Final

Tailrace Slough Instream Flow Study Report *for* Energy Northwest's Packwood Lake Hydroelectric Project FERC No. 2244 Lewis County, Washington

Submitted to

P.O. Box 968
Richland, Washington 99352-0968

Submitted by

1155 North State Street, Suite 700
Bellingham, Washington 98225
360.734.5915 phone, 360.734.5918 fax

September 2007

Table of Contents

6.0 LIST OF APPENDICES

List of Tables

List of Figures

1.0 INTRODUCTION

Energy Northwest operates the Packwood Lake Hydroelectric Project (Project) near the town of Packwood in Lewis County, Washington. On November 12, 2004 Energy Northwest filed a Notice of Intent (NOI) to file an application for a new license to operate the hydroelectric project. Energy Northwest also concurrently filed with the Federal Energy Regulatory Commission (FERC) and the resource agencies, a Pre-Application Document (PAD), containing existing, relevant, and reasonably available information describing the existing environment and the potential effects of Project facilities and operations.

Energy Northwest's Packwood Lake Hydroelectric Project, FERC No. 2244, received its initial license in 1960. The majority of the Project is located in the Gifford Pinchot National Forest, east of the town of Packwood (Figure 1.0-1). The Project consists of an intake canal, a concrete drop structure (dam) and intake building on Lake Creek located about 424 feet downstream from the outlet of Packwood Lake, a 21,691-foot system of concrete pipe and tunnels, a 5,621-foot penstock, a surge tank, powerhouse with a 26,125 kW turbine generator, 6,690-foot lined tailrace channel, and 8,009-foot 69 kV transmission line.

The source of water for the Project, Packwood Lake, is situated at an elevation of approximately 2,857 feet above mean sea level (MSL), about 1,800 feet above the powerhouse. Water discharged from the Project is released to the Cowlitz River via a tailrace channel. Power from the Project is delivered over an 8,009-foot 69 kV transmission line to the Packwood substation. Water used for Project generation is returned to the Cowlitz River via a 6,690-foot tailrace channel; water empties out of the tailrace into the tailrace slough, which ultimately empties into the Cowlitz River. Anadromous salmonids are known to spawn in the tailrace slough where it adjoins the Cowlitz River; spawner surveys were started in this area in 2004 (EES Consulting 2007).

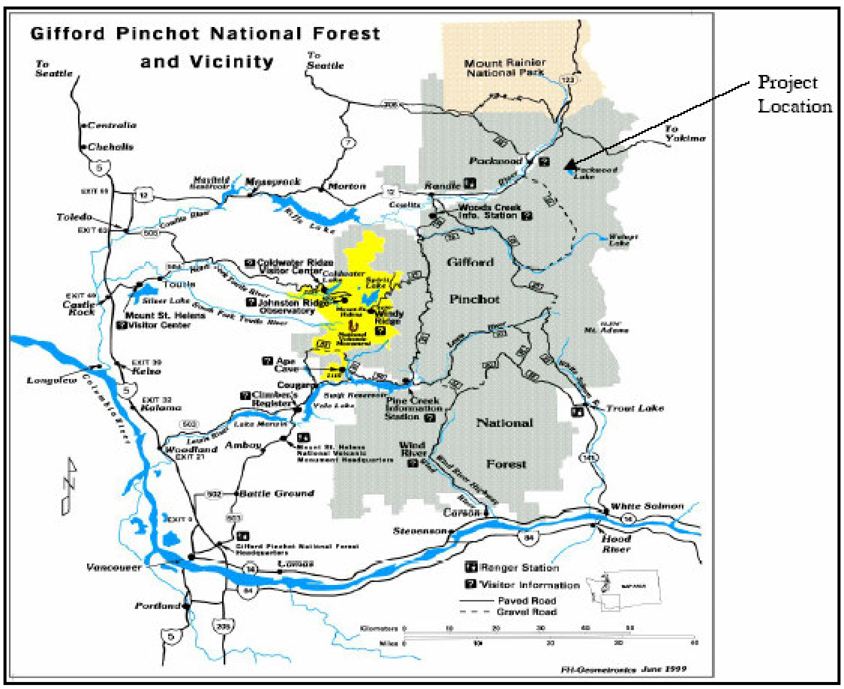
During a 1977 high flow event, the main Cowlitz River channel migrated rapidly toward the airstrip and across the end of the tailrace. During this high flow, the lower approximately 1400 feet of the lined tailrace was eroded and removed by the river. This flow event created the tailrace slough. During some years (e.g., 2005) flood flows in the Cowlitz configure the tailrace slough so that it derives most of its flow from the Cowlitz River. In contrast, during 2004 and 2006, the slough was dependent upon Project flows to keep spawning habitat inundated during the low flow period of the year (typically August through October).

During scheduled Project shutdowns in October, generation ceases and water from the Project is not added to the tailrace slough. During years when the tailrace slough is dependent upon the Project for most of its water, there is a potential for impacts to anadromous salmonids and resident fish. Due to the unpredictability of the Cowlitz River, however, it is not possible to predict when the tailrace slough will receive adequate flow via the Cowlitz River, or will be reliant on project tailrace flows to sustain spawning habitat. Another mitigating factor is that unanticipated forced outages can reduce tailrace flows which may result in decreased flows through the slough area.

NOAA Fisheries requested this study and provided their resource management goals and objectives (NOAA Fisheries 2005). Energy Northwest, in consultation with tribes and natural resource agencies, developed and implemented the study to evaluate the potential effects of Project operations on the tailrace slough (EES Consulting 2005). This report provides results of the requested study.

The Cowlitz River experienced a significant high flow event in November 2006. Therefore, the results presented in this report reflect a snapshot of the condition present during the summer of 2006, when data were collected and the volatility of the Cowlitz River system. Conditions in the tailrace slough have changed twice in the period between when the study was conducted and at the time of this draft report (May 2007). Results should be viewed as representative of evaluating potential conditions within the tailrace slough, and used as a guideline for resolving issues, realizing that these conditions will continue to change over time.

Figure 1.0-1.
Energy Northwest's Packwood Lake Hydroelectric Project



1.1 Study Area

The study area encompasses the tailrace slough immediately downstream of the Project tailrace to its confluence with the Cowlitz River. The configuration of this side channel is often changed by high flow events in the Cowlitz River. The study area includes the channel configuration at the time of the field data collection. The configuration of the side channel is shown in Figure 1.1-1. Anadromous spawner surveys conducted for Energy Northwest from 2004 – 2006 (EES Consulting 2007a) indicated that fish utilized the left channel of the tailrace slough for spawning (Figure 1.1-2).

Figure 1.1-1.
Packwood Hydroelectric Project Tailrace, Tailrace Slough, and Mainstem Cowlitz River

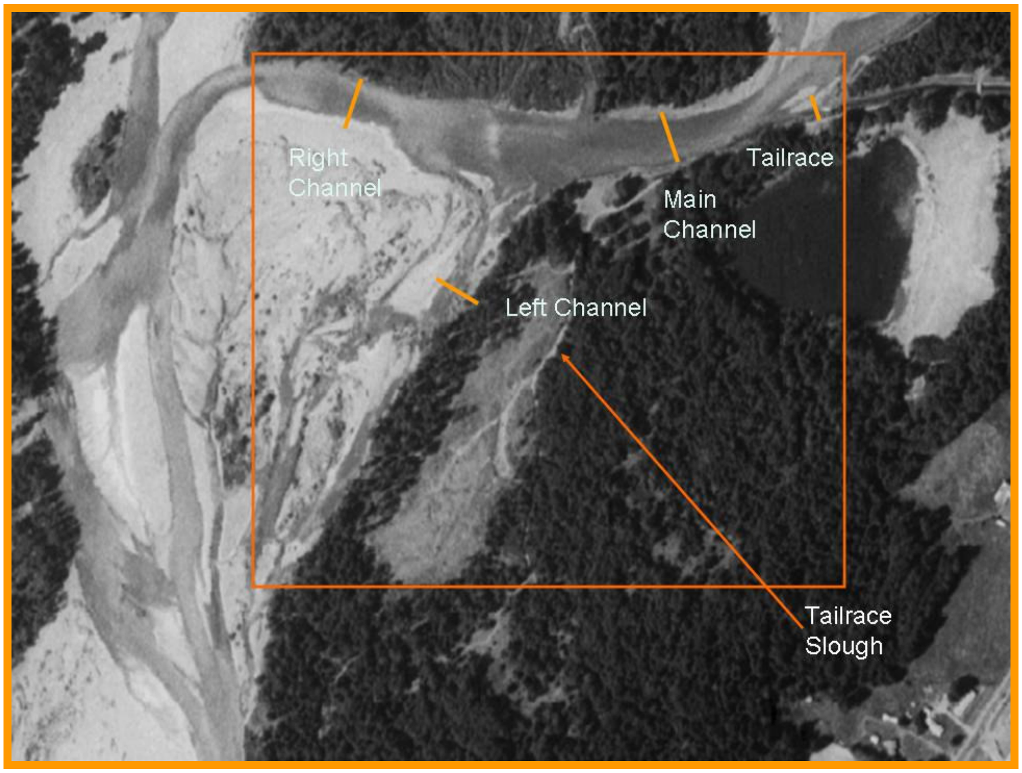
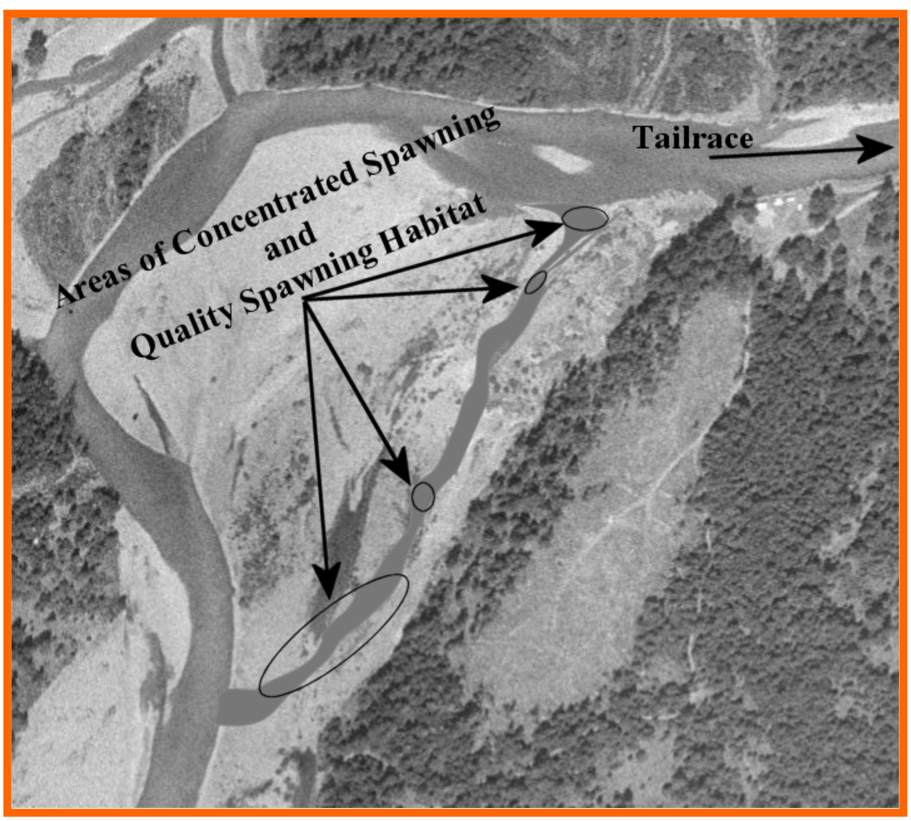


Figure 1.1-2.
Spawning Locations of Anadromous Fish in the Tailrace Slough.



