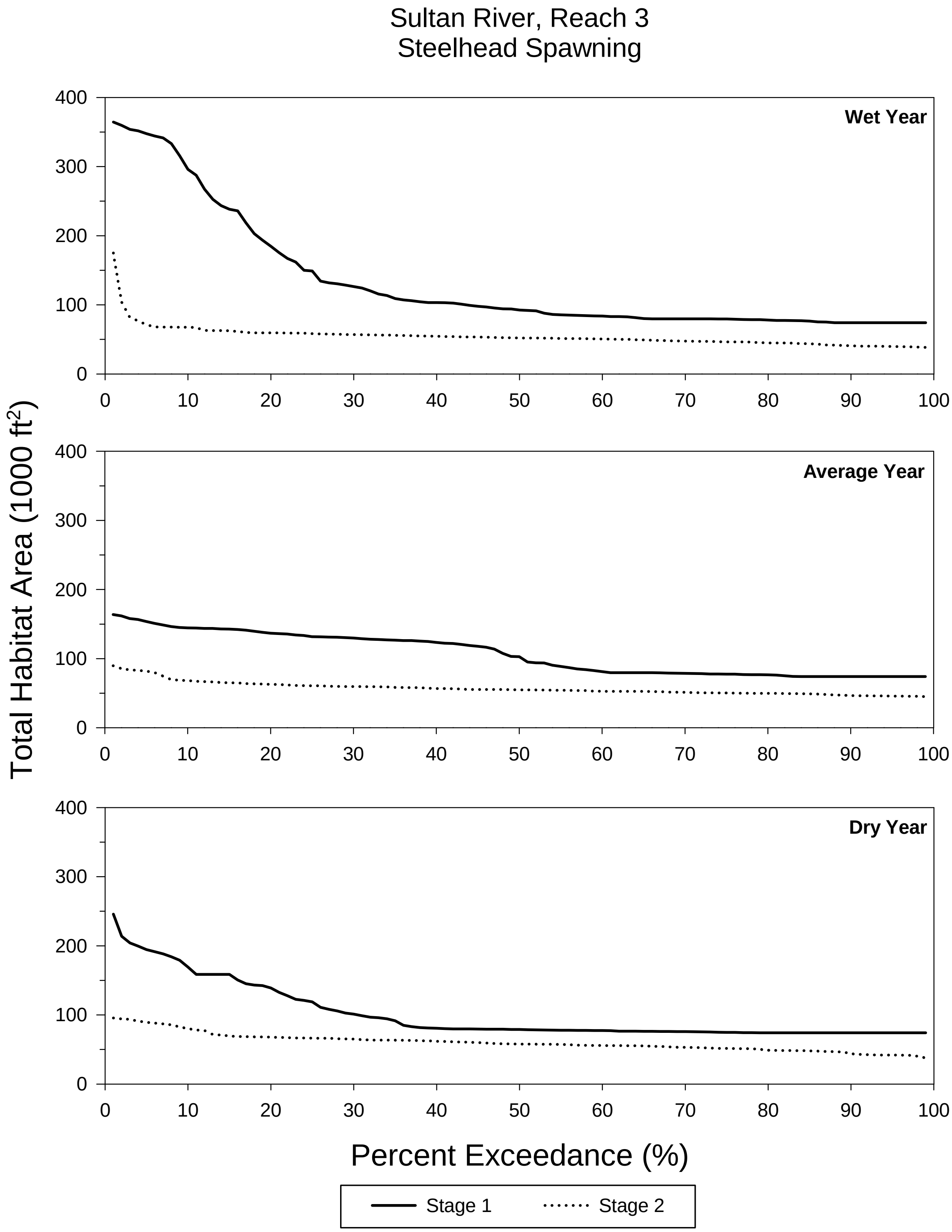


Figure 4-12. Habitat duration curves for steelhead trout spawning habitat (1000 ft^2) under wet, average, dry year scenarios for Reach 3 of the Sultan River, Washington.

Table 4-3. Comparison of median, maximum, minimum, average and percentage difference in anadromous salmonid* habitat areas provided during Wet, Average, and Dry water year types for Stage 1 and Stage 2 conditions as determined from habitat duration analysis for operational Reach 3 of the Sultan River, Washington. * Note that anadromous salmonids have not been present since 1929 within Reach 3; for comparative purposes, all anadromous species were analyzed and results displayed.

Life Stage	Species	Median (50% exceedance) Habitat Area (ft^2)		Maximum Habitat Area (ft^2)		Minimum Habitat Area (ft^2)		Average Habitat Area (ft^2)		
		Stage 1	Stage 2	Stage 1	Stage 2	Stage 1	Stage 2	Stage 1	Stage 2	% Difference
WATER YEAR - WET										
Spawning	Chinook	111,556	81,147	451,016	287,104	111,368	42,336	132,426	79,748	-39.8
	Steelhead	92,525	51,863	364,304	174,842	74,133	38,251	132,896	54,311	-59.1
	Coho	53,958	100,398	288,957	289,015	51,625	51,051	106,831	123,045	+15.2
	Chum	136,071	192,742	429,922	426,151	133,964	133,025	184,499	216,336	+17.3
	Pink	133,384	214,468	347,421	320,478	59,851	187,114	201,087	231,324	+15.0
Juvenile	Chinook	175,376	94,029	300,527	297,195	135,654	51,143	191,797	114,208	-40.5
	Steelhead	256,754	78,175	292,386	293,698	92,698	53,652	242,540	99,220	-59.1
	Coho	98,904	220,117	213,804	229,572	93,062	94,953	113,828	206,452	+81.4
WATER YEAR - AVERAGE										
Spawning	Chinook	148,575	64,552	444,958	457,179	111,186	43,039	182,840	82,748	-54.7
	Steelhead	102,724	54,794	163,638	89,639	74,143	44,918	106,464	56,890	-46.6
	Coho	59,744	99,528	291,466	273,053	51,987	65,843	82,158	113,311	+37.9
	Chum	139,536	174,911	392,349	407,856	133,979	144,069	156,850	197,077	+25.6
	Pink	176,432	191,813	347,308	332,779	60,002	103,254	201,645	213,261	+5.8
Juvenile	Chinook	182,264	97,844	299,783	295,676	50,652	48,203	183,808	109,782	-40.3
	Steelhead	259,814	77,625	292,486	285,830	53,752	52,579	237,407	87,705	-63.1
	Coho	101,797	219,766	236,153	229,329	92,950	114,525	119,967	212,478	+77.1
WATER YEAR - DRY										
Spawning	Chinook	390,792	51,771	451,501	190,677	111,556	43,983	324,994	57,104	-82.4
	Steelhead	78,875	57,690	245,605	95,441	74,142	37,749	101,134	60,076	-40.6
	Coho	124,676	81,697	288,388	218,192	52,118	62,830	138,092	87,050	-37.0
	Chum	218,118	152,759	429,613	317,814	136,071	120,966	263,367	159,906	-39.3
	Pink	109,935	207,592	337,826	315,438	59,215	192,235	146,922	217,372	+48.0
Juvenile	Chinook	204,993	80,740	302,268	208,118	140,093	53,247	209,337	90,781	-56.6
	Steelhead	269,443	68,231	292,487	152,065	161,797	55,308	259,480	74,072	-71.5
	Coho	103,254	224,129	158,845	229,742	93,047	169,873	111,454	222,037	-82.4

Table 4-4. Comparison of median, maximum, minimum, average and percentage difference in resident trout habitat areas provided during Wet, Average, and Dry water year types for Stage 1 and Stage 2 conditions as determined from habitat duration analysis for operational Reach 3 of the Sultan River, Washington.

Life Stage	Species	Median (50% exceedance) Habitat Area (ft²)		Maximum Habitat Area (ft²)		Minimum Habitat Area (ft²)		Average Habitat Area (ft²)		
		Stage 1	Stage 2	Stage 1	Stage 2	Stage 1	Stage 2	Stage 1	Stage 2	% Difference
WATER YEAR - WET										
Spawning	Rainbow	56,773	61,967	85,921	188,235	50,143	51,167	56,142	67,592	+20.4
	Cutthroat	29,785	74,033	109,694	155,481	23,495	56,211	34,278	76,339	+122.7
Juvenile	Rainbow	172,836	89,487	221,775	230,650	103,792	61,350	178,474	104,217	-41.6
	Cutthroat	143,076	77,199	196,045	210,046	98,931	34,259	148,688	88,087	-40.8
WATER YEAR - AVERAGE										
Spawning	Rainbow	53,747	61,086	183,225	113,025	49,522	47,990	57,589	64,141	+11.4
	Cutthroat	40,848	72,744	152,487	140,141	23,608	54,413	52,168	80,087	+53.5
Juvenile	Rainbow	179,395	88,955	220,899	226,835	61,399	59,970	176,181	96,689	-45.1
	Cutthroat	157,928	76,467	195,507	204,120	34,343	32,528	147,641	81,184	-45.0
WATER YEAR - DRY										
Spawning	Rainbow	56,060	63,202	118,187	119,736	49,763	50,517	56,993	65,651	+15.2
	Cutthroat	27,191	69,697	50,599	140,937	23,557	60,271	32,192	76,423	+137.4
Juvenile	Rainbow	198,500	78,766	221,712	164,451	165,900	63,476	196,144	84,529	-56.9
	Cutthroat	175,303	58,375	196,144	155,078	118,724	36,924	167,748	67,200	-59.9

4.2.1 PHABSIM Analysis

4.2.1.1 Spawning

Spawning habitat versus flow relationships generated for Reach 2 indicate that the amount of habitat provided at the habitat maximizing flow would be highest for Chinook (320 cfs provides ≈ 13 acres), followed by chum (240 cfs provides ≈ 10.5 acres), coho (150 cfs provides ≈ 10 acres), steelhead (240 cfs provides ≈ 10 acres) and then pink (75-123 cfs provides ≈ 7 acres) (Figure 4-13; Tables 4-5 and 4-6). When expressed as percentages of maximum habitat, the ascending limbs of the relationships for Chinook and steelhead are similar; descending limbs track similarly with Chinook being slightly higher than steelhead (Figure 4-14). Likewise, the ascending limbs of coho and chum spawning are similar, with the descending limb of chum remaining slightly higher than coho. The shapes of the curves indicate that habitat amounts would remain relatively high (≥ 85% of maximum) even at flows as low as 200 cfs for Chinook and steelhead, 100 cfs for coho and chum, and 50 cfs for pink (Tables 4-5 and 4-6; Figure 4-14).

The habitat-flow relationships for rainbow and cutthroat spawning peak at flows of 320 cfs and 100 cfs, respectively (Figures 4-13 and 4-14; Table 4-6). For these two species, flows as low as 200 cfs for rainbow, and 50cfs for cutthroat would still provide ≥ 85% of maximum habitat.

4.2.1.2 Juvenile and Adult Habitat

The Reach 2 habitat-flow relationships for target species juvenile and adult life stages reflected three general trends. The first trend represented by coho juvenile and steelhead adult, depicts decreasing amounts of habitat with increases in flow, the second reflecting an increase in habitat with flow up to a maximum and then decreasing habitats with flow increases (represented by Chinook and steelhead juvenile, and rainbow and cutthroat trout juvenile and adult), and the third trend, represented by Chinook adult, that reflects a continuously increasing amount of habitat with flow (Figure 4-15). Habitat maximizing flows for the target species range from the lowest to highest for coho juvenile (≈ 11 acres at 50 cfs) and steelhead adults (≈ 14.5 acres at 50 cfs), Chinook juvenile (≈ 13 acres at 240 cfs) and cutthroat juvenile and adult (≈ 9.5 acres at 240 cfs), rainbow juvenile and adult (≈ 11.5 acres at 320 cfs), steelhead juvenile (≈ 15 acres at 550 cfs), and Chinook adults (≈ 10 acres at 1500 cfs) (Figures 4-15 and 4-16; Tables 4-5 and 4-6). Juvenile habitats remain at levels ≥ 85% of maximum at flows of 240 cfs for steelhead, 200 cfs for rainbow, 123 cfs for Chinook, and 100 cfs for cutthroat (Tables 4-5 and 4-6).

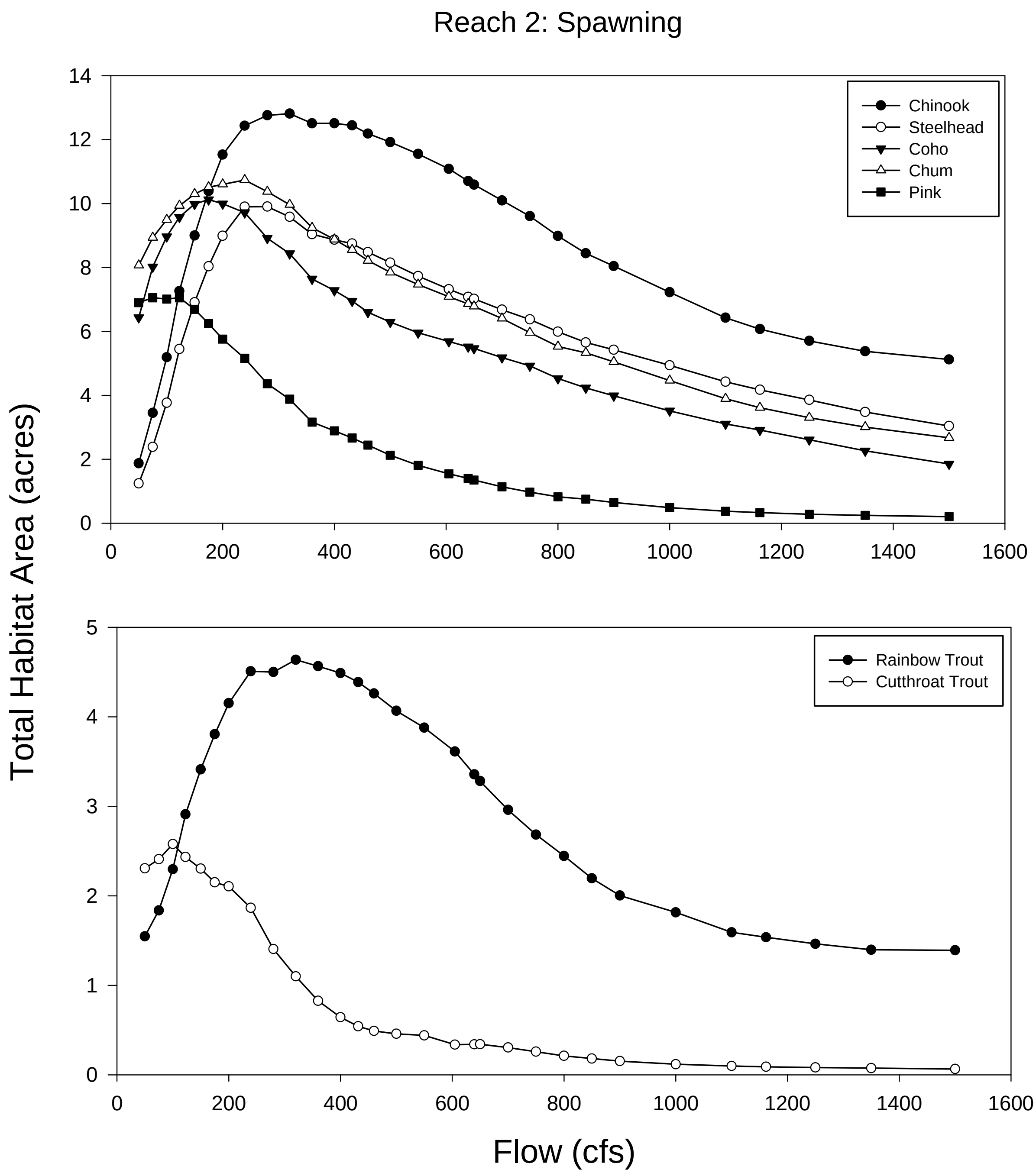


Figure 4-13. Total spawning habitat area (acres) versus flow (cfs) relationships for Chinook, coho, chum, and pink salmon and steelhead trout (upper figure), and rainbow and cutthroat trout (lower figure) in Reach 2 of the Sultan River, Washington.

Table 4-5. Percentages of maximum habitat area at specified flows (cfs) for Chinook and steelhead life stages within Reach 2 on the Sultan River, Washington.