1.2 Principal Investigators

John Blum, EES Consulting, Inc. Fisheries Biologist and Instream Flow Scientist (Project Manager)

John Blum has a Master of Science in Fisheries, a Bachelor of Science in Environmental Biology and a Bachelor of Science in Business, specializing in Business Management. Mr. Blum has over 25 years experience as a fisheries biologist and consultant in instream flow analysis, habitat assessment, Endangered Species Act studies, fisheries research, enhancement, management, water resources and endangered species assessment, FERC regulatory licensing and relicensing studies, and expert witness testimony. In his role as a senior fisheries biologist and consultant, Mr. Blum has successfully managed over 50 fisheries and aquatic resources impact assessments in the Pacific and Inland Northwest, including many on the mid Columbia River.

Mr. Blum has conducted numerous fisheries and instream flow studies throughout the Pacific Northwest, including the Columbia River System in Washington, Oregon, Idaho and Montana. He is extensively trained and certified in the Instream Flow Incremental Methodology (IFIM) and has been recently certified in 2-dimensional instream flow modeling. He is Principal Scientist for the Box Canyon Dam Relicensing, and was principal scientist for the Box Canyon License Amendment and Sullivan Creek License Amendment for Pend Oreille Public Utility District in Pend Oreille County, WA. He was also Project Manager for relicensing studies for Chelan County Public Utility District on the Lake Chelan and Rocky Reach Hydroelectric Projects. He has been principal investigator on fisheries inventory and instream flow studies throughout the Northwest, including in British Columbia and Alaska, and has co-authored the Historic and Current Resources of the Clark Fork River, and for fisheries investigations on the Bear River relicensing projects for PacifiCorp. He recently completed, as Aquatic Lead and Principal Scientist, fisheries investigations for PG&E's Haas Kings Hydroelectric Project in California. He is also currently working with PGE on its Clackamas River Relicensing Project, and was Principal Scientist for the aquatics portion of the Cedar Creek relicensing and Biological Assessment.

Mr. Blum is currently Project Manager and Principal Scientist for the Packwood Lake Hydroelectric Project, and is Principal Scientist for the Anyox and Kitsault rivers hydroelectric projects in British Columbia.

Cory Warnock, EES Consulting, Inc. Fisheries Biologist and Instream Flow Scientist (Assistant Project Manager)

Mr. Warnock has more than six years of experience as a fisheries biologist, leading and participating in numerous fisheries studies including fish population monitoring, instream flow analysis, habitat analysis and assessment, genetic sampling, entrainment studies and habitat restoration. His duties have included project implementation, logistical and technical planning, field investigations and report writing. He has managed projects and lead crews in all aspects of various fisheries studies and instream flow investigations. Clients have ranged from owners of hydroelectric facilities and timber companies to state and federal agencies.

He is adept in many aspects of field collection and analysis as related to various types of fisheries monitoring, sampling, IFIM and habitat restoration. Mr. Warnock is currently involved with the relicensing efforts by EES Consulting at Box Canyon Dam for Pend Oreille PUD and the Packwood Lake Hydroelectric Project for Energy Northwest. Both projects require extensive monitoring of the anadromous and resident species present as well as determining the quality of their habitat. Other work has included habitat mapping, fish passage and connectivity issues, anadromous barrier analysis, spawning surveys, juvenile and adult snorkeling work, genetic sampling and entrainment studies for various salmonid species at all life stages. He has played an integral role in many IFIM studies from analyzing various reaches for quality habitat and identifying potential transects to carrying out flow measurements, substrate analysis and surveying. He has participated and lead all facets of these studies from the logistics and preparation phases to the data analysis, report writing and submittal.

Pete Rittmueller, EES Consulting, Inc. Senior Instream Flow Scientist, Hydrologist

Pete Rittmueller received a Bachelor of Science Degree in Natural Resources from Southern Illinois University and a Master of Science Degree in Biology from Western Washington University. Mr. Rittmueller has 26 years experience assessing fisheries issues in Washington and throughout the Northwest. His management experience has focused on projects requiring the involvement of a wide array of natural resource specialists. Mr. Rittmueller managed the Tilton River IFIM study and negotiated a minimum flow requirement that provides adequate year-round water for the operation of a private salmon hatchery. He has also managed the Cultus Mountain instream flow study of four tributaries to the Skagit River and the Lower Skagit IFIM and Water Rights Study for the City of Anacortes and Skagit County PUD.

The Lower Skagit River Instream Flow Study resulted in the first successful instream flow rule making by the Washington Dept. of Ecology in over 13 years. From 2004 to 2006 Pete was the Project manager for a 44 transect IFIM study on the Lower Wenatchee River. Based primarily on the results of this instream flow study, all stakeholders agreed to new Wenatchee River instream flow levels in April 2006.

Nic Truscott, EES Consulting Inc. Field Biologist

Mr. Truscott has two years of experience as a field biologist for EES Consulting. He has participated in field aspects of instream flow studies on many drainages including the Spokane and Skagit River systems. Mr. Truscott has played an integral role in many of the fisheries and water quality investigations for Energy Northwest's relicensing efforts. Studies have included anadromous and resident salmonid spawning surveys, fish population assessments, habitat and barrier analysis and lake and stream water quality investigations. He has participated in a variety of studies in Washington and Oregon dealing with fisheries and water quality issues as they pertain to anadromous and resident salmonids. Currently, Mr. Truscott is working on a 5 year analysis of spawning Chinook salmon population in the Methow and Okanogan river basins.

Brian Johnson, EES Consulting, Inc. Field Biologist

Mr. Brian Johnson has a strong background in spawner surveys, snorkel and SCUBA surveys, radio-telemetry, instream flow assessment, habitat surveys, adult passage and water quality assessment.

Mr. Johnson has been the field lead for spawner surveys for Energy Northwest's Packwood Lake Hydroelectric Project re-licensing. He managed and conducted the field logistics of survey crews covering the Cowlitz River and Hall, Snyder, and Lake creeks. He is skilled at species and redd identification, and biological sample collection.

Mr. Johnson has extensive fisheries field experience in north-central Washington. He took part in aquatic habitat, plants, creel, recreation, sturgeon, mollusks, salmon spawning and snorkel surveys related to operations of the Rocky Reach Dam. He conducted salmonid snorkel surveys, creel surveys, spawner surveys and redd mapping in the Stehekin River, the major tributary to Lake Chelan. He served as part of the field crew conducting instream flow and habitat suitability analyses in the Wenatchee River watershed. His experience included collection of physical habitat and hydrologic information, habitat surveys, and habitat suitability data. The work took place in the mainstem Wenatchee River, Peshastin Creek, and the Chiwawa River and tributaries including Phelps and Rock Creek.

2.0 STUDY GOALS AND OBJECTIVES

The goals of this study are to:

1) Conduct an Instream Flow Incremental Methodology (IFIM) study of the tailrace slough, integrating the information gained from spawning surveys, habitat use surveys, and the physical habitat survey to estimate the effects of Project operations on fish and redds within the tailrace slough, and
2) Develop alternative operation scenarios to minimize negative effects on fish and redds in the tailrace slough.

3.0 METHODS

An instream flow study was conducted using the IFIM according to the guidelines as established in the Washington Department of Fish and Wildlife/Washington Department of Ecology (WDFW/WDOE) Instream Flow Guidelines Update (2004). An example of the protocol is found in the Draft Study Plan, Lake Creek Instream Flow Study and Habitat Assessment (EES Consulting 2004). The study employed habitat suitability criteria approved by the State of Washington and used habitat mapping and transect weighting in accordance with habitat distribution.

The results of the tailrace spawning surveys, habitat use and presence surveys and the Tailrace Slough IFIM study were examined. Records of Project operations were also reviewed and analyzed to determine potential impacts on spawning salmonids in this area.

3.1 Overview of the Instream Flow Incremental Methodology

Unless otherwise noted, IFIM study procedures follow the WDFW/WDOE Instream Flow Guidelines (April, 2004). The IFIM methodology is based on the premise that stream-dwelling fish are more often found in a certain range of depths, velocities, substrates, and cover types, depending upon the species and life stage, and that the availability of these preferred habitat conditions varies with stream flow. IFIM is designed to quantify potential physical habitat available for each target fish species and life stage of interest, at various levels of stream discharge, using a series of modeling programs initially developed by the U.S. Fish and Wildlife Service. Major components of the methodology include: (1) study site and transect selection; (2) transect weighting; (3) field collection of hydraulic data; (4) hydraulic simulation to determine the spatial distribution of combinations of depths and velocities with respect to substrate and cover under a variety of discharges; and (5) habitat simulation, using habitat suitability criteria, to generate an index of change in habitat relative to change in discharge. The product of the habitat simulation is expressed as Weighted Usable Area (WUA) for a range of simulated stream discharges.

It is important to recognize that the product of an IFIM analysis is not a set value but a range of values to be used as a tool for discussing and determining a range of stream flows that will meet the needs of all affected resources.

Note: *after development of the study plan, it was determined that the study would focus on maintaining sufficient water over potential redds to prevent dewatering of incubating eggs. As a result, the following information was collected during field investigations:*

- Water Surface Elevations (WSE) at three widely separated calibration flows
- Discharge measurements at the three calibration flows
- Discharge measurements in the tailrace slough, noting the relationship between the Cowlitz River, the tailrace slough, power production flows, and the split between the left and right channels.
- Substrates present along each transect

3.2 Measurements of Flow in Tailrace Slough

EES Consulting took measurements of the discharge in the tailrace slough during the late winter and early spring 2006, for the purpose of determining the proportion of the Cowlitz River that was coursing through the tailrace slough. The following data were recorded during each measurement:

- Instantaneous measurement of the Cowlitz River at Packwood
- Project flow
- Measurement of tailrace slough flow

With these three data points, EES Consulting could subtract the Project flows from the tailrace slough discharge, and determine the relationship between the Cowlitz River and tailrace slough.

3.3 Instream Flow Transect Selection

EES Consulting surveyed the tailrace slough from where it joins the tailrace downstream to its confluence with the Cowlitz River. The tailrace slough splits into two channels before emptying into the Cowlitz. Survey results indicated that the left channel (looking downstream) in the tailrace slough contained nearly all of the spawnable habitat available in the area for anadromous and resident salmonids. The balance of the spawnable habitat was found either immediately below the Project's lined tailrace before it joined the slough, or in the main channel of the slough before it split into right and left channels. The right channel consisted nearly exclusively of sand substrate, and for purposes of this study was only used to determine the relationship and distribution of flows in the left and right channels.

3.4 Transect Weighting

Transect weighting in the tailrace slough was based upon the length of habitat that was represented by each transect. Given the short length of this reach and the small number of habitat types that could be used for spawning, distances between transects were measured using a 200-ft surveyors tape and the distances apportioned to their respective transects. Transects were weighted empirically, using results of the measurements and professional judgment.

3.5 Field Methods

Field data was collected at the tailrace slough transects at a high, middle, and low flow for model calibration purposes and development of a stage/discharge relationship. Generally all field data were taken using the standard procedures described in Trihey and Wegner (1981) and Bovee (1982). Not all transects used the same benchmark. Head pin elevations, hydraulic slopes, stage of zero flow, water surface elevations (WSE) and above-water channel cross-sections were measured using a Topcon auto level and stadia rod, using standard survey techniques. The surveyor tied these features to the transect benchmark to the nearest 0.01 ft. Below water channel cross-sections were determined by subtracting measured depths from the WSE at the middle flow. Depths at high flow measurement locations that were not wetted at the middle flow measurement were subtracted from the high flow WSE.

Depth and velocity distributions at the three calibration flows were measured at some of the transects in order to determine the measured discharge. A digital, Swoffer brand, propeller-type velocity meter mounted on a standard top-set wading rod was used for discharge and velocity measurements. Velocity was measured at sixth tenths of the depth when depth was less than 2.5 feet and at two tenths and eight tenths of the depth where depths equaled or exceeded 2.5 feet, or when flow was influenced by an upstream obstruction. In addition to stationing, notes were taken regarding the position of the top-set rod base plate relative to the substrate it was touching so that the meter could be placed in the exact position at succeeding calibration flows. These notes on substrate also revealed if bed shift had occurred since the previous calibration measurement; comparison of bed elevations during discharge measurements also indicated whether substantial sediment had been added or removed. Temporary staff gage levels and the time of day were recorded at the beginning and end of each transect measurement to note changes in stage.

Substrate was classified using a three-digit code representing the most abundant particle size, the second-most abundant particle size, and the percentage of the most abundant particle size. For example, a code of 73.7 would mean that the most abundant substrate was large cobble (6 to 12-inch diameter), that small gravel (0.5 to 1.5-inch diameter) was the second-most abundant substrate, and that large cobble represented 70% of the cell area.

3.6 Affected Fish Species and Life Stages

Fisheries resources of primary concern in the tailrace slough are commercial and game fish that include Chinook (*Oncorhynchus tshawytscha*) and coho (*O. kisutch*) salmon, steelhead trout (*O. mykiss*), sea-run cutthroat trout (*O. clarki clarki*), and resident rainbow trout (*O. mykiss*). All of these species can utilize the study area during some part of their life cycle. Figure 3.6-1 presents the life-stage timing of salmonids for the tailrace slough (from the Lake Creek Instream Flow Study, EES Consulting 2007b).

Studies to determine the use of the tailrace slough by anadromous and resident fish are ongoing; the report on Tailrace Slough Use by Anadromous Salmonids is scheduled to be completed in June 2007.

Figure 3.6-1
Upper Cowlitz River Periodicity

Species	Lifestage	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug	Sept
Spring Chinook	Spawning												
	Incubation												
	Rearing												
Coho	Spawning												
	Incubation												
	Rearing												
Steelhead	Spawning												
	Incubation												
	Rearing												
Cutthroat Trout	Spawning												
	Incubation												
	Rearing												
Rainbow Trout	Spawning												
	Incubation												
	Rearing												

Based on:

John Serl, WDFW Fish Biologist, Cowlitz Falls

Key:

Black indicates periods of heaviest use

Grey indicates periods of moderate use

Blank areas indicate periods of little or no use

3.7 Habitat Suitability Indices

Salmonid species are not found randomly in streams and rivers, but rather have an affinity for particular ranges of depth, velocity, cover and substrate. Occurrence of fish due to these habitat parameters varies with species and life stage. In IFIM studies the range of each of these parameters are commonly referred to as fish preference criteria or a Habitat Suitability Index (HSI).

HSI curves for the Tailrace Slough Instream Flow study examined spawning substrate preferences for salmon, with the focus being on Chinook substrate spawning preference. These curves used were those found in Washington Department of Fish and Wildlife and Washington Department of Ecology Instream Flow Guidelines (WDFW/WDOE 2004). Appendix A lists the HSI curves for substrate used in this analysis.

For purposes of this analysis, the velocity component was not considered. Depths necessary for spawning were incorporated into the analysis, provided that a minimum depth of 0.5 ft for Chinook salmon was met. If this criterion was met, then the substrate was considered viable and was counted; if it was less than the required minimum, the substrate was given a value of 0.

3.8 Data Analysis

3.8.1 Hydraulic Modeling

Analysis and integration of physical stream measurements and habitat preference criteria require the use of a group of the RHABSIM (Riverine Habitat Simulation) computer programs. There are two main programs in the RHABSIM library: the hydraulic model (called HYDSIM), and the habitat model (called HABSIM).

Hydraulic modeling involves two sequential steps. The first step is to develop a stage-discharge relationship, and the second stage is velocity calibration. For the purposes of this evaluation, velocity calibration was not required in order to determine depth over potential spawning substrate. Accordingly, velocity calibrations were not conducted.

The stage is the height of the water surface elevation (WSE) at a location (in this case, at each transect). At a minimum of three widely separated calibration flows, stages and flows should be measured and recorded; generally, the lower flow should be half or less of the next higher flow. RHABSIM uses a power function to predict the stage/discharge relationship and calculate the depth of the water at that flow by subtracting the bed profile from the WSE.

The HABTAT program integrates the simulated hydraulic information from HYDSIM with habitat suitability criteria (i.e., preference or HSI curves) and quantifies habitat availability over a range of flows for the specified target species and life stages. Habitat quantification is expressed as an index called Weighted Useable Area (WUA), and is given in units of habitat per 1,000 linear feet of stream. In this instance, all depths and velocities were given values of 1.0, so that only the substrate spawning preference for salmon was given in the outputs.

3.8.2 Cowlitz River and Project Flows in the Tailrace Slough

EES Consulting retrieved data for the Cowlitz River at the Skate Creek Bridge in Packwood (gage No. 14226500) from the USGS for the period of record extending from 2000 until 2006. Project flows were obtained from Energy Northwest for the same period.

4.0 RESULTS

Measurements of the tailrace slough were taken during the summer of 2006. A significant flood event occurred in the upper Cowlitz River during early November 2006 (provisional peak flow of 37,100 cfs), resulting in major changes to the tailrace slough. Since that event in November, another major flood occurred during March 2007, further changing the tailrace slough.

4.1 Relationship of Tailrace Slough Flows to the Cowlitz River

EES Consulting used six measurements during the spring of 2006 to develop a relationship between the Cowlitz River and the tailrace slough. The tailrace slough flows were reduced by the Plant flow to determine the contribution of the Cowlitz River to the tailrace slough. Figure 4.1-1 depicts this relationship:

Equation 1:

$$Y = 0.1296\,X - 86.96$$
$$(r^2 = 0.975)$$

Where: Y = Contribution of the Cowlitz River to the tailrace slough; and
X = Cowlitz River Flows, as measured at Packwood.

Although this relationship was valid at the time the measurements were taken, the Cowlitz River has altered the tailrace slough twice since then; as a result, this relationship no longer represents the current condition in the tailrace slough.

4.2 Transect Selection and Weighting

A total of eight transects were selected for analysis in the tailrace slough: six of the transects were located in the left channel; one transect was chosen in the main channel above the bifurcation of the channels, and one was located immediately downstream of the Project tailrace (Figure 4.2-1). Transect 8 was wholly dependent upon Project flows and was not influenced by streamflow in the Cowlitz River. Table 4.2-1 summarizes transects, their descriptions, and transect weighting.

As mentioned above, the flood event of November 2006 significantly changed the habitat found in the tailrace slough. All transects were altered to a certain extent. Transect 5, a wide pool in the left channel, was complete obliterated and replaced with a narrow glide. Transect 7, a wide, glide with spawnable substrates in the mainstem, had all spawning substrate replaced with sand and silt.

EES Consulting used professional judgment and eliminated transects 5 and 7 from further analysis. The other transects were retained; however, it is important to note that the channels and configurations have changed twice since the measurements were taken. All analysis is based on the relationships that existed at the time of the measurements. The analysis presented can only be used as an index of what habitat exists in the Tailrace Slough.