	Chinook			Steelhead			Coho	
Flow (cfs)	Spawning	Juvenile	Adult	Spawning	Juvenile	Adult	Spawning	Juvenile
50	14.6	44.0	19.0	12.5	27.7	100.0	63.5	100.0
75	26.9	69.5	23.2	24.1	38.8	95.8	79.2	**85.0**
100	40.5	80.4	26.9	38.1	48.5	**93.1**	**88.6**	79.7
123	56.7	85.9	30.1	55.0	57.5	85.3	94.6	74.6
150	70.2	**90.3**	33.9	69.8	66.4	79.5	98.6	68.3
175	81.1	93.8	37.3	81.2	73.2	75.9	100.0	62.7
200	**90.0**	96.4	40.6	**90.8**	78.7	72.7	98.7	58.9
240	97.1	100.0	45.6	100.0	86.8	70.2	96.0	58.4
280	99.6	98.8	50.3	100.0	**91.5**	63.1	**88.1**	51.3
320	100.0	97.5	54.8	96.8	94.5	58.5	83.4	50.1
360	97.6	95.9	58.4	91.3	96.1	52.1	75.5	47.4
400	97.6	96.0	61.9	**89.6**	96.9	48.2	71.9	46.0
432	97.1	94.9	64.4	88.4	97.4	46.1	68.7	45.2
460	95.1	93.0	66.5	85.6	97.9	44.8	65.2	44.8
500	93.0	**90.7**	69.4	82.3	99.1	43.1	62.1	43.5
550	**90.2**	87.9	72.6	78.1	100.0	41.9	58.9	42.2
605	86.5	85.5	75.7	73.9	100.0	40.7	56.2	41.3
640	83.5	84.3	77.1	71.5	99.8	39.3	54.5	40.2
650	82.7	84.1	77.6	70.9	99.7	39.0	54.0	40.0
700	78.8	83.0	79.5	67.4	99.0	37.0	51.2	37.9
750	75.0	81.8	81.3	64.4	97.9	34.9	48.6	36.9
800	70.1	81.6	83.5	60.5	97.3	33.8	44.7	36.7
850	65.9	79.5	85.2	57.1	96.2	30.9	41.9	35.2
900	62.8	77.9	87.1	54.8	95.0	30.0	39.4	35.5
1000	56.4	74.7	**90.5**	49.9	93.0	31.4	34.7	35.5
1100	50.2	72.3	93.1	44.7	90.7	33.6	30.7	37.0
1161.7	47.4	70.5	94.4	42.2	**89.6**	32.6	28.8	37.1
1250	44.5	68.4	96.1	38.9	88.0	31.0	25.8	37.0
1350	42.0	66.3	97.8	35.1	86.8	30.6	22.4	37.8
1500	40.0	64.0	100.0	30.7	84.3	29.8	18.3	39.4

Table 4-6. Percentages of maximum habitat area at specified flows (cfs) for chum and pink salmon life stages, as well as for rainbow and cutthroat trout life stages, within Reach 2 on the Sultan River, Washington.

	Chum	Pink	Rainbow		Cutthroat	
Flow (cfs)	Spawning	Spawning	Spawning	Juvenile	Spawning	Juvenile
50	75.1	97.8	33.3	41.7	**89.4**	57.6
75	83.2	100.0	39.6	56.2	93.4	74.8
100	**88.4**	99.4	49.5	65.7	100.0	**87.2**
123	92.5	100.0	62.8	73.2	94.3	93.5
150	95.9	94.8	73.6	79.7	**89.3**	96.5
175	97.9	**88.5**	82.1	84.3	83.4	98.2
200	98.7	81.7	**89.6**	**87.9**	81.6	98.6
240	100.0	73.1	97.3	94.2	72.3	100.0
280	96.6	61.9	97.1	97.9	54.5	97.8
320	**92.8**	55.0	100.0	100.0	42.6	97.0
360	86.1	44.8	98.5	99.7	32.1	95.8
400	82.7	41.0	96.8	99.9	24.9	96.1
432	79.6	37.8	94.6	98.8	21.0	96.2
460	76.5	34.6	**91.9**	97.7	19.0	96.1
500	73.1	30.1	87.7	96.3	17.7	96.0
550	69.6	25.7	83.6	94.6	17.0	96.0
605	66.0	21.9	77.9	92.7	13.0	96.0
640	63.9	19.8	72.4	91.6	13.1	95.4
650	63.2	19.2	70.8	91.3	13.2	95.3
700	59.6	16.2	63.8	**90.4**	11.8	94.1
750	55.5	13.8	57.9	89.4	10.0	92.7
800	51.5	11.8	52.7	89.5	8.2	92.4
850	49.7	10.7	47.4	88.0	7.0	91.0
900	47.0	9.2	43.2	86.9	5.9	**89.2**
1000	41.6	6.9	39.1	84.8	4.6	84.9
1100	36.3	5.4	34.3	83.5	3.8	81.0
1161.7	33.7	4.7	33.2	83.4	3.5	78.7
1250	30.7	4.0	31.5	83.1	3.1	75.6
1350	28.0	3.5	30.1	82.0	2.9	72.9
1500	24.9	3.0	30.0	80.8	2.5	70.8

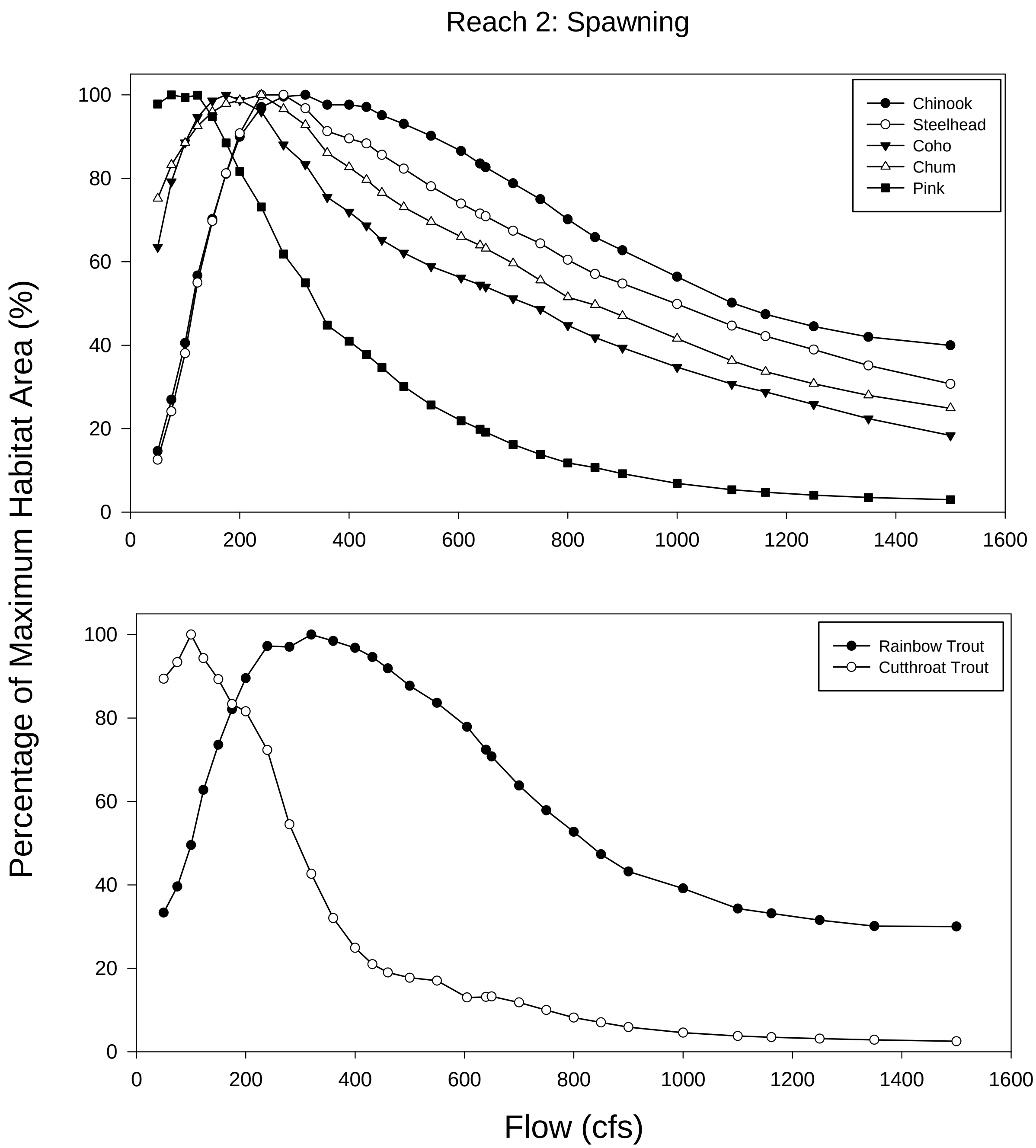


Figure 4-14. Percentage (%) of maximum spawning habitat area versus flow (cfs) relationships for Chinook, coho, chum, and pink salmon and steelhead trout (upper figure), and rainbow and cutthroat trout (lower figure) in Reach 2 of the Sultan River, Washington.

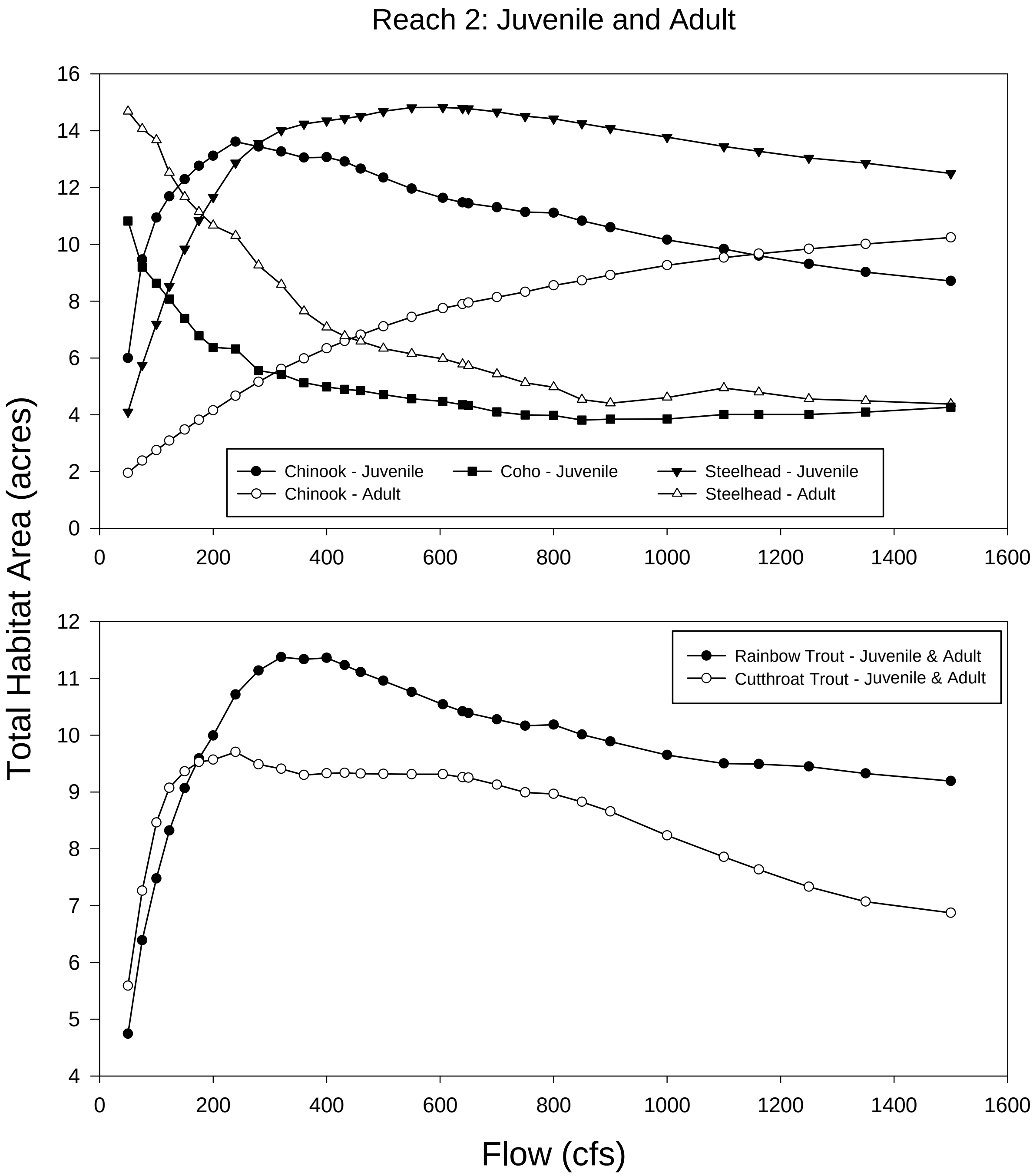


Figure 4-15. Total juvenile and adult habitat area (acres) versus flow (cfs) relationships for Chinook and coho salmon and steelhead trout (upper figure), and rainbow and cutthroat trout (lower figure) in Reach 2 of the Sultan River, Washington.

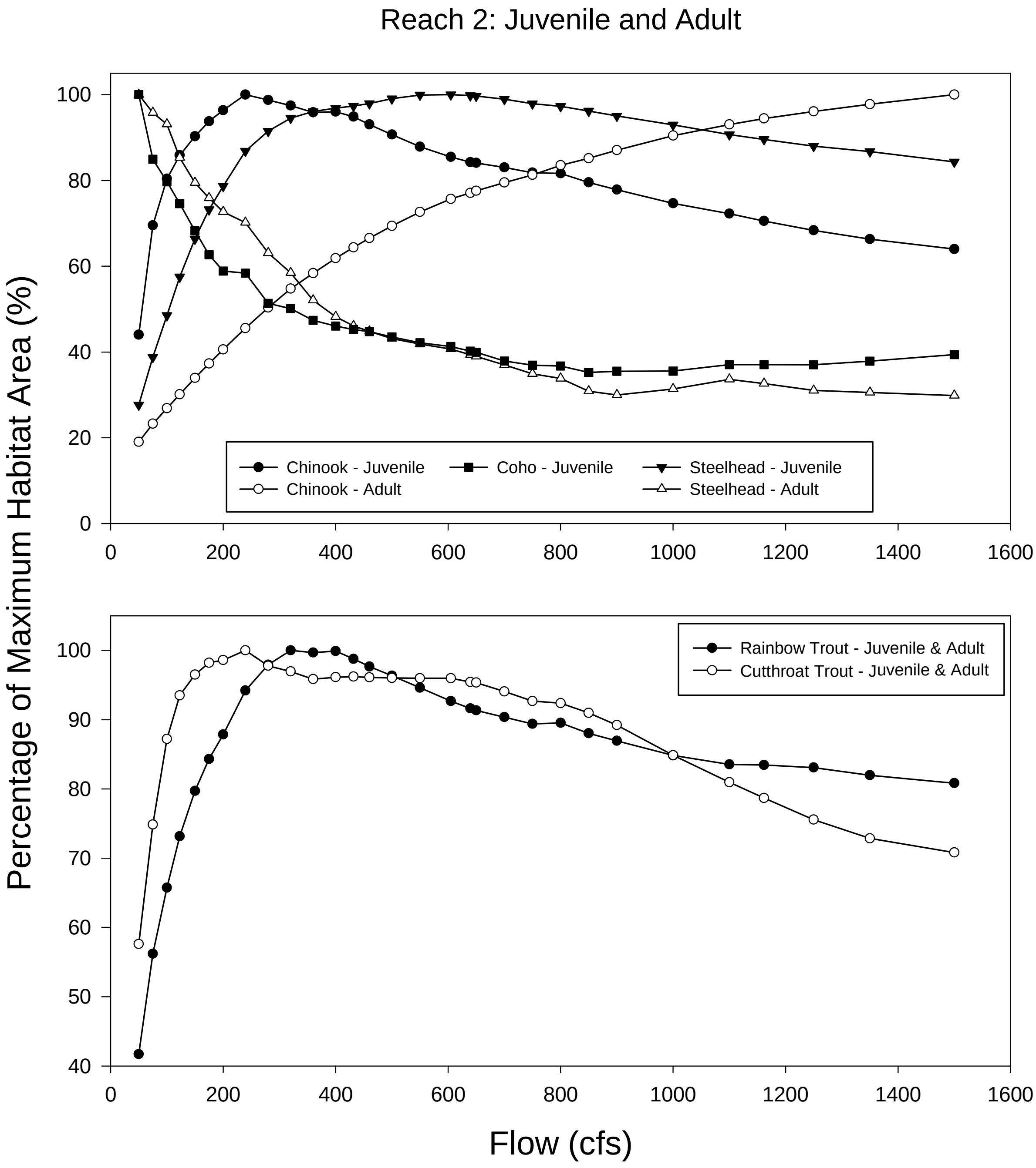


Figure 4-16. Percentage (%) of maximum juvenile and adult habitat area versus flow (cfs) relationships for Chinook and coho salmon and steelhead trout (upper figure), and rainbow and cutthroat trout (lower figure) in Reach 2 of the Sultan River, Washington.

4.2.1.3 Habitat Time Series

For Reach 2, Stage 1 conditions represent flow conditions resulting from the diversion of flows to Lake Chaplain for water supply purposes, without consideration for minimum flow releases as were afforded under Stage 2 conditions. The habitat time series and duration analysis reflect this, and demonstrate that Stage 2 operations provide greater and more stable Chinook and steelhead spawning habitats than under Stage 1 conditions (Figures 4-17 through 4-20). This is likewise true for coho, pink and chum salmon, and both rainbow and cutthroat trout spawning (Figures D3-1 to D3-10; Appendix D3).

Stage 2 flow conditions also provide greater and more stable juvenile rearing habitats for Chinook and coho salmon, and rainbow and cutthroat trout (Figures D3-11 to D3-18; Appendix D3). Stage 2 operations tend to provide higher and more stable juvenile rearing habitats for steelhead during the late summer early fall low flow periods (July to October), while Stage 1 conditions provided greater habitats during other times of the year (Figure D3-19 and Figure D3-20; Appendix D3). Comparisons of the median (50%), maximum, minimum and average habitat areas and percentage differences under Stage 1 and Stage 2 operations for all target species in Reach 2 based on the time series analysis are presented in Tables 4-7 and 4-8.