Figure 4.1-1. Cowlitz River Flows vs Tailrace Slough

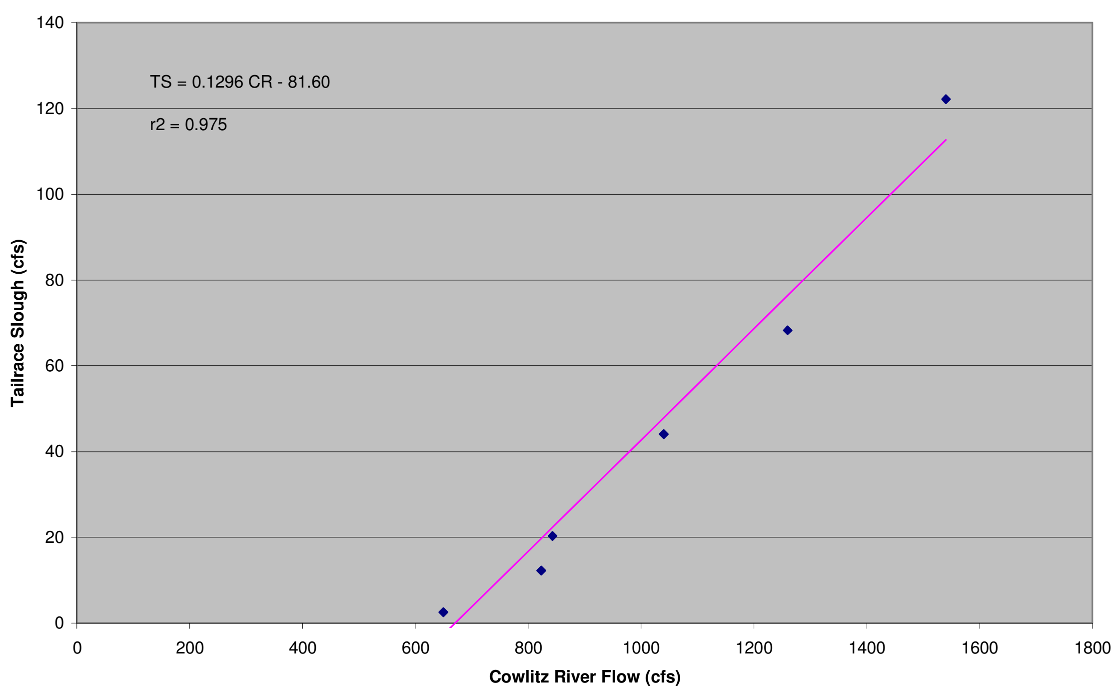


Figure 4.2-1.
Tailrace Slough Transects

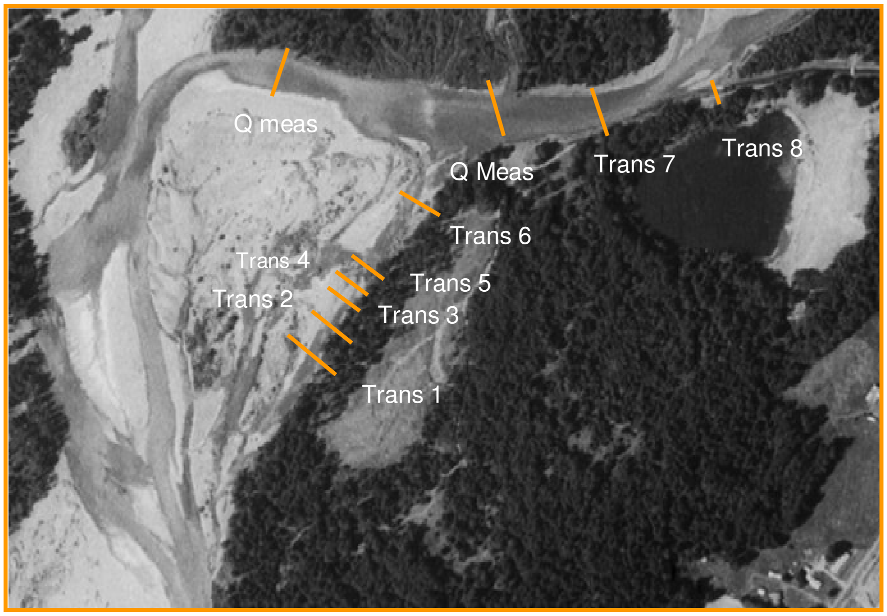


Table 4.2-1
Transect Descriptions and Weighting

Transect	*Description*	*Length (feet)*	*Analysis Length (feet)*	*Percent*
1	Glide with lateral pocket water	123	123	13.1%
2	Riffle below split channel	150	150	16.0%
3	Split channel run	196	196	20.9%
4	Split channel run	169	169	18.0%
5	Deep Pool [1/]	231	N/A	N/A
6	Spawning riffle/run	300	300	32.0%
7	Wide Glide below tailrace discharge with Cowlitz River [1/]	1091	N/A	N/A
8	Pool/Glide immediately below tailrace	28	28	3.0%
Total		2260	938	

[1/] Transects 5 and 7 were eliminated after flood event of November 2006.

4.3 Measured Flows and Spawning Substrate WUA

4.3.1 Measured Flows

EES Consulting collected three sets of velocity calibration measurements at each transect at high, medium and low flows. The three calibration flows are shown in Table 4.3-1. During the low flow measurement, the Cowlitz River was fluctuating rapidly, which resulted in different flow measurements for many of the transects.

Table 4.3-1
Summary of Calibration Flow Measurements and Water Surface Elevations for Tailrace Slough Transects

	Low Calibration Measurement		*Mid Calibration Measurement*		*High Calibration Measurement*	
Transect	*Flow- cfs*	*WSE-ft*	*Flow-cfs*	*WSE-ft*	*Flow-cfs*	*WSE-ft*
1	**6.30**	90.87	151.66	92.05	309.86	92.88
2	**9.92**	90.31	**151.66**	91.35	**309.86**	92.01
3	**8.01**	96.51	154.50	97.75	324.86	98.51
4	**10.77**	97.42	155.00	98.46	339.86	99.05
5	**11.12**	93.16	156.00	94.78	354.86	95.57
6	**11.07**	96.53	**158.58**	97.75	**370.95**	98.52
7	89.19	91.45	251.34	92.17	471.96	92.71
8	**102.04**	92.18	159.00	92.92	220.00	93.08

EES Consulting measured flows at three places in the tailrace slough (Table 4.3-2):

- Main channel upstream of the split channels (downstream of Transect 7)
- Left channel (on Transects 1 and 6)
- Right Channel

In addition, EES Consulting recorded the Project flows so that flow levels could be determined for Transect 8. Photos of the tailrace slough at calibration flows are found in Appendix B.

Table 4.3-2
Measured Flows in the Tailrace Slough During Calibration Measurements [1/]

Main Channel (cfs)	Right Channel (cfs)	Left Channel (cfs)
89	82	7
251	126	152
472	150	371

[1/] Differences due to hourly fluctuations in Cowlitz River.

Figure 4.3-1 depicts the relationship between the main channel of the tailrace slough and the left channel as represented by the equation:

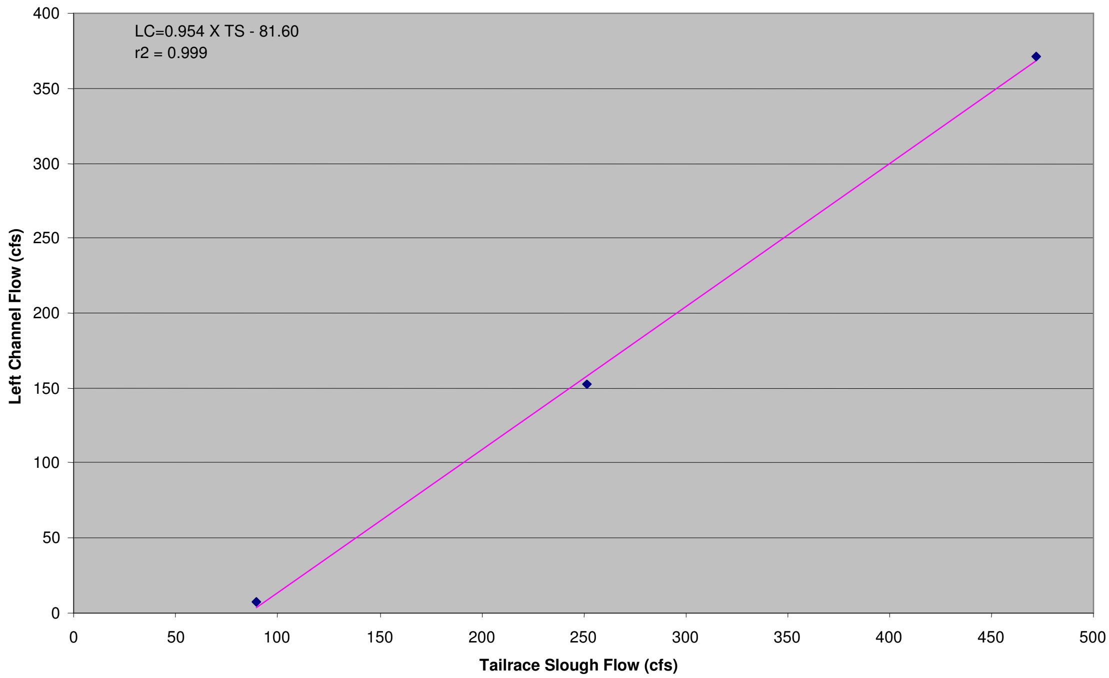
Equation 2:

$$Y = 0.954\,X - 84.60$$
$$(r^2 = 0.999)$$

Where Y = Flow in the left channel of the tailrace slough; and
X = Flow in the main channel of the tailrace slough.

As stated previously, although this relationship was valid at the time the measurements were taken, the Cowlitz River has altered the tailrace slough twice since then; as a result, this relationship no longer represents the current condition in the tailrace slough.

Figure 4.3-1
Calculation of Left Channel Flow v. Tailrace Slough Flow



4.3.2 Spawning Substrate WUA

EESC calibrated the WSEs for each transect using the three water surface regression. Mean error of all transect calculations fell within the acceptable range (<10%). The HABTAT sub module was run for each transect, using WDFW/WDOE HSI curves for Chinook salmon and steelhead trout. Preference values for all depths and velocities were given a value of 1, which allows WUA to respond only to substrate preferences for spawning.

Tables 4.3-3 to 4.3-8 and Figures 4.3-2 – 4.3-7 show the results of this modeling effort. Appendix C shows calibration details for the stage/discharge relationship for the tailrace slough transects.

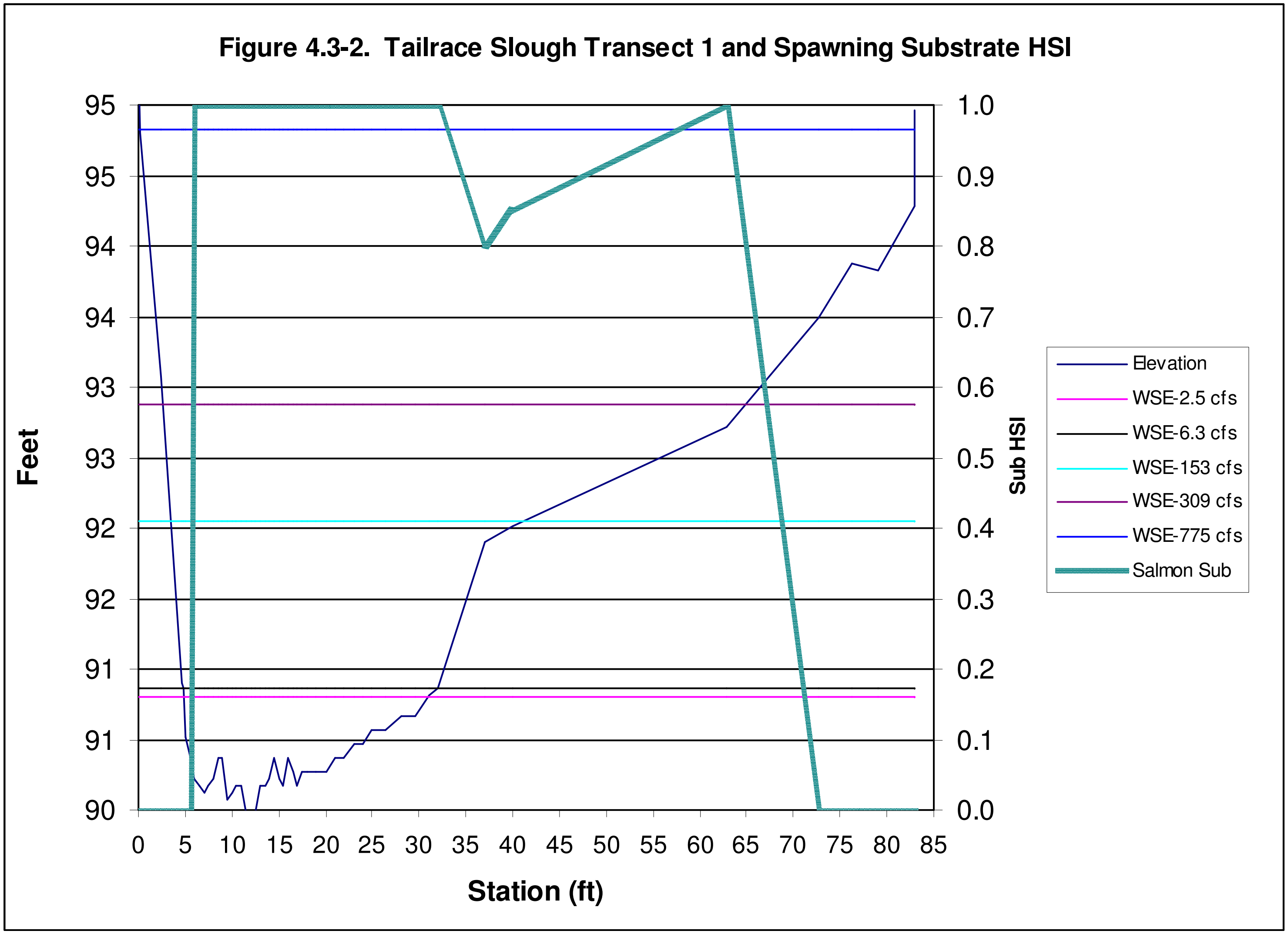


Figure 4.3-2. Tailrace Slough Transect 1 and Spawning Substrate HSI
Feet
Sub HSI
Station (ft)
95
95
94
94
93
93
92
92
91
91
90
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
Elevation
WSE-2.5 cfs
WSE-6.3 cfs
WSE-153 cfs
WSE-309 cfs
WSE-775 cfs
Salmon Sub