4.3 REACH 1 – POWERHOUSE TO SKYKOMISH RIVER

Habitat-flow relationships for Reach 1 were derived for seven target fish species, including the spawning lifestages of Chinook, coho, chum, and pink salmon, and steelhead trout, all of which are known to spawn in Reach 1; rainbow and cutthroat trout were also included since they are found and presumably spawn within the reach. Because of the short residence time of juvenile chum and pink salmon in the Sultan River following emergence, modeling results for juvenile rearing in Reach 1 were limited to Chinook and coho salmon, and steelhead, rainbow and cutthroat trout.

This section includes habitat-flow analysis for both the mainstem reach of the Sultan River as well as the three side channel complexes that enter within the reach.

4.3.1 Mainstem PHABSIM Analysis

4.3.1.1 Spawning Habitat

Over the range of flows modeled in Reach 1, the greatest amounts of spawning habitat would be provided for Chinook at a flow of 800 cfs (provides ≈ 21 acres), followed by chum (495 cfs

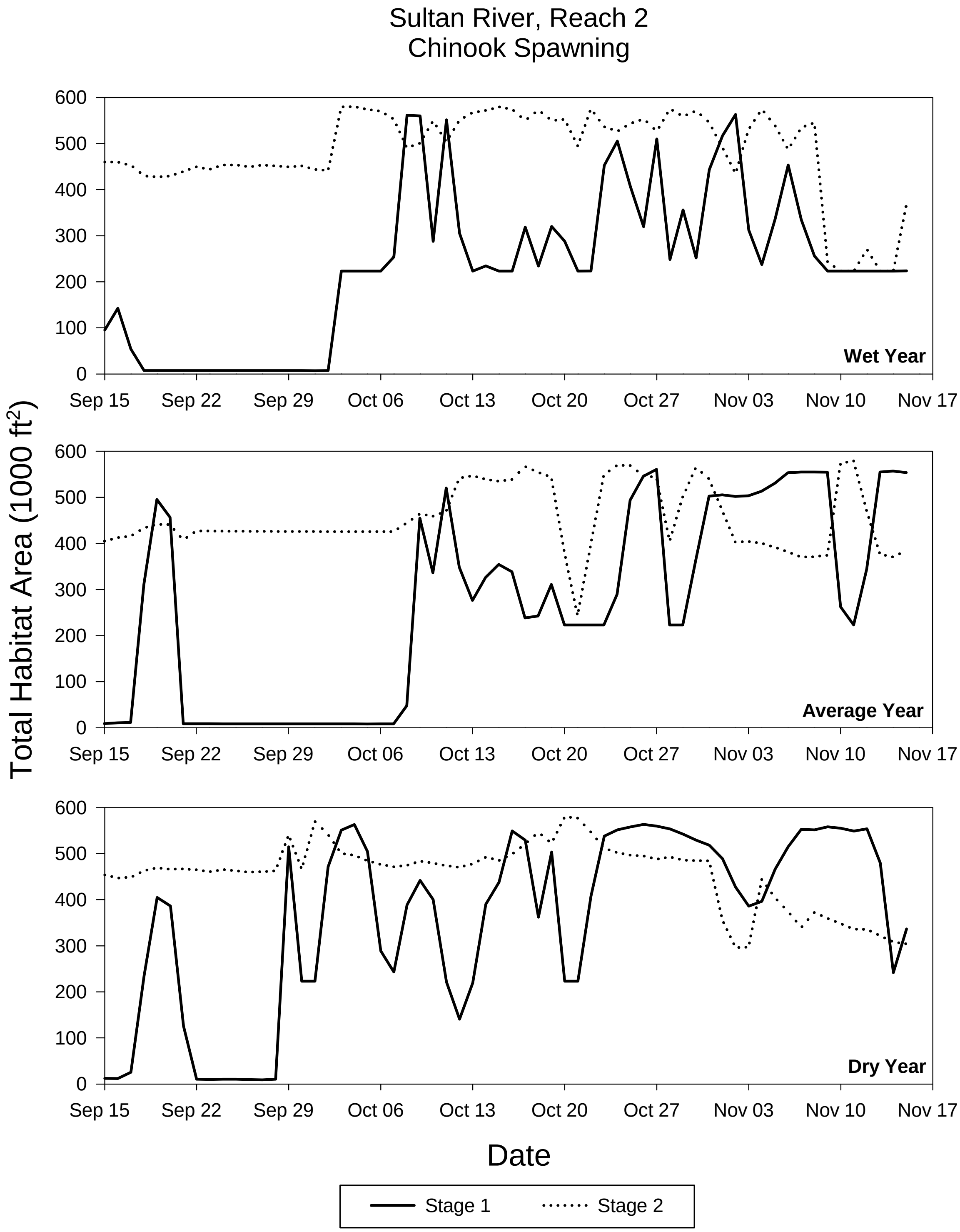


Figure 4-17. Time series analysis depicting total Chinook salmon spawning habitat (1000 ft^2) available over the period of spawning under wet, average and dry year scenarios for Reach 2 of the Sultan River, Washington.

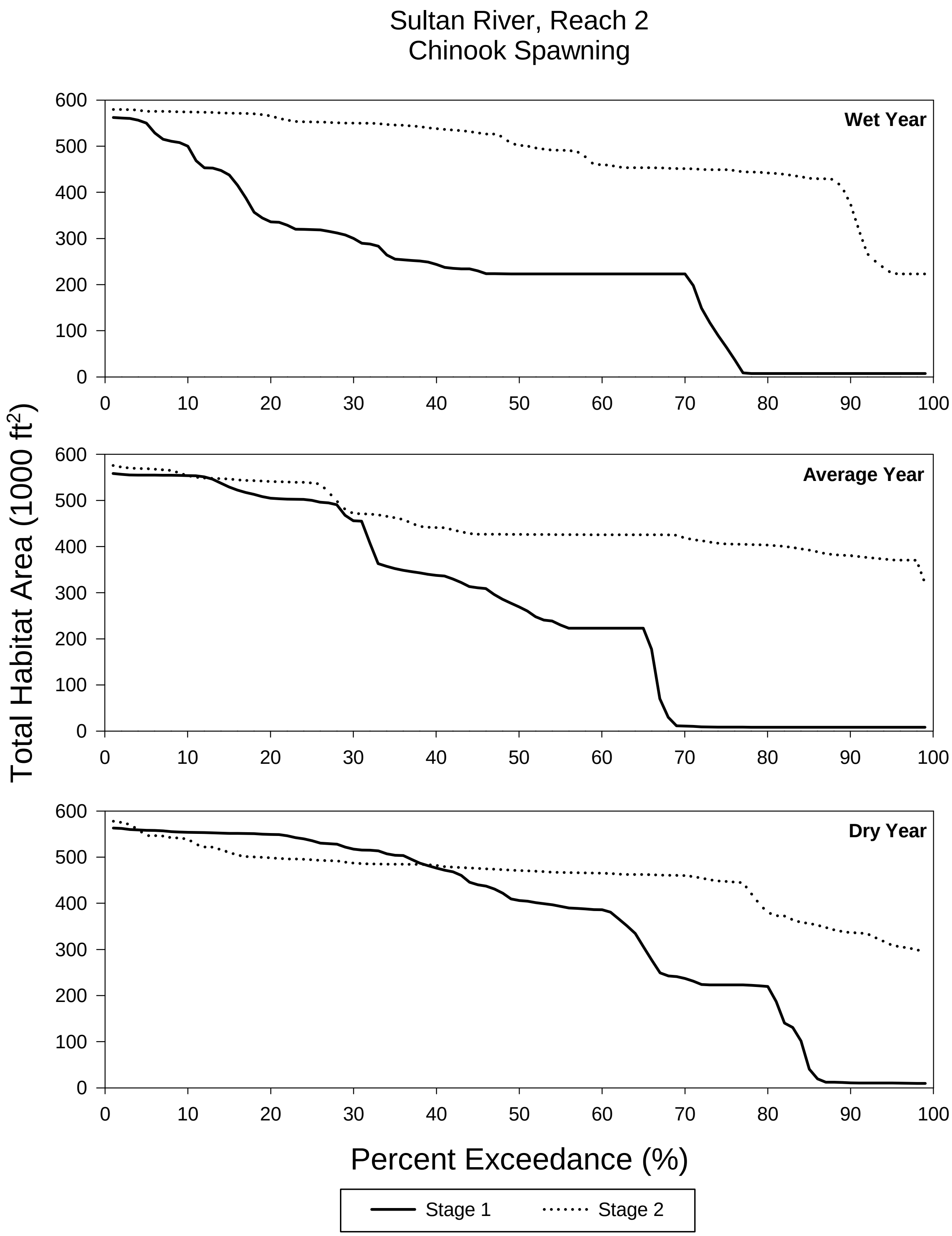


Figure 4-18. Habitat duration curves for Chinook salmon spawning habitat (1000 ft^2) under wet, average, dry year scenarios for Reach 2 of the Sultan River, Washington.

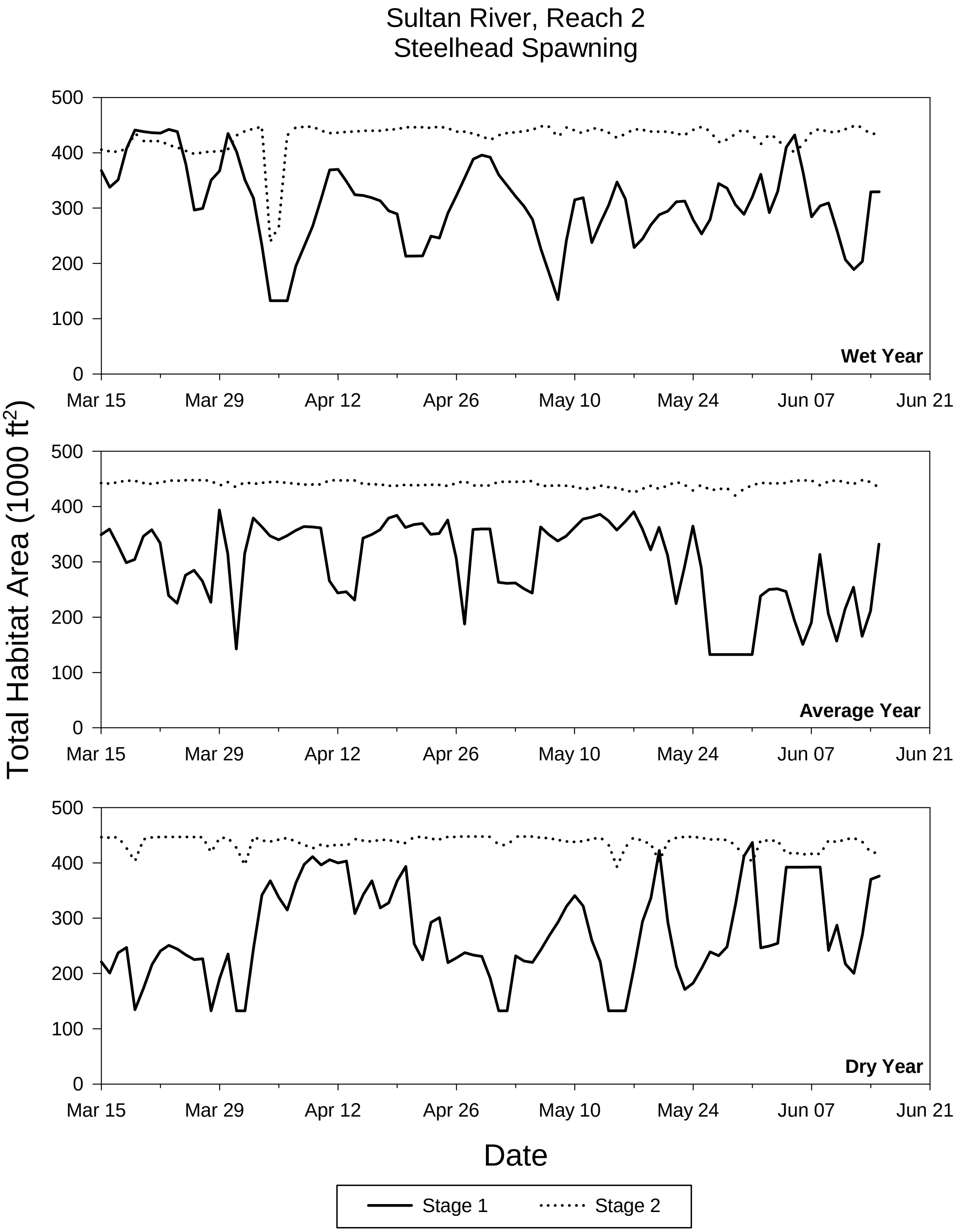


Figure 4-19. Time series analysis depicting total steelhead trout spawning habitat (1000 ft^2) available over the period of spawning under wet, average and dry year scenarios for Reach 1 of the Sultan River, Washington.

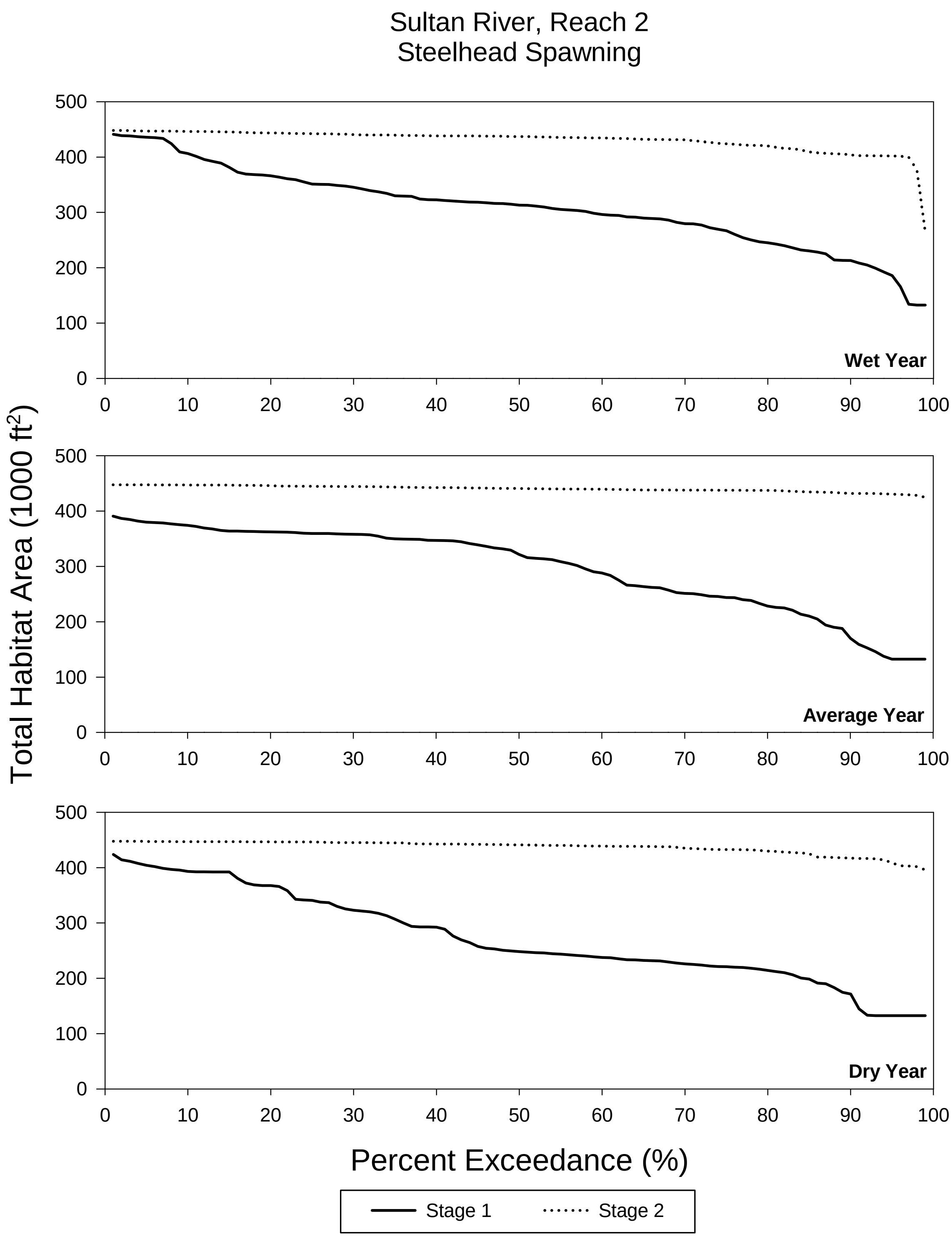


Figure 4-20. Habitat duration curves for steelhead trout spawning habitat (1000 ft^2) under wet, average, dry year scenarios for Reach 2 of the Sultan River, Washington.

Table 4-7. Comparison of median, maximum, minimum, average and percentage difference in anadromous salmonid habitat areas provided during Wet, Average, and Dry water year types for Stage 1 and Stage 2 conditions as determined from habitat duration analysis for operational Reach 2 of the Sultan River, Washington.

Life Stage	Species	Median (50% exceedance) Habitat Area (ft^2)		Maximum Habitat Area (ft^2)		Minimum Habitat Area (ft^2)		Average Habitat Area (ft^2)		
		Stage 1	Stage 2	Stage 1	Stage 2	Stage 1	Stage 2	Stage 1	Stage 2	% Difference
WATER YEAR - WET										
Spawning	Chinook	223,054	502,061	561,974	579,447	7,211	223,054	230,599	484,656	+110.2
	Steelhead	312,865	436,760	440,987	447,759	132,459	264,596	308,092	429,940	+39.5
	Coho	173,925	427,333	446,783	452,045	78,656	80,886	221,932	350,632	+58.0
	Chum	191,295	453,081	463,375	474,969	99,098	116,350	225,054	362,809	+61.2
	Pink	40,067	271,611	305,006	308,574	9,071	102,883	53,240	251,812	+373.0
Juvenile	Chinook	494,325	578,545	593,649	597,489	29,795	450,094	442,199	563,421	+27.4
	Steelhead	583,381	534,030	647,925	645,246	20,404	345,554	482,868	507,806	+5.2
	Coho	185,663	279,691	391,402	359,888	63,098	165,615	191,805	274,761	+43.3
WATER YEAR - AVERAGE										
Spawning	Chinook	269,212	426,349	558,437	575,403	8,103	320,588	267,084	454,269	+70.1
	Steelhead	321,578	440,532	390,897	447,471	132,459	424,612	296,384	440,374	+48.6
	Coho	249,646	438,331	441,662	451,859	80,886	108,076	227,882	414,805	+82.0
	Chum	325,687	456,524	467,789	471,656	116,350	186,407	302,074	445,811	+47.6
	Pink	47,869	281,431	310,749	312,465	9,071	25,022	78,331	251,056	+220.5
Juvenile	Chinook	477,761	587,597	583,887	599,152	21,050	469,932	385,872	560,392	+45.2
	Steelhead	607,739	506,923	647,849	638,217	14,860	305,812	454,255	474,767	+4.5
	Coho	185,663	282,870	397,343	377,519	43,187	167,573	177,988	292,621	+64.4
WATER YEAR - DRY										
Spawning	Chinook	406,103	470,710	563,096	577,783	9,383	296,557	360,923	456,213	+26.4
	Steelhead	248,126	440,762	423,544	447,395	132,459	395,693	272,834	436,833	+60.1
	Coho	323,244	436,499	447,397	452,536	81,073	338,277	320,016	433,348	+35.4
	Chum	354,101	444,903	469,827	474,522	117,581	408,653	361,047	447,331	+23.9
	Pink	107,058	265,648	311,502	309,285	9,071	97,178	152,862	263,668	+72.5
Juvenile	Chinook	510,619	572,664	591,642	596,974	43,528	502,634	462,904	562,727	+21.6
	Steelhead	598,590	477,240	647,881	638,201	30,864	342,028	489,163	465,665	-4.8
	Coho	208,000	288,390	430,414	357,703	100,666	208,977	226,253	297,117	+31.3

Table 4-8. Comparison of median, maximum, minimum, average and percentage difference in resident trout habitat areas provided during Wet, Average, and Dry water year types for Stage 1 and Stage 2 conditions as determined from habitat duration analysis for operational Reach 2 of the Sultan River, Washington.

Life Stage	Species	Median (50% exceedance) Habitat Area (ft^2)		Maximum Habitat Area (ft^2)		Minimum Habitat Area (ft^2)		Average Habitat Area (ft^2)		
		Stage 1	Stage 2	Stage 1	Stage 2	Stage 1	Stage 2	Stage 1	Stage 2	% Difference
WATER YEAR - WET										
Spawning	Rainbow	138,151	193,634	200,275	201,326	60,461	106,204	132,669	186,422	+40.5
	Cutthroat	17,512	86,427	109,901	107,840	3,849	55,388	28,049	89,687	+219.8
Juvenile	Rainbow	422,237	441,554	492,300	483,376	24,155	348,825	366,819	429,399	+17.1
	Cutthroat	381,888	411,733	420,551	420,692	28,245	299,319	318,500	404,721	+27.1
WATER YEAR - AVERAGE										
Spawning	Rainbow	175,595	194,259	198,848	203,300	60,570	118,911	145,229	185,120	+27.5
	Cutthroat	18,560	83,005	107,557	111,983	2,805	33,846	24,824	85,791	+245.6
Juvenile	Rainbow	431,551	436,796	491,229	480,367	17,429	320,860	343,849	417,107	+21.3
	Cutthroat	385,015	410,353	385,015	410,353	20,447	362,865	296,675	402,388	+35.6
WATER YEAR - DRY										
Spawning	Rainbow	143,734	194,096	201,936	202,185	60,570	127,420	139,001	184,349	+32.6
	Cutthroat	20,182	95,701	111,861	107,606	2,805	34,256	31,447	89,106	+183.4
Juvenile	Rainbow	437,451	421,733	492,988	478,311	36,846	351,683	387,145	416,024	+7.5
	Cutthroat	403,109	411,047	421,518	419,909	42,961	386,377	347,864	405,787	+16.7

provides ≈ 16 acres), steelhead (410 cfs provides ≈ 16 acres), coho (296 cfs provides ≈ 13 acres) and then pink (150 cfs provides ≈ 11 acres) (Figure 4-21; Tables 4-7 and 4-8). When expressed as percentages of maximum habitat, Chinook and steelhead relationships track together on the ascending portion of the curve, but then diverge slightly at their peaks with Chinook maintaining a broader and more gently sloping descending limb. The chum and coho curves share common origins and after diverging slightly and crossing, eventually converge at the tail end of the descending limb (Figure 4-22). With the exception of the pink salmon curve which has a relatively narrow peak range of flows, the curve shapes for the other species are broad and gently sloping indicating that habitat amounts would remain relatively high (≥ 85% of maximum) even at flows as low as 320 cfs for Chinook, 296 cfs for steelhead, 260 cfs for chum, 180 cfs for coho (Tables 4-9 and 4-10; Figure 4-22).

The spawning habitat-flow relationships for rainbow and cutthroat peak at flows of 495 cfs and 100 cfs, respectively (Figure 4-21 and 4-22; Table 4-10). For these two species, flows as low as 396 cfs for rainbow, and 80cfs for cutthroat would still provide ≥ 85% of maximum habitat.

4.3.1.2 Juvenile and Adult Habitat

The Reach 1 habitat-flow relationships for target species juvenile and adult life stages reflected the same three general trends as exhibited in Reach 2, a trend of decreasing amounts of habitat with increasing flow (reflected by coho juvenile and steelhead adult), the trend of increasing habitat with flow up to a maximum and then decreasing habitats with flow (represented by Chinook and steelhead juvenile, and rainbow and cutthroat trout juvenile and adult), and the third trend that reflects a continuously increasing amount of habitat with flow (represented by Chinook adult) (Figure 4-23). Habitat maximizing flows for the target species range from the lowest to highest for coho juvenile (≈ 9.5 acres at 80 cfs) and steelhead adults (≈ 15 acres at 80 cfs), cutthroat juvenile and adult (≈ 10 acres at 260 cfs), rainbow juvenile and adult (≈ 11 acres at 320 cfs), steelhead juvenile (≈ 15 acres at 850 cfs), and Chinook juvenile and adult (both ≈ 10 acres at 1500 cfs) (Figure 4-23 and 4-24; Tables 4-9 and 4-10). Juvenile habitats remain at levels ≥ 85% of maximum at flows of 296 cfs for steelhead, 200 cfs for rainbow, 220 cfs for Chinook, and 120 cfs for cutthroat (Tables 4-9 and 4-10).

4.3.1.3 Habitat Time Series

The Reach 1 Stage 1 conditions would be similar to Reach 2 in that they represent flow conditions below the Diversion Dam (resulting from diversion of flows to Lake Chaplain for water supply) plus accretion and tributary inflow. Stage 2 conditions reflect operation of the hydroelectric Project and Powerhouse releases, subject to minimum required instream flow releases of from 165 to 200 cfs. In general, Stage 2 operations have increased and stabilized

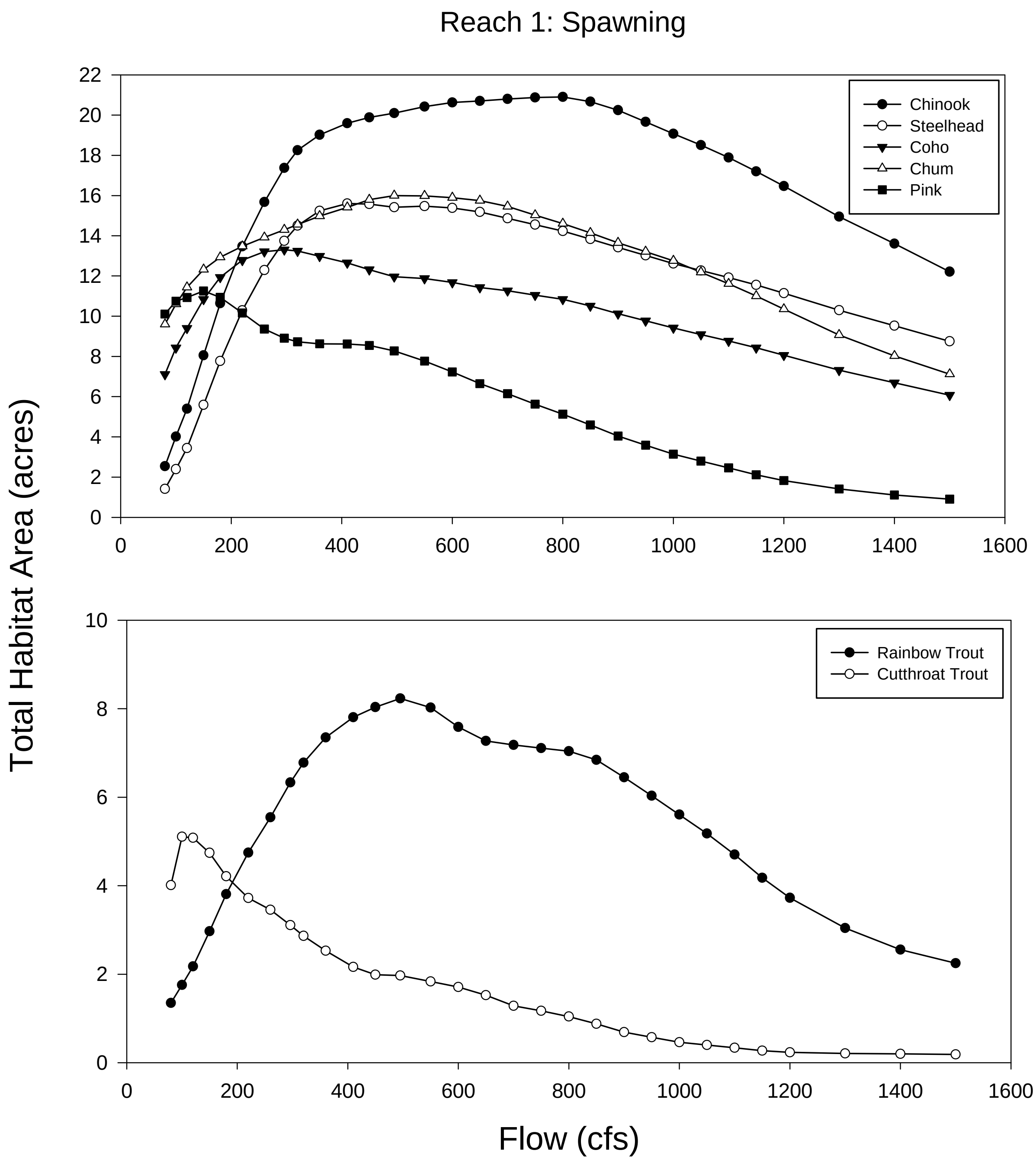


Figure 4-21. Total spawning habitat area (acres) versus flow (cfs) relationships for Chinook, coho, chum and pink salmon and steelhead trout (upper figure), and rainbow and cutthroat trout (lower figure) in Reach 1 of the Sultan River, Washington.

Table 4-9. Percentages of maximum habitat area at specified flows (cfs) for Chinook, steelhead, and coho salmon life stages within Reach 1 on the Sultan River, Washington.

Flow (cfs)	Chinook			Steelhead			Coho	
	Spawning	Juvenile	Adult	Spawning	Juvenile	Adult	Spawning	Juvenile
80	12.1	52.1	22.2	9.0	33.5	100.0	53.5	100.0
100	19.2	63.3	26.4	15.3	40.1	93.0	63.4	**87.2**
120	25.9	71.8	29.7	22.1	46.2	**87.1**	70.7	81.5
150	38.5	79.6	32.8	35.8	54.6	76.0	81.5	74.8
180	50.9	83.9	35.7	49.8	61.9	66.9	**89.7**	72.8
220	64.4	**88.9**	37.8	66.0	70.2	56.0	96.1	68.2
260	75.0	92.1	40.9	78.8	77.3	49.8	99.3	63.8
296	83.1	93.7	45.0	**88.1**	82.3	46.4	100.0	59.3
320	87.3	95.3	48.5	92.9	85.0	44.1	99.5	55.9
360	**91.0**	96.3	51.4	97.6	**88.5**	42.4	97.6	51.8
410	93.7	96.4	54.4	100.0	91.9	40.4	95.1	46.4
450	95.1	96.2	57.3	99.8	93.9	39.5	92.6	42.8
495	96.2	95.5	59.7	98.8	96.1	39.5	**89.9**	39.9
550	97.7	95.3	61.9	99.2	97.6	38.0	89.2	37.2
600	98.7	95.1	64.7	98.6	98.3	36.7	87.8	35.2
650	99.0	94.5	68.7	97.3	98.4	35.9	85.9	33.8
700	99.5	94.1	71.6	95.3	98.9	35.1	84.7	32.5
750	99.9	93.8	73.8	93.3	99.3	33.5	83.1	31.2
800	100.0	94.0	75.5	**91.2**	99.9	32.2	81.5	30.3
850	98.9	94.3	77.2	88.7	100.0	30.8	79.0	29.4
900	96.9	94.8	79.0	86.1	99.7	29.4	76.1	28.3
950	94.1	95.3	80.9	83.4	98.4	27.9	73.5	27.6
1000	**91.3**	95.6	82.5	80.8	97.3	26.6	70.8	27.0
1050	88.5	95.7	83.5	78.7	95.5	25.4	68.3	26.6
1100	85.6	95.7	86.9	76.4	93.8	24.3	65.9	26.3
1150	82.3	95.4	**91.2**	74.0	91.9	23.5	63.3	26.0
1200	78.8	95.7	93.1	71.4	**90.6**	22.9	60.6	25.6
1300	71.5	97.3	95.0	66.0	88.8	22.0	55.0	24.9
1400	65.1	99.0	97.1	61.1	88.1	21.0	50.3	24.6
1500	58.4	100.0	100.0	56.1	87.5	19.4	45.7	23.6

Table 4-10. Percentages of maximum habitat area at specified flows (cfs) for chum and pink salmon life stages, as well as for rainbow and cutthroat trout life stages, within Reach 1 on the Sultan River, Washington.

	Chum	Pink	Rainbow		Cutthroat	
Flow (cfs)	Spawning	Spawning	Spawning	Juvenile	Spawning	Juvenile
80	60.0	**89.8**	16.4	58.0	78.5	66.9
100	66.3	95.5	21.3	66.7	100.0	78.5
120	71.5	97.2	26.4	73.4	99.5	**87.0**
150	77.1	100.0	36.1	82.0	**92.8**	94.5
180	80.9	97.2	46.3	**88.8**	82.5	98.0
220	84.3	**90.3**	57.6	94.6	72.9	99.6
260	87.0	83.2	67.3	98.0	67.7	100.0
296	**89.4**	79.2	76.9	99.5	60.9	98.0
320	91.0	77.6	82.3	100.0	56.1	96.5
360	93.6	76.7	**89.3**	99.1	49.5	92.9
410	96.4	76.6	94.8	97.8	42.3	**89.1**
450	98.7	76.0	97.6	96.5	39.0	85.8
495	100.0	73.5	100.0	96.7	38.5	83.9
550	99.9	69.1	97.5	95.8	36.0	84.2
600	99.4	64.2	92.1	95.8	33.5	85.0
650	98.4	59.1	**88.3**	95.7	29.8	84.5
700	96.6	54.7	87.2	95.3	25.1	84.2
750	93.9	50.0	86.3	94.5	22.9	83.2
800	**91.3**	45.6	85.5	94.0	20.4	82.1
850	88.4	40.8	83.1	93.4	17.2	80.8
900	85.4	35.9	78.3	93.3	13.5	79.1
950	82.6	31.9	73.3	92.9	11.2	78.1
1000	79.8	27.9	68.1	92.6	9.0	77.2
1050	76.2	24.9	62.9	91.2	7.8	76.6
1100	72.6	21.9	57.1	**89.8**	6.6	75.9
1150	68.8	18.8	50.7	88.2	5.3	75.4
1200	64.7	16.3	45.3	86.8	4.5	75.1
1300	56.7	12.5	37.0	84.0	4.1	74.6
1400	50.2	9.9	31.0	81.6	3.9	74.9
1500	44.5	8.0	27.3	79.5	3.6	73.3