Table 4.3-3
Summary of Bed Elevation and Water Surface Elevations for Tailrace Instream Flow Study, Packwood Hydroelectric Project, Transect 1

WSE (ft)			*HSI Value*	*HSI Value*	*90.80*	*90.87*	*92.05*	*92.88*	*94.83*
Discharge (cfs)	*Elevation (ft)*				*2.50*	*6.30*	*153.66*	*309.86*	*775.00*
Station		*Substrate*	*Salmon*	*Steelhead*	*Depth(ft)*	*Depth(ft)*	*Depth(ft)*	*Depth(ft)*	*Depth(ft)*
0.00	95.31	22.90	0.000	0.000					
0.10	94.80	22.90	0.000	0.000					0.03
2.50	93.07	22.90	0.000	0.000					1.76
4.60	90.90	22.90	0.000	0.000			1.15	1.98	3.93
4.80	90.87	11.90	0.000	0.000		0.00	1.18	2.01	3.96
5.00	90.52	11.90	0.000	0.000	0.28	0.35	1.53	2.36	4.31
5.50	90.37	11.90	0.000	0.000	0.43	0.50	1.68	2.51	4.46
6.00	90.22	56.70	1.000	1.000	0.58	0.65	1.83	2.66	4.61
6.50	90.17	56.70	1.000	1.000	0.63	0.70	1.88	2.71	4.66
7.00	90.12	56.70	1.000	1.000	0.68	0.75	1.93	2.76	4.71
7.50	90.17	56.60	1.000	1.000	0.63	0.70	1.88	2.71	4.66
8.00	90.22	56.60	1.000	1.000	0.58	0.65	1.83	2.66	4.61
8.50	90.37	56.60	1.000	1.000	0.43	0.50	1.68	2.51	4.46
9.00	90.37	56.60	1.000	1.000	0.43	0.50	1.68	2.51	4.46
9.50	90.07	56.60	1.000	1.000	0.73	0.80	1.98	2.81	4.76
10.00	90.12	56.60	1.000	1.000	0.68	0.75	1.93	2.76	4.71
10.50	90.17	56.60	1.000	1.000	0.63	0.70	1.88	2.71	4.66
11.00	90.17	56.60	1.000	1.000	0.63	0.70	1.88	2.71	4.66
11.50	89.97	56.60	1.000	1.000	0.83	0.90	2.08	2.91	4.86
12.00	89.92	56.60	1.000	1.000	0.88	0.95	2.13	2.96	4.91
12.50	89.97	56.60	1.000	1.000	0.83	0.90	2.08	2.91	4.86
13.00	90.17	56.60	1.000	1.000	0.63	0.70	1.88	2.71	4.66
13.50	90.17	56.60	1.000	1.000	0.63	0.70	1.88	2.71	4.66
14.00	90.22	56.60	1.000	1.000	0.58	0.65	1.83	2.66	4.61
14.50	90.37	56.60	1.000	1.000	0.43	0.50	1.68	2.51	4.46
15.00	90.22	56.60	1.000	1.000	0.58	0.65	1.83	2.66	4.61
15.50	90.17	56.60	1.000	1.000	0.63	0.70	1.88	2.71	4.66
16.00	90.37	56.60	1.000	1.000	0.43	0.50	1.68	2.51	4.46
16.50	90.27	56.60	1.000	1.000	0.53	0.60	1.78	2.61	4.56
17.00	90.17	56.60	1.000	1.000	0.63	0.70	1.88	2.71	4.66
17.50	90.27	56.60	1.000	1.000	0.53	0.60	1.78	2.61	4.56
18.00	90.27	56.60	1.000	1.000	0.53	0.60	1.78	2.61	4.56
19.00	90.27	56.60	1.000	1.000	0.53	0.60	1.78	2.61	4.56
20.00	90.27	56.60	1.000	1.000	0.53	0.60	1.78	2.61	4.56
21.00	90.37	56.50	1.000	1.000	0.43	0.50	1.68	2.51	4.46
22.00	90.37	56.50	1.000	1.000	0.43	0.50	1.68	2.51	4.46
23.00	90.47	56.50	1.000	1.000	0.33	0.40	1.58	2.41	4.36
24.00	90.47	56.50	1.000	1.000	0.33	0.40	1.58	2.41	4.36
25.00	90.57	56.50	1.000	1.000	0.23	0.30	1.48	2.31	4.26
26.50	90.57	65.70	1.000	1.000	0.23	0.30	1.48	2.31	4.26
28.00	90.67	65.70	1.000	1.000	0.13	0.20	1.38	2.21	4.16
29.50	90.67	65.70	1.000	1.000	0.13	0.20	1.38	2.21	4.16

Table 4.3-3
Summary of Bed Elevation and Water Surface Elevations for Tailrace Instream Flow Study,
Packwood Hydroelectric Project, Transect 1

WSE (ft)			*HSI Value*	*HSI Value*	*90.80*	*90.87*	*92.05*	*92.88*	*94.83*
Discharge (cfs)	*Elevation (ft)*				*2.50*	*6.30*	*153.66*	*309.86*	*775.00*
Station		*Substrate*	*Salmon*	*Steelhead*	*Depth(ft)*	*Depth(ft)*	*Depth(ft)*	*Depth(ft)*	*Depth(ft)*
31.00	90.82	65.70	1.000	1.000		0.05	1.23	2.06	4.01
32.00	90.87	65.70	1.000	1.000		0.00	1.18	2.01	3.96
37.00	91.90	57.60	0.800	0.720			0.15	0.98	2.93
40.00	92.01	57.70	0.850	0.790			0.04	0.87	2.82
62.90	92.71	56.70	1.000	1.000				0.17	2.12
72.80	93.49	52.70	0.000	0.000					1.34
76.20	93.88	32.60	0.000	0.000					0.95
79.00	93.83	22.90	0.000	0.000					1.00
82.95	94.28	22.90	0.000	0.000					0.55
82.96	94.96	22.90	0.000	0.000					

Figure 4.3-3. Tailrace Slough Transect 2 and Spawning Substrate HSI

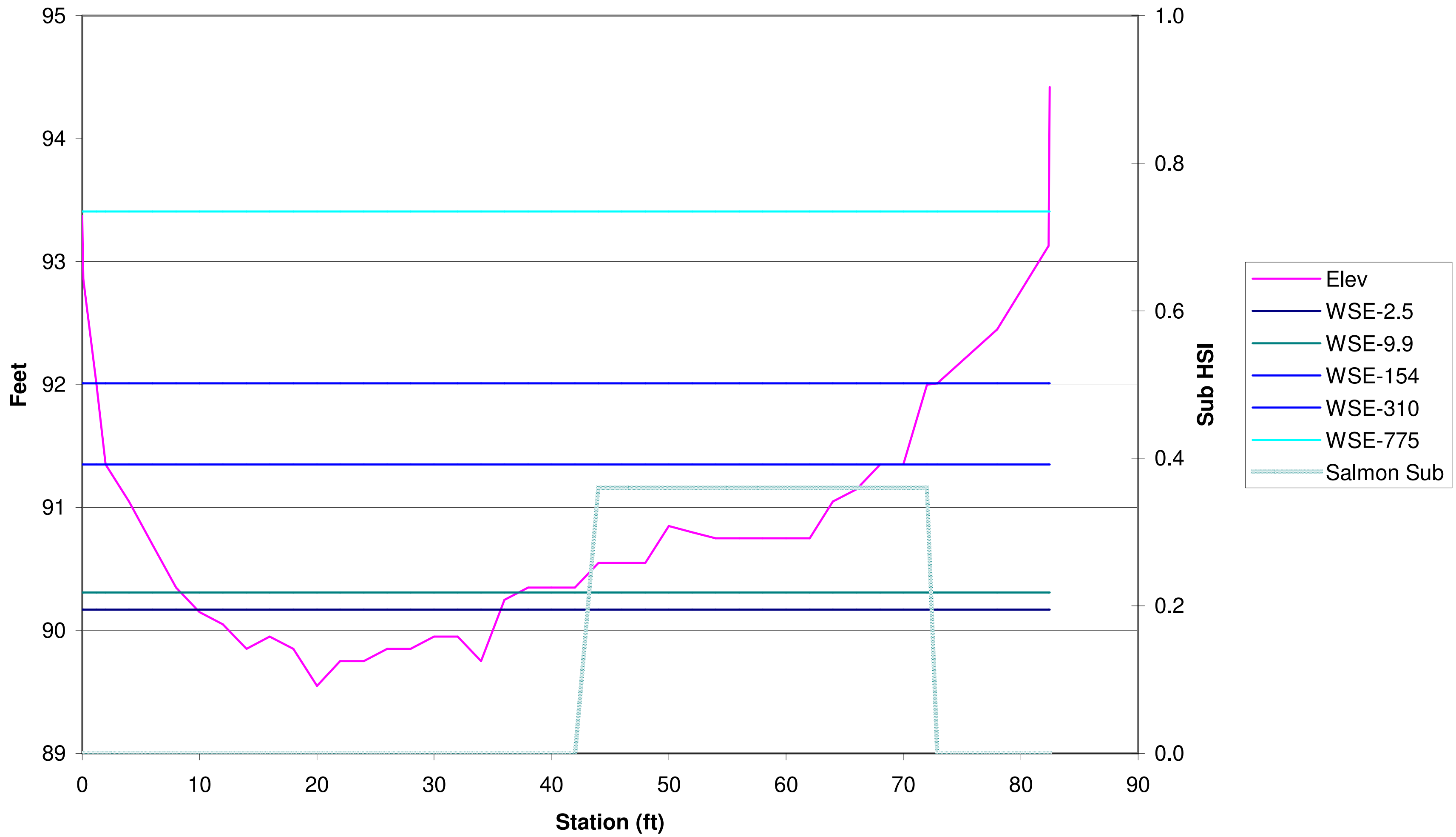


Table 4.3-4
Summary of Bed Elevation and Water Surface Elevations for Tailrace Instream Flow Study, Packwood Hydroelectric Project, Transect 2