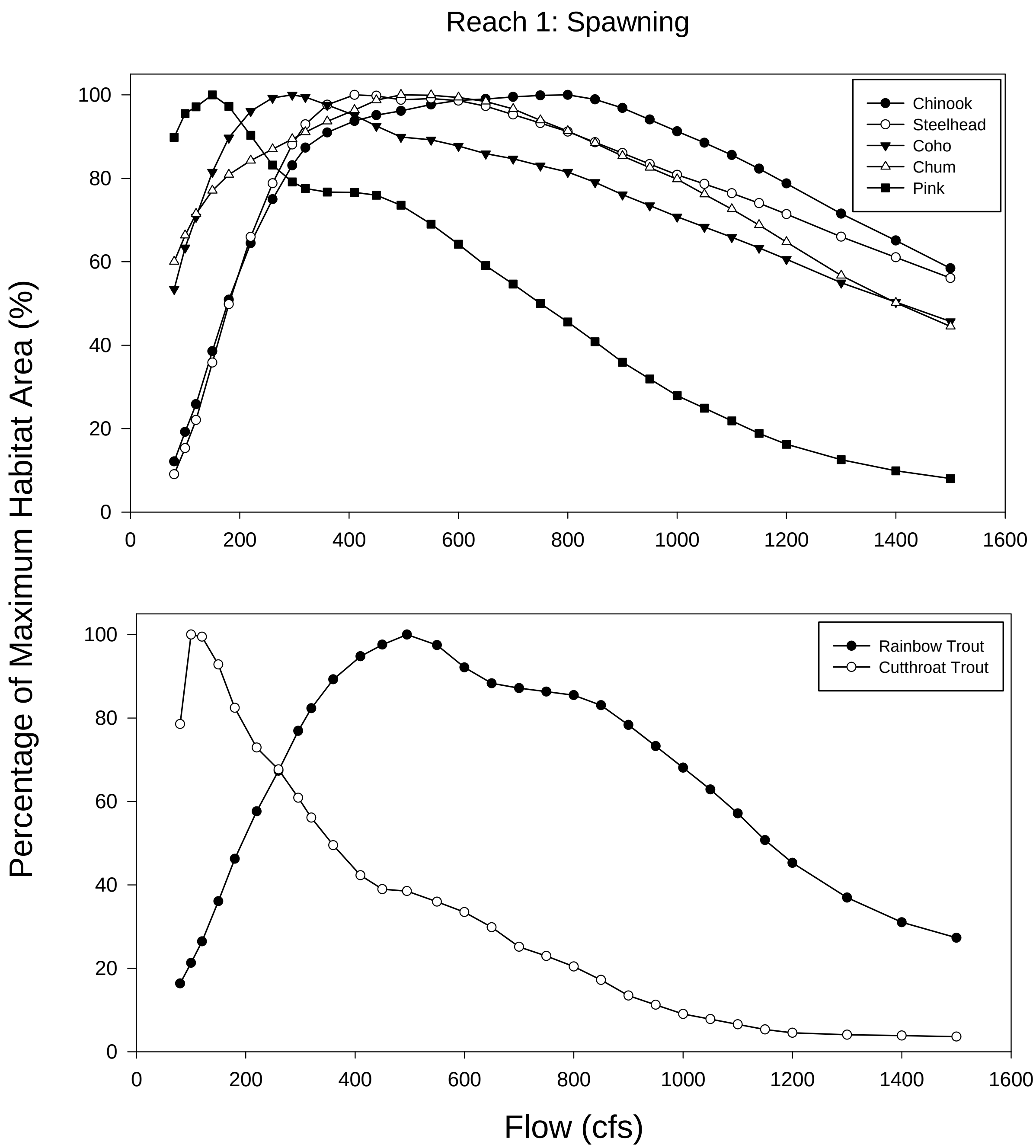


Figure 4-22. Percentage (%) of maximum spawning habitat area versus flow (cfs) relationships for Chinook, coho, chum and pink salmon and steelhead trout (upper figure), and rainbow and cutthroat trout (lower figure) in Reach 1 of the Sultan River, Washington.

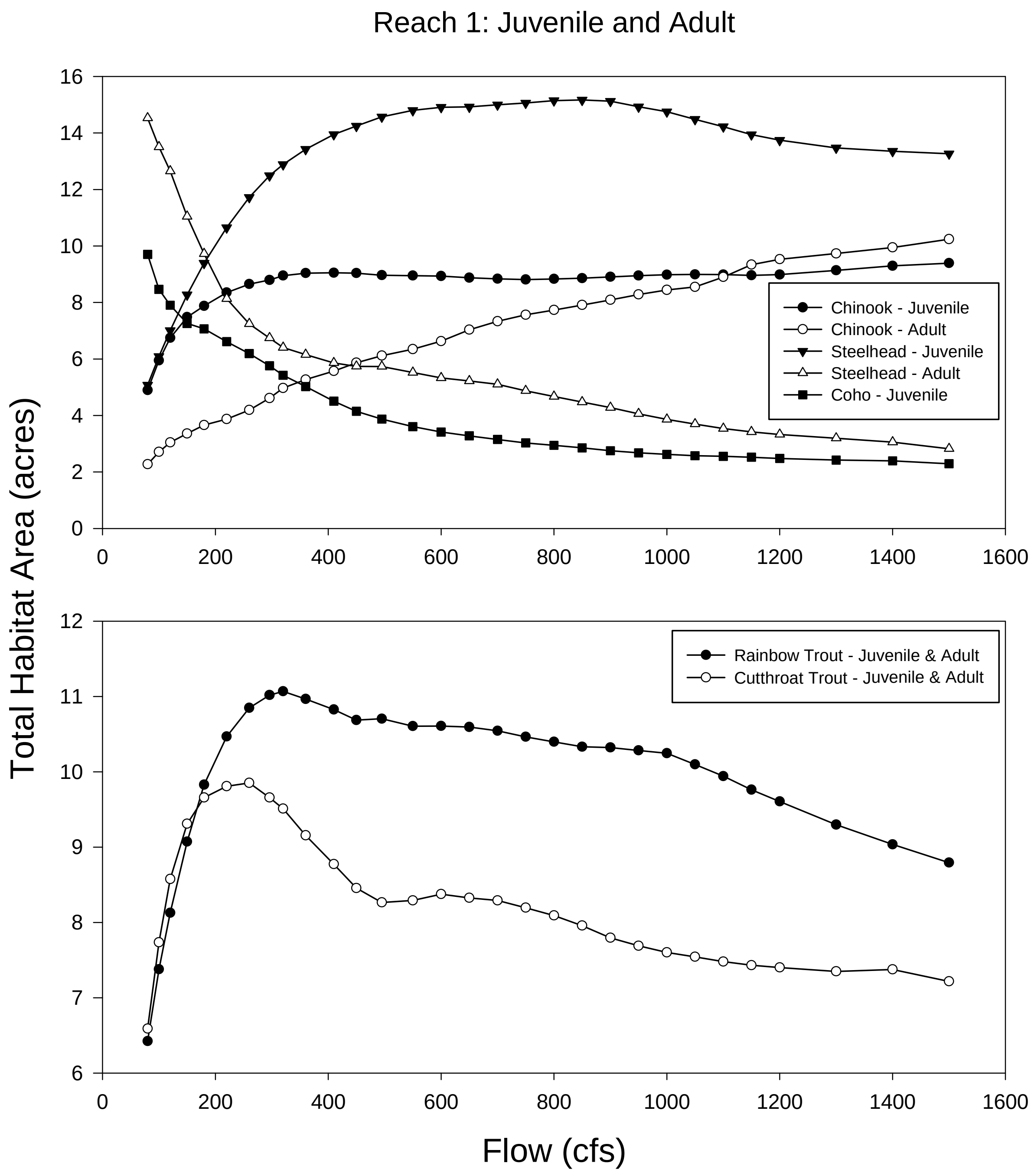


Figure 4-23. Total juvenile and adult habitat area (acres) versus flow (cfs) relationships for Chinook and coho salmon and steelhead trout (upper figure), and rainbow and cutthroat trout (lower figure) in Reach 1 of the Sultan River, Washington.

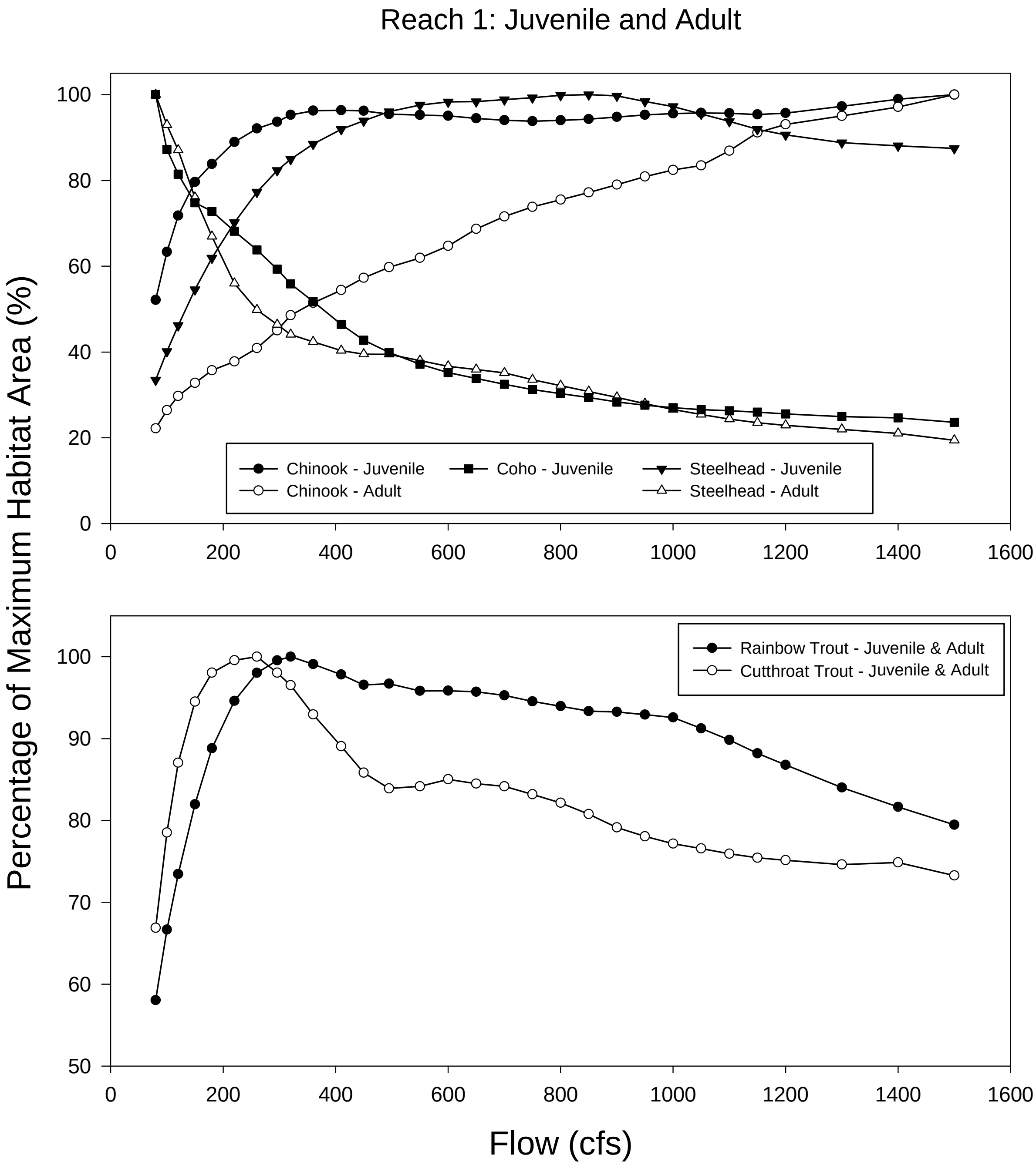


Figure 4-24. Percentage (%) of maximum spawning habitat area versus flow (cfs) relationships for Chinook, and coho salmon and steelhead trout (upper figure), and rainbow and cutthroat trout (lower figure) in Reach 1 of the Sultan River, Washington.

flows during the summer and early fall periods compared to Stage 1 conditions. This has tended to benefit those species and life stages active during these periods, as indicated in the time series analysis for Chinook spawning (Figure 4-25 and Figure 4-26), as well as pink salmon spawning (Figures D4-1 and D4-2; Appendix D4), and to a lesser degree, cutthroat spawning (Figures D4-3 and D4-4; Appendix D4). Such effects are less pronounced for species whose life stage activities occur earlier in the year when Stage 1 flow conditions are higher. Thus, there is essentially little difference between habitat conditions provided Stage 1 versus Stage 2 for steelhead spawning (Figure 4-27 and Figure 4-28), or rainbow trout spawning (Figures D4-5 and D4-6; Appendix D4). In contrast, species spawning later in the year (coho and chum salmon) would be afforded higher amounts of habitat overall under Stage 1 conditions (Figures D4-7 to D4-10; Appendix D4), but the provision of such would be more variable (i.e., less stable) than habitats occurring under Stage 2 conditions.

In general, Stage 2 flow conditions provide slightly greater and more stable juvenile rearing habitats for all of the target species (Chinook and coho salmon, steelhead, rainbow and cutthroat trout) (Figures D4-11 to D4-20; Appendix D4), especially during the summer and early fall low flow periods. Comparisons of the median (50%), maximum, minimum and average habitat areas and percentage differences under Stage 1 and Stage 2 operations for all target species in Reach 1 based on the time series analysis are presented in Tables 4-11 and 4-12.

Comparisons of total estimated amounts of anadromous salmonid (all species) habitat provided under Stage 1 and Stage 2 conditions for each reach and for all reaches combined are presented in Table 4-13. In general, the table illustrates that overall habitat amounts of anadromous salmonids are higher for Reaches 2 and 1 under Stage 2 operations, while the reverse of this occurs (if anadromous salmonids were present) for Reach 3. When all reaches are combined, Stage 2 operations would, with the exception of slight differences in amounts of steelhead juvenile habitat) provide more anadromous salmonid habitat overall (even when Reach 3 is included) than under Stage 1 conditions.

4.3.2 Side Channel Habitat:Flow Analysis

Operational Reach 1 includes three side channels depicted in Figures 3-10 to 3-12 that were surveyed as part of the instream flow study. Results of fish surveys have indicated these side channels provide important spawning and rearing habitat for a number of target salmonid species. R2 therefore surveyed the side channels with a focus on 1) determining the flow connectivity relationship between the mainstem and side channels; 2) estimating individual and cumulative wetted surface areas provided by mainstem flows; and 3) defining habitat-flow

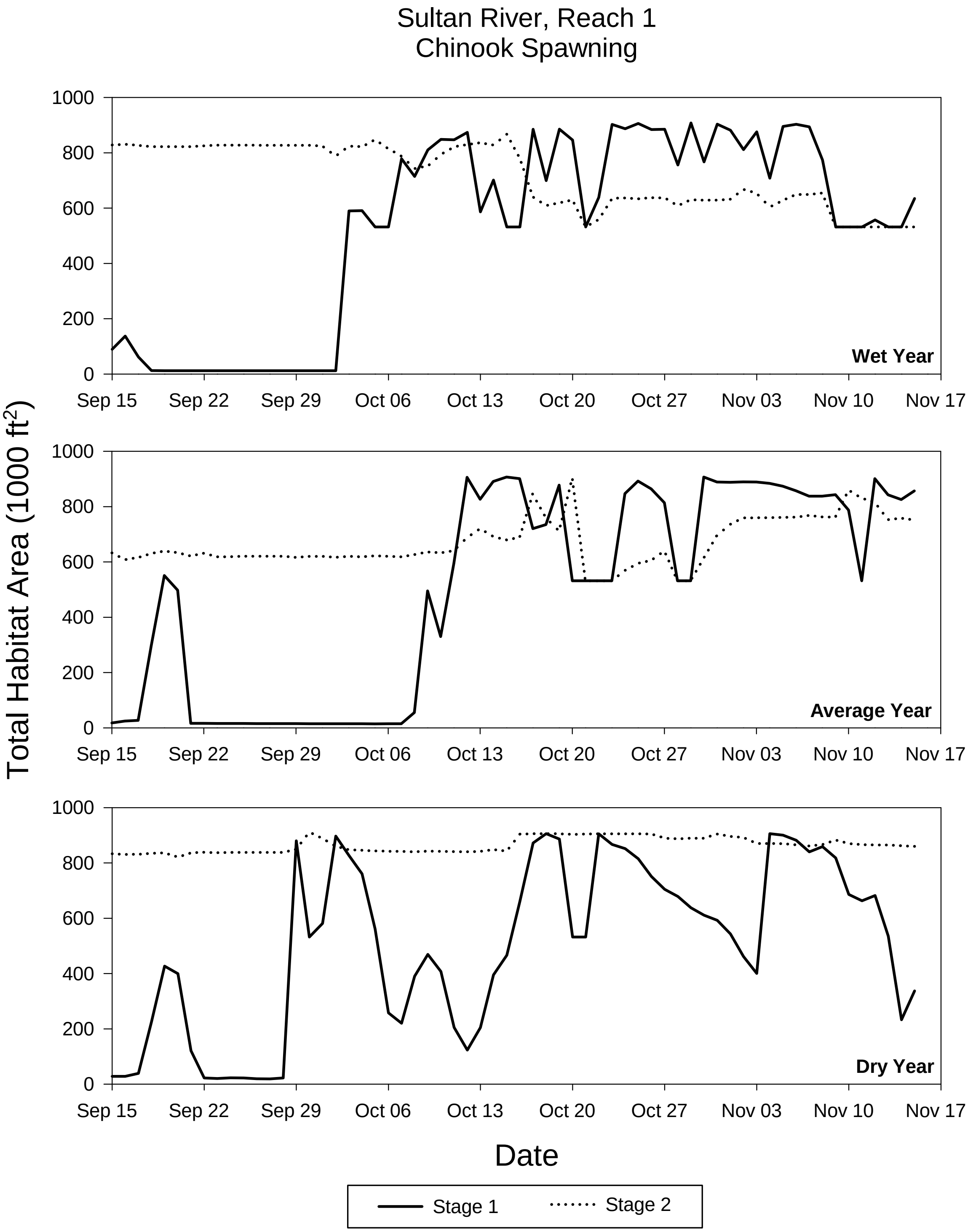


Figure 4-25. Time series analysis depicting total Chinook salmon spawning habitat (1000 ft^2) available over the period of spawning under wet, average and dry year scenarios for Reach 1 of the Sultan River, Washington.

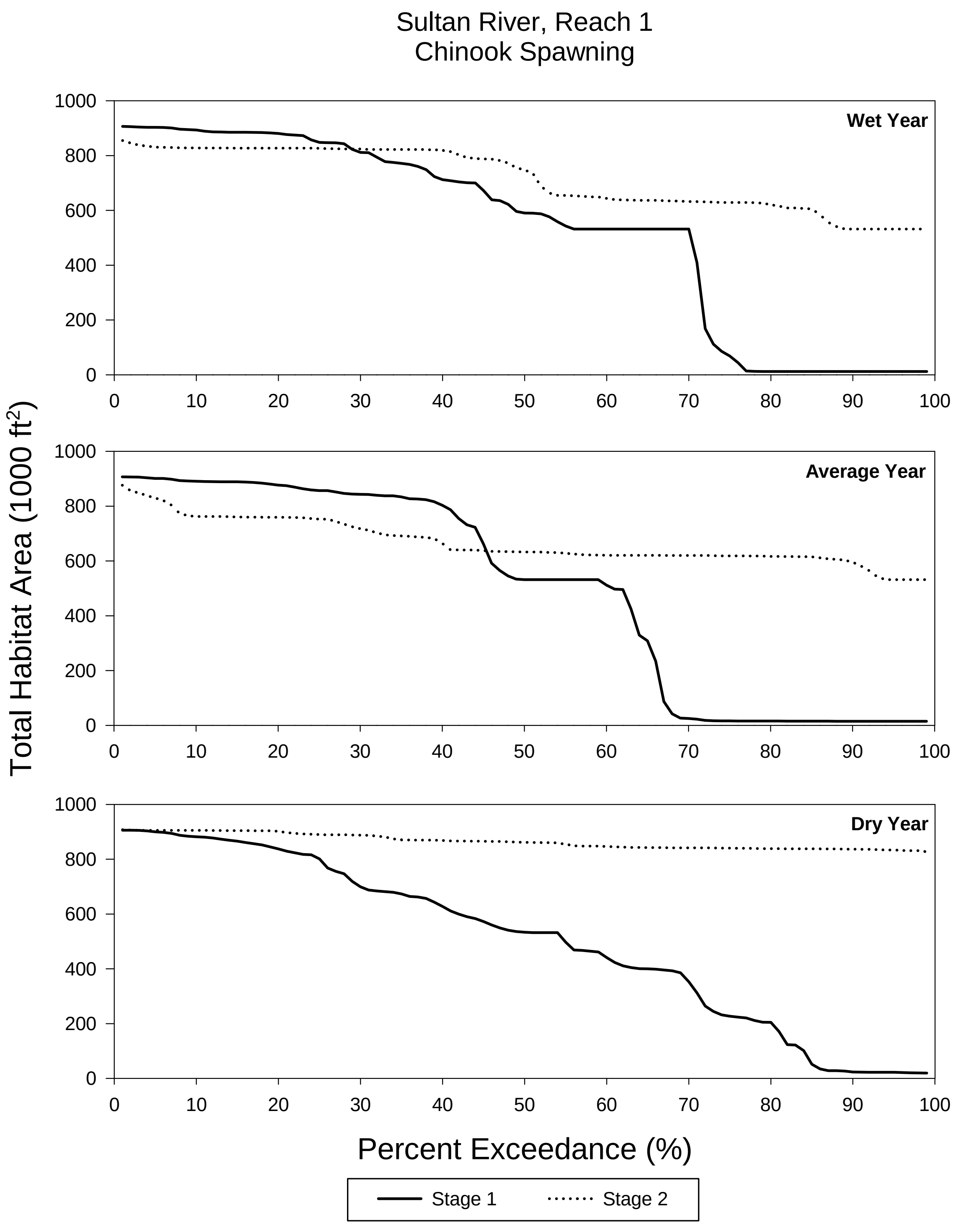


Figure 4-26. Habitat duration curves for Chinook salmon spawning habitat (1000 ft^2) under wet, average, dry year scenarios for Reach 1 of the Sultan River, Washington.

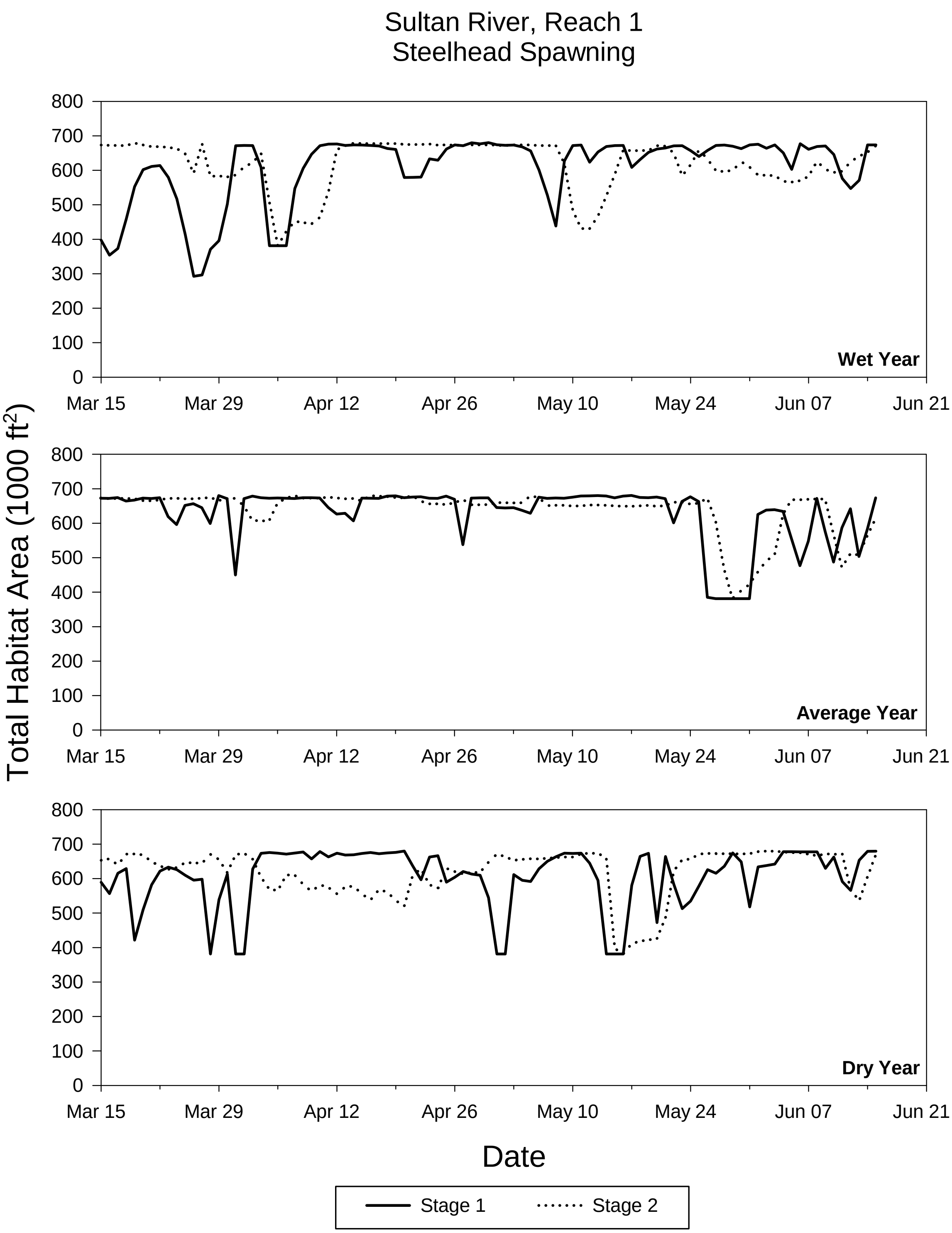


Figure 4-27. Time series analysis depicting total steelhead trout spawning habitat (1000 ft^2) available over the period of spawning under wet, average and dry year scenarios for Reach 1 of the Sultan River, Washington.

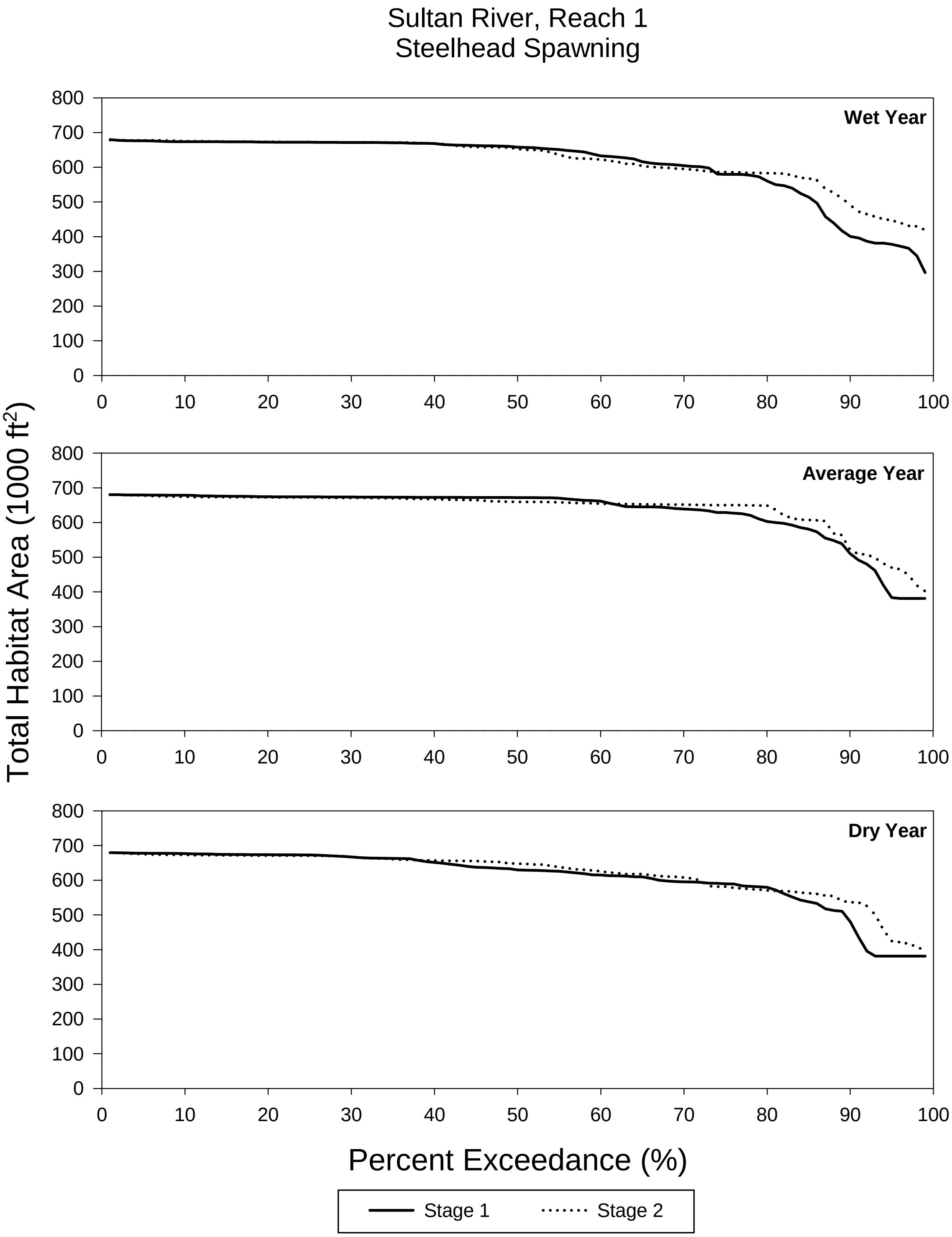


Figure 4-28. Habitat duration curves for steelhead trout spawning habitat (1000 ft^2) under wet, average, dry year scenarios for Reach 1 of the Sultan River, Washington.

Table 4-11. Comparison of median, maximum, minimum, average and percentage difference in anadromous salmonid habitat areas provided during Wet, Average, and Dry water year types for Stage 1 and Stage 2 conditions as determined from habitat duration analysis for operational Reach 1 of the Sultan River, Washington.

Life Stage	Species	Median (50% exceedance) Habitat Area (ft²)		Maximum Habitat Area (ft²)		Minimum Habitat Area (ft²)		Average Habitat Area (ft²)		
		Stage 1	Stage 2	Stage 1	Stage 2	Stage 1	Stage 2	Stage 1	Stage 2	% Difference
WATER YEAR - WET										
Spawning	Chinook	590,410	747,331	906,339	854,945	11,582	531,893	530,798	714,643	+34.6
	Steelhead	657,696	652,219	679,775	678,084	296,070	419,094	608,021	619,160	+1.8
	Coho	446,621	299,762	579,002	539,637	186,210	264,787	412,387	318,511	-22.8
	Chum	544,544	339,854	696,611	407,598	206,508	310,055	489,336	346,238	-29.2
	Pink	77,348	376,239	460,493	459,088	39,383	41,822	134,737	284,250	+111.0
Juvenile	Chinook	491,342	524,170	611,315	612,889	46,387	392,502	448,141	508,229	+13.4
	Steelhead	577,776	577,773	643,547	642,762	25,910	433,556	484,810	576,371	+18.9
	Coho	130,717	143,378	364,941	299,244	56,400	99,745	157,365	166,721	+5.9
WATER YEAR - AVERAGE										
Spawning	Chinook	531,893	632,405	906,736	876,231	14,538	531,893	498,516	667,826	+34.0
	Steelhead	671,599	659,153	679,913	679,713	381,125	401,743	631,866	638,999	+1.1
	Coho	485,427	368,206	579,183	575,571	264,787	264,787	451,540	390,778	-13.5
	Chum	668,964	400,331	696,944	695,539	310,055	310,055	617,696	455,557	-26.2
	Pink	81,977	430,810	488,285	470,242	33,253	39,383	163,724	364,797	+122.8
Juvenile	Chinook	446,382	570,276	608,582	612,939	26,224	392,502	387,741	541,098	+39.6
	Steelhead	596,188	577,647	643,870	647,054	15,842	420,541	455,799	555,541	+21.9
	Coho	131,203	208,904	405,340	303,696	34,388	99,745	147,561	197,885	+34.1
WATER YEAR - DRY										
Spawning	Chinook	533,391	861,225	905,844	907,804	19,116	826,630	503,204	864,682	+71.8
	Steelhead	629,514	647,540	679,510	679,369	381,125	395,215	608,028	619,042	+1.8
	Coho	518,185	547,229	579,771	566,034	151,569	330,448	499,266	539,702	+8.1
	Chum	633,065	677,008	696,935	696,775	194,058	411,664	597,175	669,053	+12.0
	Pink	367,239	376,895	487,619	395,516	39,383	196,841	298,497	339,342	+13.7
Juvenile	Chinook	515,141	589,876	611,924	610,948	77,901	398,167	470,455	568,892	+20.9
	Steelhead	576,873	592,362	643,766	646,436	44,693	515,500	479,149	588,152	+22.7
	Coho	177,907	211,841	411,122	264,763	97,481	103,559	203,884	205,247	+0.7

Table 4-12. Comparison of median, maximum, minimum, average and percentage difference in resident trout habitat areas provided during Wet, Average, and Dry water year types for Stage 1 and Stage 2 conditions as determined from habitat duration analysis for operational Reach 1 of the Sultan River, Washington.

Life Stage	Species	Median (50% exceedance) Habitat Area (ft^2)		Maximum Habitat Area (ft^2)		Minimum Habitat Area (ft^2)		Average Habitat Area (ft^2)		
		Stage 1	Stage 2	Stage 1	Stage 2	Stage 1	Stage 2	Stage 1	Stage 2	% Difference
WATER YEAR - WET										
Spawning	Rainbow	323,146	306,306	359,871	358,908	97,908	114,696	313,940	292,244	-6.9
	Cutthroat	76,730	105,713	221,881	162,979	16,892	8,718	86,324	99,049	+14.7
Juvenile	Rainbow	438,038	448,302	481,375	481,901	33,224	383,067	369,319	434,846	+17.7
	Cutthroat	346,083	357,108	426,976	428,187	33,663	314,374	306,558	360,146	+17.5
WATER YEAR - AVERAGE										
Spawning	Rainbow	343,306	311,698	359,568	353,163	93,466	105,927	306,203	299,329	-2.2
	Cutthroat	52,595	116,905	216,848	177,584	8,066	8,376	65,587	113,157	+72.5
Juvenile	Rainbow	442,100	454,322	481,593	482,276	20,335	383,067	344,166	444,762	+29.2
	Cutthroat	346,418	391,188	426,358	428,462	20,688	314,401	280,373	378,052	+34.8
WATER YEAR - DRY										
Spawning	Rainbow	314,402	298,754	358,060	359,790	97,908	103,389	303,152	290,776	-4.1
	Cutthroat	86,088	88,127	222,527	141,464	8,066	8,279	91,404	93,252	+2.0
Juvenile	Rainbow	449,149	474,955	481,989	482,779	57,272	390,201	391,749	469,860	+19.9
	Cutthroat	358,583	391,530	428,742	428,163	57,862	317,376	335,023	389,571	+16.3

Table 4-13. Comparison of average anadromous salmonid habitat areas provided during Wet, Average, and Dry water year types for Stage 1 and Stage 2 conditions as determined from habitat duration analysis for operational Reaches 1, 2, and 3, as well as the total of all three reaches of the Sultan River, Washington.