WSE (ft) Discharge (cfs) Station	*Elevation (ft)*	*Substrate*	*HSI Value Salmon*	*HSI Value Steelhead*	*90.17 2.50 Depth(ft)*	*90.31 9.92 Depth(ft)*	*91.35 153.66 Depth(ft)*	*92.01 309.86 Depth(ft)*	*93.41 775.00 Depth(ft)*
0.00	93.37	26.80	0.000	0.000					0.04
0.10	92.86	26.80	0.000	0.000					0.55
1.20	92.01	26.80	0.000	0.000				0.00	1.40
2.00	91.35	52.70	0.000	0.000			0.00	0.66	2.06
4.00	91.05	52.70	0.000	0.000			0.30	0.96	2.36
6.00	90.70	52.70	0.000	0.000			0.65	1.31	2.71
8.00	90.35	52.70	0.000	0.000			1.00	1.66	3.06
10.00	90.15	52.70	0.000	0.000	0.02	0.16	1.20	1.86	3.26
12.00	90.05	52.70	0.000	0.000	0.12	0.26	1.30	1.96	3.36
14.00	89.85	52.70	0.000	0.000	0.32	0.46	1.50	2.16	3.56
16.00	89.95	52.70	0.000	0.000	0.22	0.36	1.40	2.06	3.46
18.00	89.85	52.70	0.000	0.000	0.32	0.46	1.50	2.16	3.56
20.00	89.55	52.70	0.000	0.000	0.62	0.76	1.80	2.46	3.86
22.00	89.75	52.70	0.000	0.000	0.42	0.56	1.60	2.26	3.66
24.00	89.75	52.70	0.000	0.000	0.42	0.56	1.60	2.26	3.66
26.00	89.85	52.70	0.000	0.000	0.32	0.46	1.50	2.16	3.56
28.00	89.85	52.70	0.000	0.000	0.32	0.46	1.50	2.16	3.56
30.00	89.95	52.70	0.000	0.000	0.22	0.36	1.40	2.06	3.46
32.00	89.95	52.70	0.000	0.000	0.22	0.36	1.40	2.06	3.46
34.00	89.75	52.70	0.000	0.000	0.42	0.56	1.60	2.26	3.66
36.00	90.25	52.70	0.000	0.000		0.06	1.10	1.76	3.16
38.00	90.35	52.70	0.000	0.000			1.00	1.66	3.06
40.00	90.35	52.70	0.000	0.000			1.00	1.66	3.06
42.00	90.35	52.70	0.000	0.000			1.00	1.66	3.06
44.00	90.55	37.70	0.360	0.440			0.80	1.46	2.86
46.00	90.55	37.70	0.360	0.440			0.80	1.46	2.86
48.00	90.55	37.70	0.360	0.440			0.80	1.46	2.86
50.00	90.85	37.70	0.360	0.440			0.50	1.16	2.56
52.00	90.80	37.70	0.360	0.440			0.55	1.21	2.61
54.00	90.75	37.70	0.360	0.440			0.60	1.26	2.66
56.00	90.75	37.70	0.360	0.440			0.60	1.26	2.66
58.00	90.75	37.70	0.360	0.440			0.60	1.26	2.66
60.00	90.75	37.70	0.360	0.440			0.60	1.26	2.66
62.00	90.75	37.70	0.360	0.440			0.60	1.26	2.66
64.00	91.05	37.70	0.360	0.440			0.30	0.96	2.36
66.00	91.15	37.70	0.360	0.440			0.20	0.86	2.26
68.00	91.35	37.70	0.360	0.440			0.00	0.66	2.06
70.00	91.35	37.70	0.360	0.440			0.00	0.66	2.06
72.00	92.00	37.70	0.360	0.440				0.01	1.41
72.90	92.01	26.70	0.000	0.000				0.00	1.40
78.00	92.45	22.90	0.000	0.000					0.96
82.37	93.13	22.90	0.000	0.000					0.28

Table 4.3-4
Summary of Bed Elevation and Water Surface Elevations for Tailrace Instream Flow Study, Packwood Hydroelectric Project, Transect 2

WSE (ft) *Discharge (cfs)* *Station*	*Elevation (ft)*	*Substrate*	*HSI Value* *Salmon*	*HSI Value* *Steelhead*	*90.17* *2.50* *Depth(ft)*	*90.31* *9.92* *Depth(ft)*	*91.35* *153.66* *Depth(ft)*	*92.01* *309.86* *Depth(ft)*	*93.41* *775.00* *Depth(ft)*
82.47	94.42	22.90	0.000	0.000					
82.37	93.13	22.90	0.000	0.000					
82.47	94.42	22.90	0.000	0.000					

Figure 4.3-4 Tailrace Slough Transect 3 and Spawning Substrate HSI

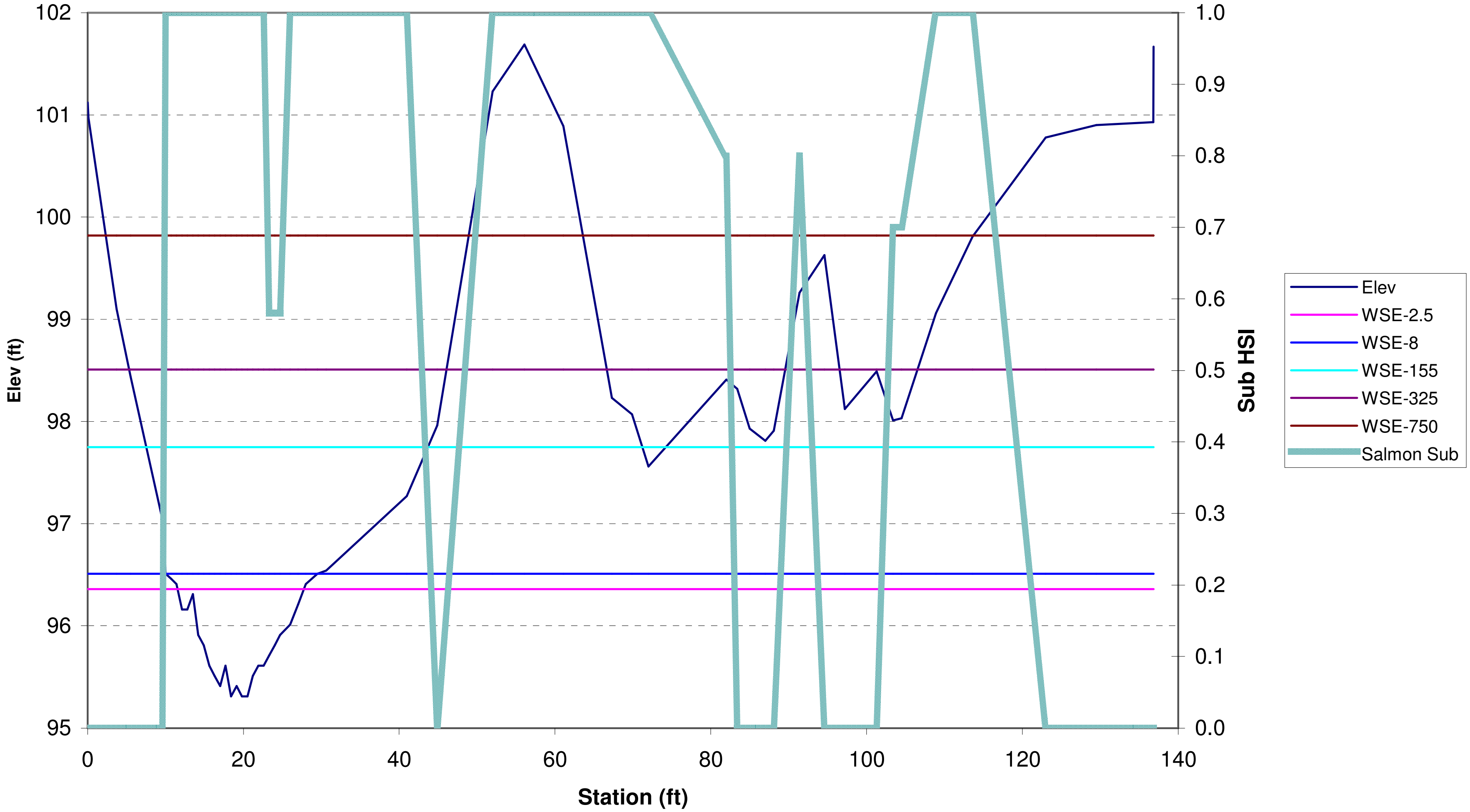


Table 4.3-5
Summary of Bed Elevation and Water Surface Elevations for Tailrace Instream Flow Study, Packwood Hydroelectric Project, Transect 3

WSE (ft) Discharge (cfs) Station	*Elevation (ft)*	*Substrate*	*HSI Value Salmon*	*HSI Value Steelhead*	*96.36 2.50 Depth(ft)*	*96.51 8.01 Depth(ft)*	*97.75 154.5 Depth(ft)*	*98.51 324.9 Depth(ft)*	*99.82 750.0 Depth(ft)*
0	101.12	22.9	0	0					
0.1	100.97	22.9	0	0					
3.7	99.1	22.9	0	0					0.72
5.5	98.44	23.8	0	0				0.07	1.38
9.6	97.04	23.8	0	0			0.71	1.47	2.78
10	96.51	45.8	1	1		0	1.24	2	3.31
10.7	96.46	45.8	1	1		0.05	1.29	2.05	3.36
11.4	96.41	45.8	1	1		0.1	1.34	2.1	3.41
12.1	96.16	45.8	1	1	0.2	0.35	1.59	2.35	3.66
12.8	96.16	45.8	1	1	0.2	0.35	1.59	2.35	3.66
13.5	96.31	54.6	1	1	0.05	0.2	1.44	2.2	3.51
14.2	95.91	54.6	1	1	0.45	0.6	1.84	2.6	3.91
14.9	95.81	54.6	1	1	0.55	0.7	1.94	2.7	4.01
15.6	95.61	54.6	1	1	0.75	0.9	2.14	2.9	4.21
16.3	95.51	54.6	1	1	0.85	1	2.24	3	4.31
17	95.41	54.6	1	1	0.95	1.1	2.34	3.1	4.41
17.7	95.61	54.6	1	1	0.75	0.9	2.14	2.9	4.21
18.4	95.31	54.6	1	1	1.05	1.2	2.44	3.2	4.51
19.1	95.41	56.7	1	1	0.95	1.1	2.34	3.1	4.41
19.8	95.31	56.7	1	1	1.05	1.2	2.44	3.2	4.51
20.5	95.31	56.7	1	1	1.05	1.2	2.44	3.2	4.51
21.2	95.51	56.7	1	1	0.85	1	2.24	3	4.31
21.9	95.61	56.7	1	1	0.75	0.9	2.14	2.9	4.21
22.6	95.61	56.7	1	1	0.75	0.9	2.14	2.9	4.21
23.3	95.71	34.6	0.58	0.7	0.65	0.8	2.04	2.8	4.11
24	95.81	34.6	0.58	0.7	0.55	0.7	1.94	2.7	4.01
24.7	95.91	34.6	0.58	0.7	0.45	0.6	1.84	2.6	3.91
26	96.01	56.8	1	1	0.35	0.5	1.74	2.5	3.81
27	96.21	56.8	1	1	0.15	0.3	1.54	2.3	3.61
28	96.41	65.6	1	1		0.1	1.34	2.1	3.41
29.5	96.51	65.6	1	1		0	1.24	2	3.31
30.6	96.54	65.6	1	1			1.21	1.97	3.28
41	97.27	56.8	1	1			0.48	1.24	2.55
44.9	97.96	26.6	0	0				0.55	1.86
52	101.23	45.8	1	1					
56.1	101.69	45.8	1	1					
61.1	100.89	45.8	1	1					
67.3	98.23	54.6	1	1				0.28	1.59
69.9	98.07	54.7	1	1				0.44	1.75
72	97.56	54.7	1	1			0.19	0.95	2.26
82	98.41	42.8	0.8	0.8				0.1	1.41
83.4	98.32	22.9	0	0				0.19	1.5