Life Stage	Species	**Reach 1** Average Habitat Area (ft^2)		**Reach 2** Average Habitat Area (ft^2)		**Reach 3** Average Habitat Area (ft^2)		**All Reaches** Average Habitat Area (ft^2)		
		Stage 1	Stage 2	Stage 1	Stage 2	Stage 1	Stage 2	Stage 1	Stage 2	% Difference
WATER YEAR - WET										
Spawning	Chinook	530,798	714,643	230,599	484,656	132,426	79,748	893,823	1,279,047	+43.1
	Steelhead	608,021	619,160	308,092	429,940	132,896	54,311	1,049,009	1,103,411	+5.2
	Coho	412,387	318,511	221,932	350,632	106,831	123,045	741,150	792,188	+6.9
	Chum	489,336	346,238	225,054	362,809	184,499	216,336	898,889	925,383	+2.9
	Pink	134,737	284,250	53,240	251,812	201,087	231,324	389,064	767,386	+97.2
Juvenile	Chinook	448,141	508,229	442,199	563,421	191,797	114,208	1,082,137	1,185,858	+9.6
	Steelhead	484,801	576,371	482,868	507,806	242,540	99,220	1,210,209	1,183,397	-2.2
	Coho	157,365	166,721	191,805	274,761	113,828	206,452	462,998	647,934	+39.9
WATER YEAR - AVERAGE										
Spawning	Chinook	498,516	667,826	267,084	454,269	182,840	82,748	948,440	1,204,843	+27.0
	Steelhead	631,866	638,999	296,384	440,374	106,464	56,890	1,034,714	1,136,263	+9.8
	Coho	451,540	390,778	227,882	414,805	82,158	113,311	761,580	918,894	+20.7
	Chum	617,696	455,557	302,074	445,811	156,850	197,077	1,076,620	1,098,445	+2.0
	Pink	163,724	364,797	78,331	251,056	201,645	213,261	443,700	829,114	+86.9
Juvenile	Chinook	387,741	541,098	385,872	560,392	183,808	109,782	957,421	1,211,272	+26.5
	Steelhead	455,799	555,541	454,255	474,767	237,407	87,705	1,147,461	1,118,013	-2.6
	Coho	147,561	197,885	177,988	292,621	119,967	212,478	445,516	702,984	+57.8
WATER YEAR - DRY										
Spawning	Chinook	503,204	864,682	360,923	456,213	324,994	57,104	1,189,121	1,377,999	+15.9
	Steelhead	608,028	619,042	272,834	436,833	101,134	60,076	981,996	1,115,951	+13.6
	Coho	499,266	539,702	320,016	433,348	138,092	87,050	957,374	1,060,100	+10.7
	Chum	597,175	669,053	361,047	447,331	263,367	159,906	1,221,589	1,276,290	+4.5
	Pink	298,497	339,342	152,862	263,668	146,922	217,372	598,281	820,382	+37.1
Juvenile	Chinook	470,455	568,892	462,904	562,727	209,337	90,781	1,142,696	1,222,400	+7.0
	Steelhead	479,149	588,152	489,163	465,665	259,480	74,072	1,227,792	1,127,889	-8.1
	Coho	203,884	205,247	226,253	297,117	111,454	222,037	541,591	724,401	+33.8

relationships (based on PHABSIM analysis) within the channels for selected target fish species and life stages.

Survey results indicate that the upstream ends of the three side channels would become disconnected from the Sultan River at flows < 200 cfs for Side Channel 3, <300 cfs for Side Channel 2, and < ≈ 375 cfs for Side Channel 1 (Figure 4-29). Based on water depths measured at each of the side channel inlets and corresponding mainstem flow measurements made during each of the field surveys, the relationships of inlet flow depth as a function of mainstem flow were developed (Figure 4-29). Mainstem flows as low as 200 cfs would still provide water depths of about 0.5 ft at the inlet of Side Channel 3, although no flow would be entering side channels 2 or 1. Flow into Side Channel 2 just begins to occur at a mainstem flow of about 300 cfs which provides an inlet depth of 0.1 ft. For Side Channel 1, flow just begins to occur at a mainstem flow of 400 cfs which provides an inlet depth of 0.1 ft. Mainstem flow increases between 400 and 500 cfs result in gradual increases in inlet water depths. A threshold is apparently reached in Side Channel 1 as mainstem flows reach and exceed 500 cfs resulting in a sharp increase in inlet depths to 0.6 ft.

Similar increases in surface area occur within Side Channels 1 and 2 ranging from about 25,000 ft^2 at mainstem flows of around 400 cfs to about 40-50,000 ft^2 at flows greater than 1000 cfs (Figure 4-30). Surface areas within Side Channel 3 are more than two-fold higher over this range of flows than found in Side Channels 1 and 2. This is likely due to the greater size and location of Side Channel 3 that results in a greater proportion of mainstem flow entering the channel, than would occur in either Side Channel 2 or 1 (Figure 4-31). On a cumulative basis, flows of about 550 cfs would provide over 225,000 ft^2 of surface area, which represents about 90% of the overall total (250,000 ft^2).

Habitat-flow relationships based on PHABSIM modeling indicate that the side channels provide greater amounts of pink and chum spawning habitat than other target species (Figure 4-32 and 4-33). Of the three channels, Side Channel 2 provides the overall greatest amount of pink and chum spawning habitats. In that system, pink spawning habitat would be maximized at flows of about 25 cfs (10,000 ft^2/1000 ft), while chum spawning habitat is maximized at the highest flow modeled, 45 cfs (≈ 10,000 ft^2/1000 ft). Pink and chum spawning habitats in Side Channel 2 would be maximized at flows of about 90 cfs (≈ 7,500 ft^2/1000 ft) and 225 cfs (≈ 9,000 ft^2/1000 ft), respectively, and at flows of 7 cfs (≈ 3000 ft^2/1000 ft) and 24 cfs (≈ 3,500 ft^2/1000 ft) for Side Channel 1. Spawning habitat:flow relationships for Chinook, coho and steelhead for all three side channels generally reflect increasing amounts of spawning habitat over the range of flows modeled. One exception to this relates to coho spawning in Side Channel 1 which is maximized at flows of about 20 cfs and then begins to gradually decline.

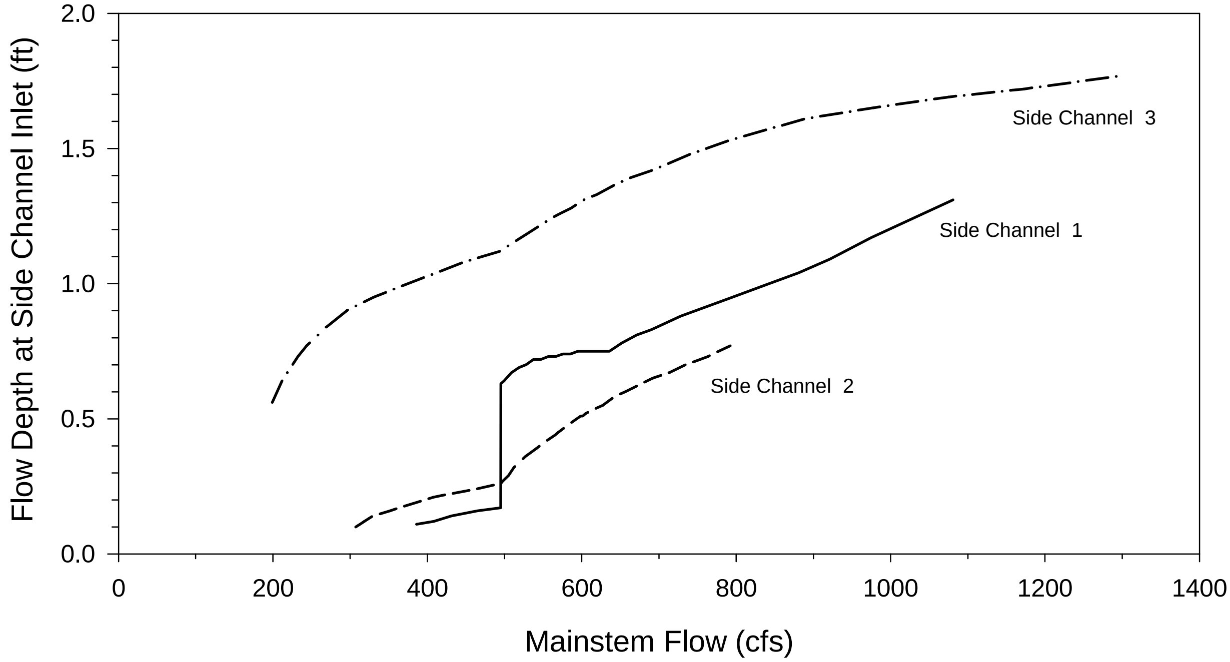


Figure 4-29. Relationship of flow depth within side channel inlets to flow within the mainstem Sultan River, Washington for Side Channels 1, 2, and 3. Side Channel 3 is the uppermost and 1 the lowermost of the channels.

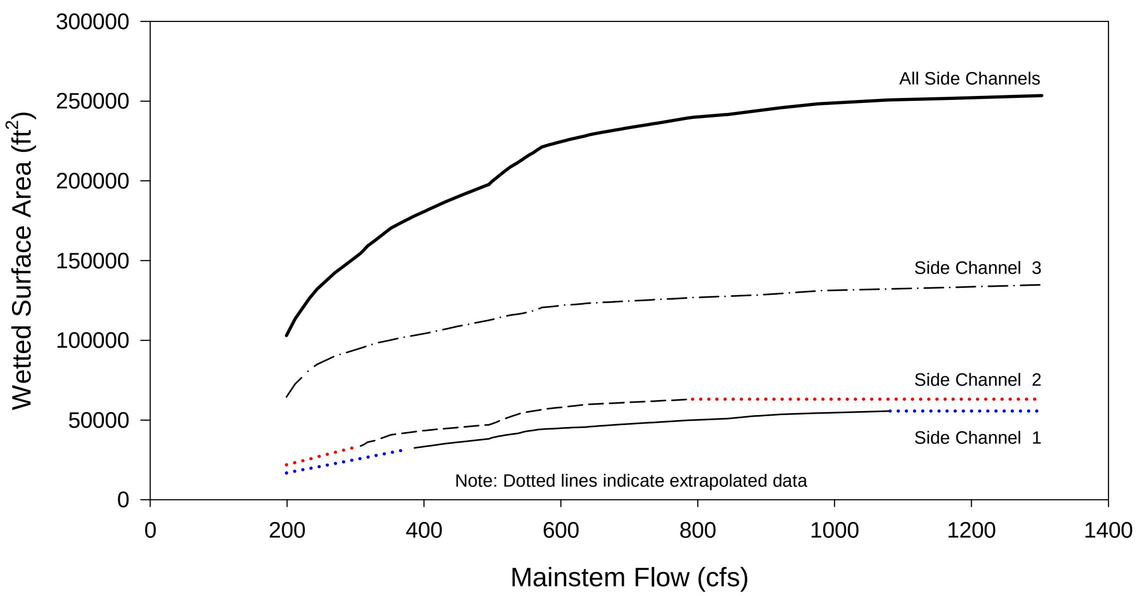


Figure 4-30. Relationship of wetted surface area (ft^2) within Side Channels 1, 2, and 3 in Reach 1 and flow within the mainstem Sultan, River, Washington.

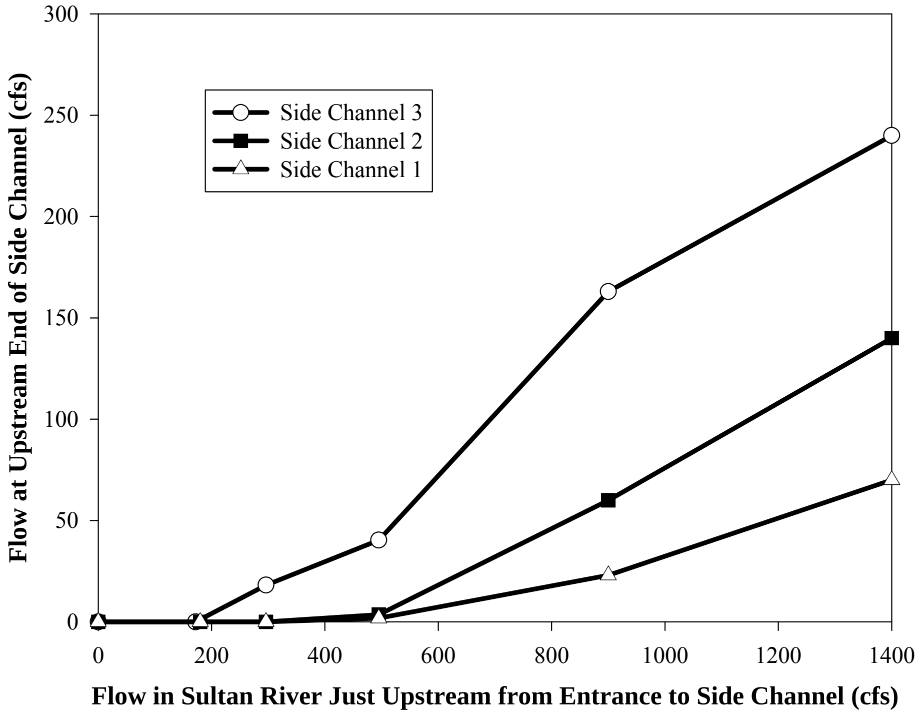


Figure 4-31. Flows occurring at the upstream end of Side Channels 1, 2, and 3 in Operational Reach 1 of the Sultan River, and corresponding flows in the Sultan River just upstream from the entrance to each side channel.

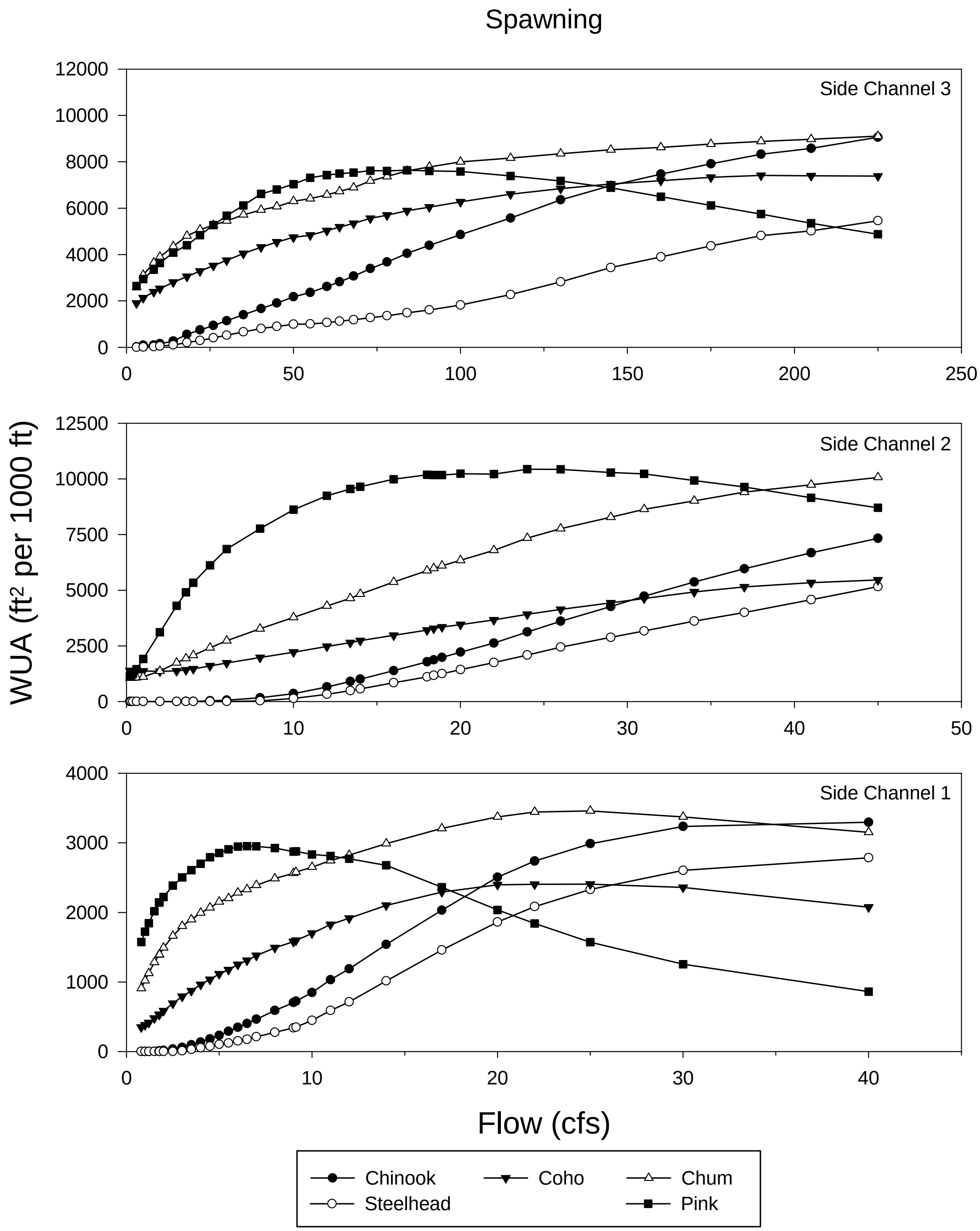


Figure 4-32. Weighted Useable Area (WUA) (ft^2/1000 ft) versus flow (cfs) relationships for Chinook, coho, pink, and chum salmon and steelhead trout spawning habitat as defined in Side Channels 1, 2, and 3 in Operational Reach 1 of the Sultan River, Washington.

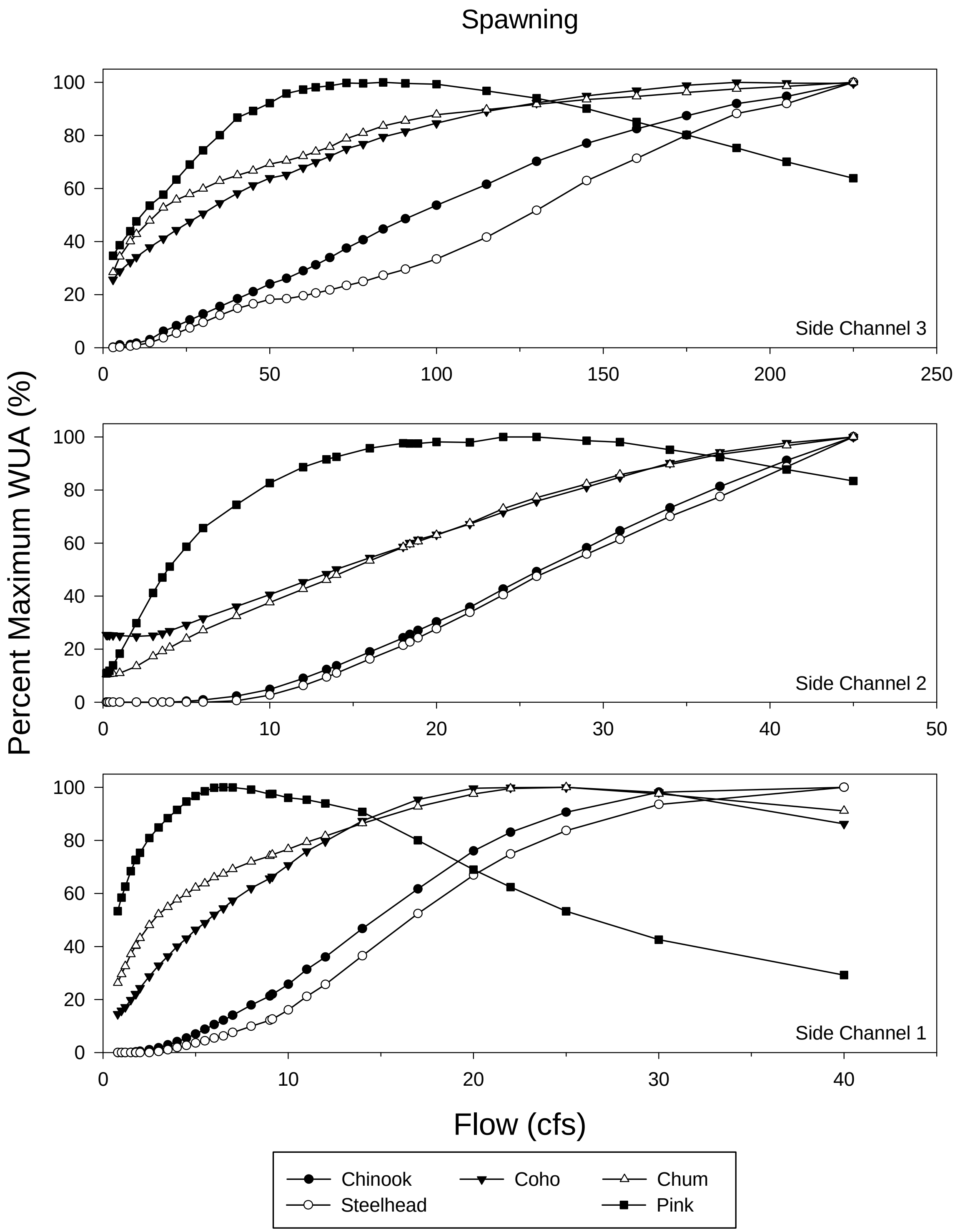


Figure 4-33. Percentage of maximum Weighted Useable Area (WUA) versus flow (cfs) relationships for Chinook, coho, pink and chum salmon and steelhead trout spawning habitat a as defined in Side Channels 1, 2, and 3 in Operational Reach 1 of the Sultan River, Washington.

Habitat-flow relationships indicate that the greatest amounts of juvenile rearing habitat occur in Side Channel 3 (Figures 4-34 and 4-35); habitat maxima for all species are ≥ 9,000 ft^2/1000 ft. For comparison, the greatest amount of juvenile habitat in the other two side channels is for coho in Side Channel 2 (≈ 3200 ft^2/1000 ft). In all three channels, coho juvenile habitats peak at relatively low flows compared to other species; ≈10 cfs in Side Channel 3, and about 3-4 cfs for Side Channels 2 and 1. With the exception of coho, juvenile rearing habitat for all other species is maximized at the highest modeled flow (45 cfs). Flows maximizing Chinook, rainbow and cutthroat juvenile habitat in Side Channel 3 occur at about 75 cfs; Chinook juvenile habitats are maximized at a flow of about 20 cfs in Side Channel 1.

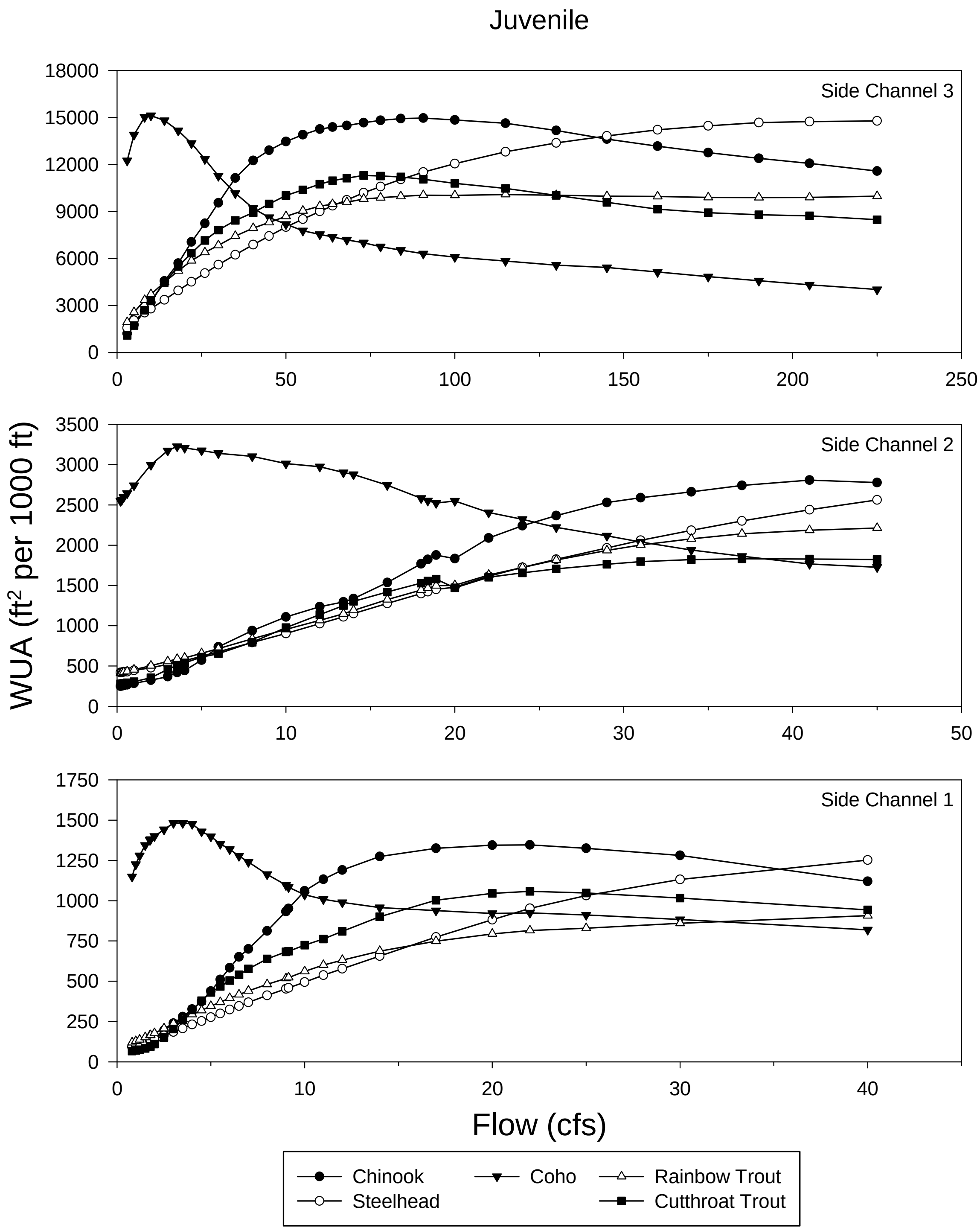


Figure 4-34. Weighted Useable Area (WUA) (ft^2/1000 ft) versus flow (cfs) relationships for Chinook and coho salmon and steelhead, rainbow and cutthroat trout juvenile rearing habitat as defined in Side Channels 1, 2, and 3 in Operational Reach 1 of the Sultan River, Washington.

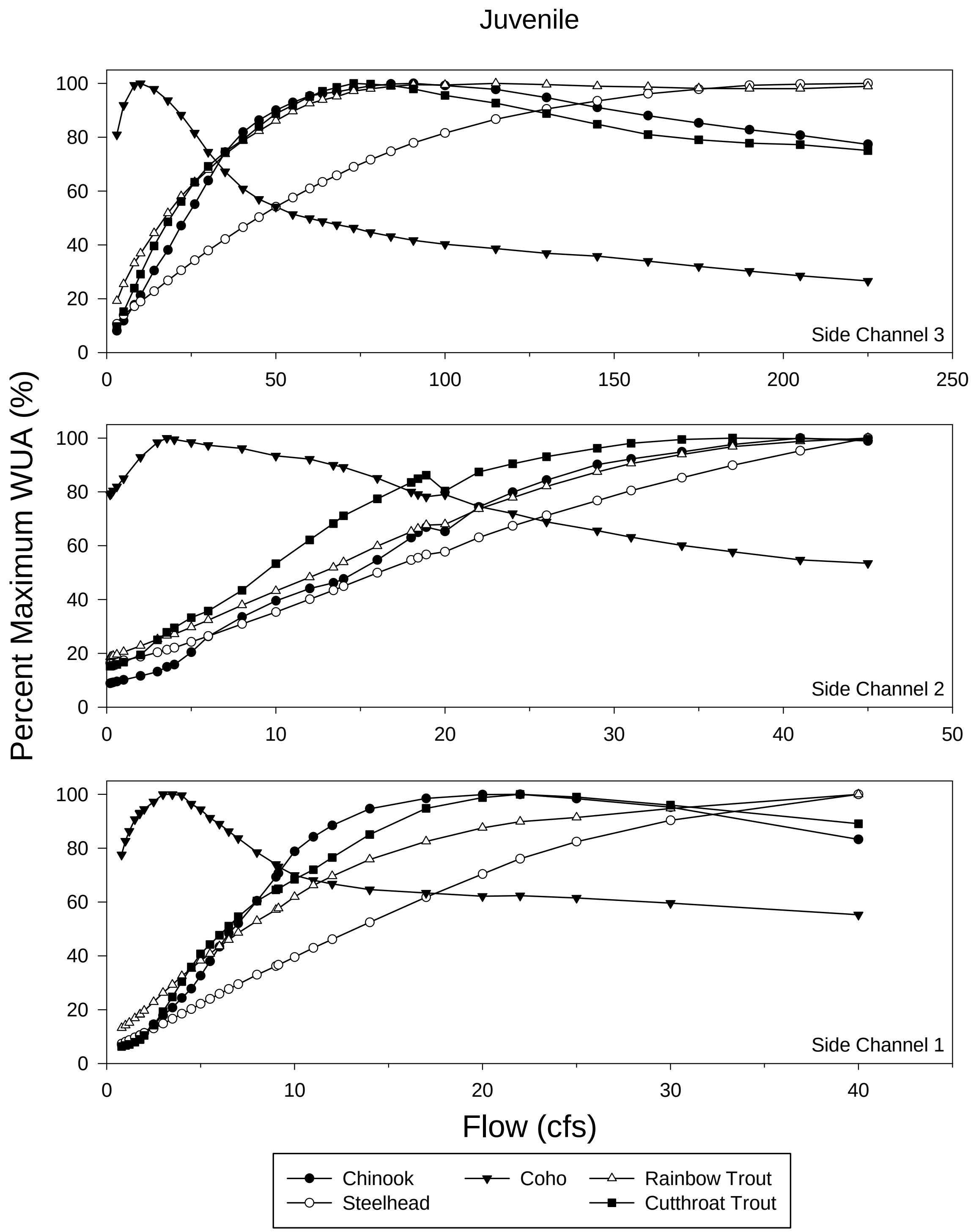


Figure 4-35. Percentage of maximum Weighted Useable Area (WUA) versus flow (cfs) relationships for Chinook and coho salmon and steelhead, rainbow, and cutthroat trout spawning habitat a as defined in Side Channels 1, 2, and 3 in Operational Reach 1 of the Sultan River, Washington.

5. SUMMARY

The Sultan River Instream Flow Study (RSP3) was conducted to assist the District and agency/stakeholders in balancing the flow needs of the Henry M. Jackson Hydroelectric Project with the flow needs to support and sustain fish populations within the Sultan River. The study focused on and provided information useful for addressing the following questions as originally posed in Section 1:

- What are the species and life stage specific habitat – flow relationships in each of the three mainstem reaches?
- How much habitat of a given fish species and life stage is available in each of the three mainstem reaches under existing Project operations and existing instream flow requirements?
- How much habitat of a given fish species and life stage would be available in each reach of the three mainstem reaches under Stage 1 conditions?
- What are the incremental gains or losses of habitat for a given fish species and life stage corresponding to incremental flow increases in each reach above those provided under existing operations?
- How much anadromous salmonid habitat would be available in Reach 3 under varying flow conditions if fish passage facilities were provided?
- What mainstem flows in Reach 1 provide connectivity to adjoining side channel areas?
- What are the species and life stage specific habitat – flow relationships in side channel areas associated with Reach 1?

The study resulted in the development of a series of habitat-flow relationships for each operational reach of the mainstem Sultan River, as well as for three side channels in the lower reach (Reach 1). Such relationships can serve as indices of how changes in flow may influence the quantity of habitats of various target fish species and life stages. Relative to flow connectivity in the side channels, the study also defined the relationship of mainstem flow to side channel flow and determined the amount of surface areas available in each. In addition, time series and habitat duration analysis were completed that estimated the amounts of habitat for a given species and life stage that would occur under both Stage 1 and Stage 2 conditions for three different water year types.

The information provided from this study should be useful for evaluating tradeoffs relative to gains in habitat versus changes in flow both on a reach scale basis as well as for the overall system. It should be noted however, that given the varying shapes in the habitat: flow relationships, it is likely that flows beneficial (defined as increasing habitat) to one or more species and life stage may be detrimental (reduce habitat) to other species. Thus, formulation of flow regimes for each of the three operational reaches of the Sultan River can be complex and will likely need to revolve around balancing reach - specific resource objectives (which may involve more than just fish) with operational constraints that include, in addition to hydropower generation and water supply, flood control and lake recreation. In combination with information provided in a number of other studies listed in Section 1, the results can also be used for identifying and evaluating potential protection, mitigation and enhancement measures.

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APPENDIX A

Transect Selection Presentation
June 12, 2008

APPENDIX B

Target Flow Memorandum
June 11, 2007

APPENDIX C

Habitat Suitability Criteria (HSC)

APPENDIX C1

**Proposed Habitat Suitability Criteria (HSC) Curves
for Application in Habitat-Flow Modeling for the
Sultan River Instream Flow Study – RSP 3, June 5, 2008**

APPENDIX C2

Technical Memorandum: Sultan River Instream Flow Study – HSC Preference Analysis and Revised Steelhead and Chinook Curves, July 31, 2008

APPENDIX C3

HSC Curves Used in Habitat-flow Modeling

APPENDIX D

Habitat:Flow Relationships and Time Series Analysis

APPENDIX D1

Weighted Useable Area (ft^2/1000 ft) Versus Flow (cfs) Relationships for Target Fish Species for Upper and Lower Study Sites within Three Operational Reaches of the Sultan River, Washington

APPENDIX D2

Time Series Analysis for Reach 3 – Sultan River

APPENDIX D3

Time Series Analysis for Reach 2 – Sultan River

APPENDIX D4

Time Series Analysis for Reach 1 – Sultan River

APPENDIX D5

Weighted Usable Area (ft^2/1000 ft) Versus Flow (cfs) Relationships for the Three Side Channels within Reach 1 of the Sultan River, Washington

APPENDIX E

Transect Photographs

APPENDIX F

Transect Cross Sectional Profiles and Model Calibration Details

APPENDIX G

Field Notes