Table 4.3-5
Summary of Bed Elevation and Water Surface Elevations for Tailrace Instream Flow Study, Packwood Hydroelectric Project, Transect 3

WSE (ft) Discharge (cfs) Station	*Elevation (ft)*	*Substrate*	*HSI Value Salmon*	*HSI Value Steelhead*	*96.36 2.50 Depth(ft)*	*96.51 8.01 Depth(ft)*	*97.75 154.5 Depth(ft)*	*98.51 324.9 Depth(ft)*	*99.82 750.0 Depth(ft)*
85	97.93	22.9	0	0				0.58	1.89
87	97.81	22.9	0	0				0.7	2.01
88.1	97.91	22.9	0	0				0.6	1.91
91.4	99.26	42.8	0.8	0.8					0.56
94.6	99.63	42.6	0	0					0.19
97.2	98.12	22.9	0	0				0.39	1.7
101.3	98.49	26.9	0	0				0.02	1.33
103.4	98.01	75.6	0.7	0.58				0.5	1.81
104.5	98.03	75.6	0.7	0.58				0.48	1.79
108.9	99.06	54.6	1	1					0.76
113.6	99.81	54.6	1	1					0.01
123	100.78	25.8	0	0					
129.5	100.9	25.8	0	0					
136.8	100.93	25.8	0	0					
136.85	101.67	25.8	0	0					

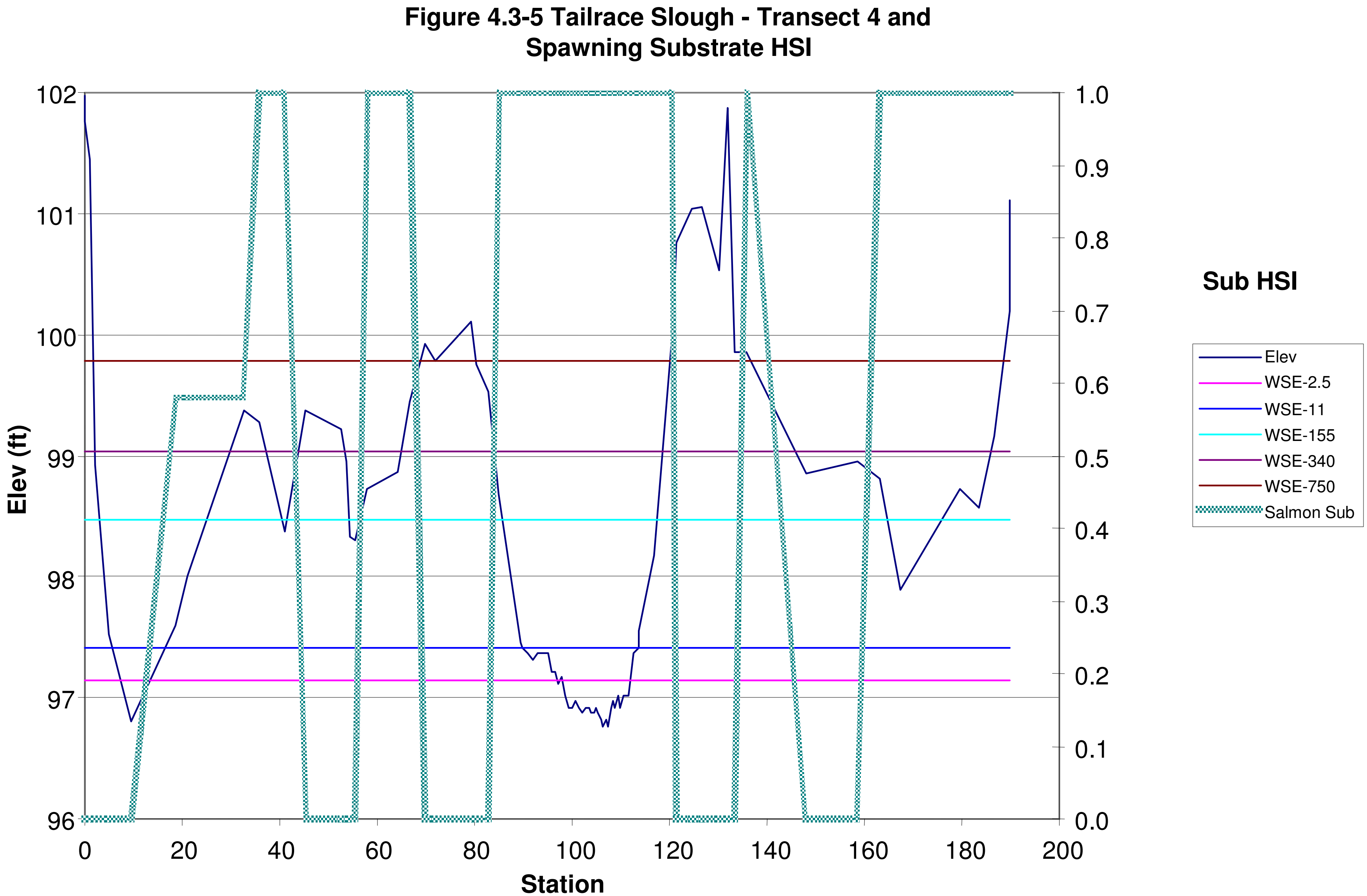


Figure 4.3-5 Tailrace Slough - Transect 4 and
Spawning Substrate HSI
Elev (ft)
102
101
100
99
98
97
96
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
Station
Sub HSI
Elev
WSE-2.5
WSE-11
WSE-155
WSE-340
WSE-750
Salmon Sub

Table 4.3-6
Summary of Bed Elevation and Water Surface Elevations for Tailrace Instream Flow Study, Packwood Hydroelectric Project, Transect 4

WSE (ft) Discharge (cfs) Station	*Elevation (ft)*	*Substrate*	*HSI Value Salmon*	*HSI Value Steelhead*	*97.15 2.50 Depth(ft)*	*97.42 10.77 Depth(ft)*	*98.47 155 Depth(ft)*	*99.04 339.86 Depth(ft)*	*99.79 750 Depth(ft)*
0	101.98	22.9	0	0					
0.1	101.77	22.9	0	0					
1	101.45	22.9	0	0					
2.1	98.93	22.9	0	0				0.11	0.86
4.8	97.53	22.9	0	0			0.94	1.51	2.26
9.6	96.81	87.7	0	0	0.34	0.61	1.66	2.23	2.98
18.8	97.6	35.6	0.58	0.7			0.87	1.44	2.19
21.1	98.01	35.6	0.58	0.7			0.46	1.03	1.78
32.6	99.37	35.6	0.58	0.7					0.42
35.8	99.27	46.7	1	1					0.52
41	98.37	46.7	1	1			0.1	0.67	1.42
45.5	99.38	23.8	0	0					0.41
52.7	99.22	23.8	0	0					0.57
53.9	98.95	23.8	0	0				0.09	0.84
54.3	98.33	23.8	0	0			0.14	0.71	1.46
55.5	98.31	23.8	0	0			0.16	0.73	1.48
58.1	98.72	45.8	1	1				0.32	1.07
64.2	98.87	45.8	1	1				0.17	0.92
66.8	99.45	45.8	1	1					0.34
69.9	99.92	23.7	0	0					
71.9	99.78	32.7	0	0					0.01
79.2	100.11	32.7	0	0					
80.5	99.76	32.7	0	0					0.03
82.9	99.53	32.7	0	0					0.26
85.1	98.69	56.7	1	1				0.35	1.1
89.6	97.45	56.7	1	1			1.02	1.59	2.34
89.9	97.42	56.7	1	1		0	1.05	1.62	2.37
91	97.37	56.7	1	1		0.05	1.1	1.67	2.42
92	97.32	56.7	1	1		0.1	1.15	1.72	2.47
93	97.37	56.7	1	1		0.05	1.1	1.67	2.42
94	97.37	56.7	1	1		0.05	1.1	1.67	2.42
95	97.37	56.7	1	1		0.05	1.1	1.67	2.42
96	97.22	56.7	1	1		0.2	1.25	1.82	2.57
96.7	97.22	56.7	1	1		0.2	1.25	1.82	2.57
97.4	97.12	56.7	1	1	0.03	0.3	1.35	1.92	2.67
98.1	97.17	56.7	1	1		0.25	1.3	1.87	2.62
98.8	97.02	56.7	1	1	0.13	0.4	1.45	2.02	2.77
99.5	96.92	56.7	1	1	0.23	0.5	1.55	2.12	2.87
100.2	96.92	56.7	1	1	0.23	0.5	1.55	2.12	2.87
100.9	96.97	56.7	1	1	0.18	0.45	1.5	2.07	2.82
101.6	96.92	56.7	1	1	0.23	0.5	1.55	2.12	2.87
102.3	96.87	56.7	1	1	0.28	0.55	1.6	2.17	2.92

Table 4.3-6
Summary of Bed Elevation and Water Surface Elevations for Tailrace Instream Flow Study, Packwood Hydroelectric Project, Transect 4

WSE (ft) Discharge (cfs) Station	*Elevation (ft)*	*Substrate*	*HSI Value Salmon*	*HSI Value Steelhead*	*97.15 2.50 Depth(ft)*	*97.42 10.77 Depth(ft)*	*98.47 155 Depth(ft)*	*99.04 339.86 Depth(ft)*	*99.79 750 Depth(ft)*
103	96.92	56.7	1	1	0.23	0.5	1.55	2.12	2.87
103.5	96.92	56.7	1	1	0.23	0.5	1.55	2.12	2.87
104	96.87	56.7	1	1	0.28	0.55	1.6	2.17	2.92
104.5	96.87	56.7	1	1	0.28	0.55	1.6	2.17	2.92
105	96.92	56.7	1	1	0.23	0.5	1.55	2.12	2.87
105.5	96.87	56.7	1	1	0.28	0.55	1.6	2.17	2.92
106	96.82	56.7	1	1	0.33	0.6	1.65	2.22	2.97
106.5	96.77	56.7	1	1	0.38	0.65	1.7	2.27	3.02
107	96.82	56.7	1	1	0.33	0.6	1.65	2.22	2.97
107.5	96.77	56.7	1	1	0.38	0.65	1.7	2.27	3.02
108	96.92	56.7	1	1	0.23	0.5	1.55	2.12	2.87
108.5	96.97	56.7	1	1	0.18	0.45	1.5	2.07	2.82
109	96.92	56.7	1	1	0.23	0.5	1.55	2.12	2.87
109.5	97.02	56.7	1	1	0.13	0.4	1.45	2.02	2.77
110	96.92	56.7	1	1	0.23	0.5	1.55	2.12	2.87
110.5	97.02	56.7	1	1	0.13	0.4	1.45	2.02	2.77
111.5	97.02	56.7	1	1	0.13	0.4	1.45	2.02	2.77
112.5	97.37	56.7	1	1		0.05	1.1	1.67	2.42
113.8	97.42	56.7	1	1		0	1.05	1.62	2.37
113.85	97.55	56.7	1	1			0.92	1.49	2.24
117	98.18	56.7	1	1			0.29	0.86	1.61
120.6	100.07	56.7	1	1					
121.5	100.76	23.9	0	0					
124.6	101.04	23.9	0	0					
126.8	101.06	23.9	0	0					
130.2	100.54	24.8	0	0					
132	101.87	24.8	0	0					
133.4	99.86	24.8	0	0					
136	99.86	65.6	1	1					
148	98.86	62.6	0	0				0.18	0.93
158.5	98.95	62.6	0	0				0.09	0.84
163.3	98.81	56.7	1	1				0.23	0.98
167.6	97.9	56.7	1	1			0.57	1.14	1.89
179.6	98.72	56.7	1	1				0.32	1.07
183.5	98.57	56.7	1	1				0.47	1.22
186.7	99.17	56.7	1	1					0.62
189.7	100.2	56.7	1	1					
189.8	101.12	56.7	1	1					

Figure 4.3-6 Tailrace Slough Transect 6 and Spawning Substrate HSI

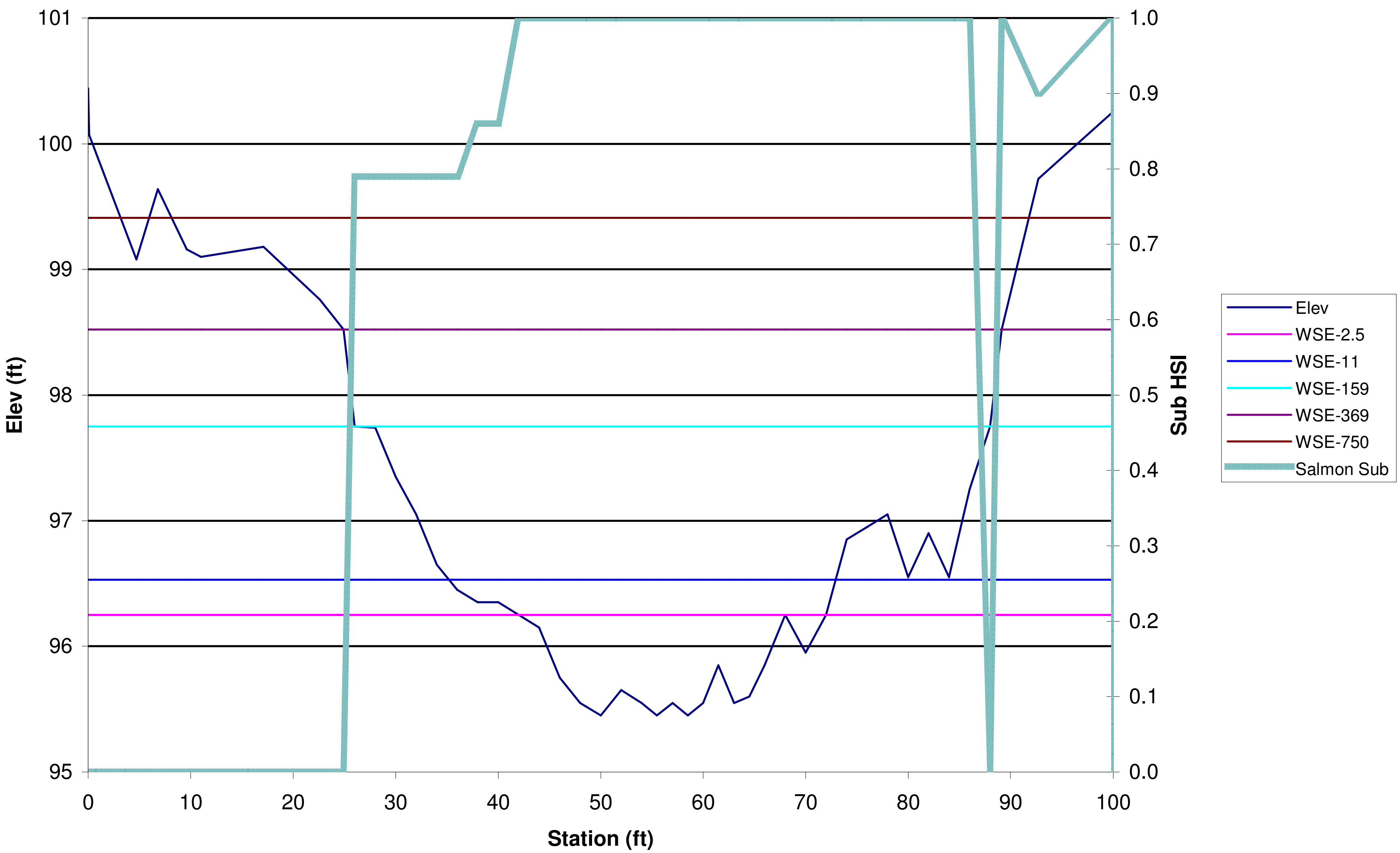


Table 4.3-7
Summary of Bed Elevation and Water Surface Elevations for Tailrace Instream Flow Study, Packwood Hydroelectric Project, Transect 6

WSE (ft) Discharge (cfs) Station	*Elevation (ft)*	*Slubstrate*	*HSI Value Salmon*	*HSI Value Steelhead*	*96.25 2.5 Depth(ft)*	*96.53 11.07 Depth(ft)*	*97.75 158.58 Depth(ft)*	*98.52 368.95 Depth(ft)*	*99.41 750 Depth(ft)*
0.0	100.44	22.9	0	0					
0.1	100.07	22.9	0	0					
4.7	99.08	22.9	0	0					0.33
6.8	99.64	22.9	0	0					
9.6	99.16	22.9	0	0					0.25
11.0	99.1	23.7	0	0					0.31
17.1	99.18	22.9	0	0					0.23
22.6	98.76	23.8	0	0					0.65
24.9	98.52	32.7	0	0				0	0.89
26.0	97.75	43.7	0.79	0.85			0	0.77	1.66
28.0	97.74	43.7	0.79	0.85			0.01	0.78	1.67
30.0	97.35	53.7	0.79	0.85			0.4	1.17	2.06
32.0	97.05	53.7	0.79	0.85			0.7	1.47	2.36
34.0	96.65	53.7	0.79	0.85			1.1	1.87	2.76
36.0	96.45	53.7	0.79	0.85		0.08	1.3	2.07	2.96
38.0	96.35	43.8	0.86	0.9		0.18	1.4	2.17	3.06
40.0	96.35	43.8	0.86	0.9		0.18	1.4	2.17	3.06
42.0	96.25	65.6	1	1	0	0.28	1.5	2.27	3.16
44.0	96.15	65.6	1	1	0.1	0.38	1.6	2.37	3.26
46.0	95.75	65.6	1	1	0.5	0.78	2	2.77	3.66
48.0	95.55	65.6	1	1	0.7	0.98	2.2	2.97	3.86
50.0	95.45	65.6	1	1	0.8	1.08	2.3	3.07	3.96
52.0	95.65	65.6	1	1	0.6	0.88	2.1	2.87	3.76
54.0	95.55	65.6	1	1	0.7	0.98	2.2	2.97	3.86
55.5	95.45	65.6	1	1	0.8	1.08	2.3	3.07	3.96
57.0	95.55	65.6	1	1	0.7	0.98	2.2	2.97	3.86
58.5	95.45	65.8	1	1	0.8	1.08	2.3	3.07	3.96
60.0	95.55	65.8	1	1	0.7	0.98	2.2	2.97	3.86
61.5	95.85	65.8	1	1	0.4	0.68	1.9	2.67	3.56
63.0	95.55	65.8	1	1	0.7	0.98	2.2	2.97	3.86
64.5	95.6	65.8	1	1	0.65	0.93	2.15	2.92	3.81
66.0	95.85	65.8	1	1	0.4	0.68	1.9	2.67	3.56
68.0	96.25	65.8	1	1	0	0.28	1.5	2.27	3.16
70.0	95.95	65.8	1	1	0.3	0.58	1.8	2.57	3.46
72.0	96.25	65.8	1	1	0	0.28	1.5	2.27	3.16
74.0	96.85	65.8	1	1			0.9	1.67	2.56
76.0	96.95	65.8	1	1			0.8	1.57	2.46
78.0	97.05	65.8	1	1			0.7	1.47	2.36
80.0	96.55	65.8	1	1			1.2	1.97	2.86
82.0	96.9	65.8	1	1			0.85	1.62	2.51
84.0	96.55	65.8	1	1			1.2	1.97	2.86
86.0	97.25	65.8	1	1			0.5	1.27	2.16

Table 4.3-7
Summary of Bed Elevation and Water Surface Elevations for Tailrace Instream Flow Study, Packwood Hydroelectric Project, Transect 6

WSE (ft) *Discharge (cfs)* *Station*	*Elevation (ft)*	*Slubstrate*	*HSI Value* *Salmon*	*HSI Value* *Steelhead*	*96.25* *2.5* *Depth(ft)*	*96.53* *11.07* *Depth(ft)*	*97.75* *158.58* *Depth(ft)*	*98.52* *368.95* *Depth(ft)*	*99.41* *750* *Depth(ft)*
88.0	97.75	25.8	0	0			0	0.77	1.66
89.1	98.52	64.7	1	1				0	0.89
92.7	99.72	57.8	0.9	0.86					
100.1	100.26	65.8	1	1					
100.1	101.11	25.8	0	0					

Figure 4.3-7 Tailrace Slough Transect 8 and Spawning Substrate HSI

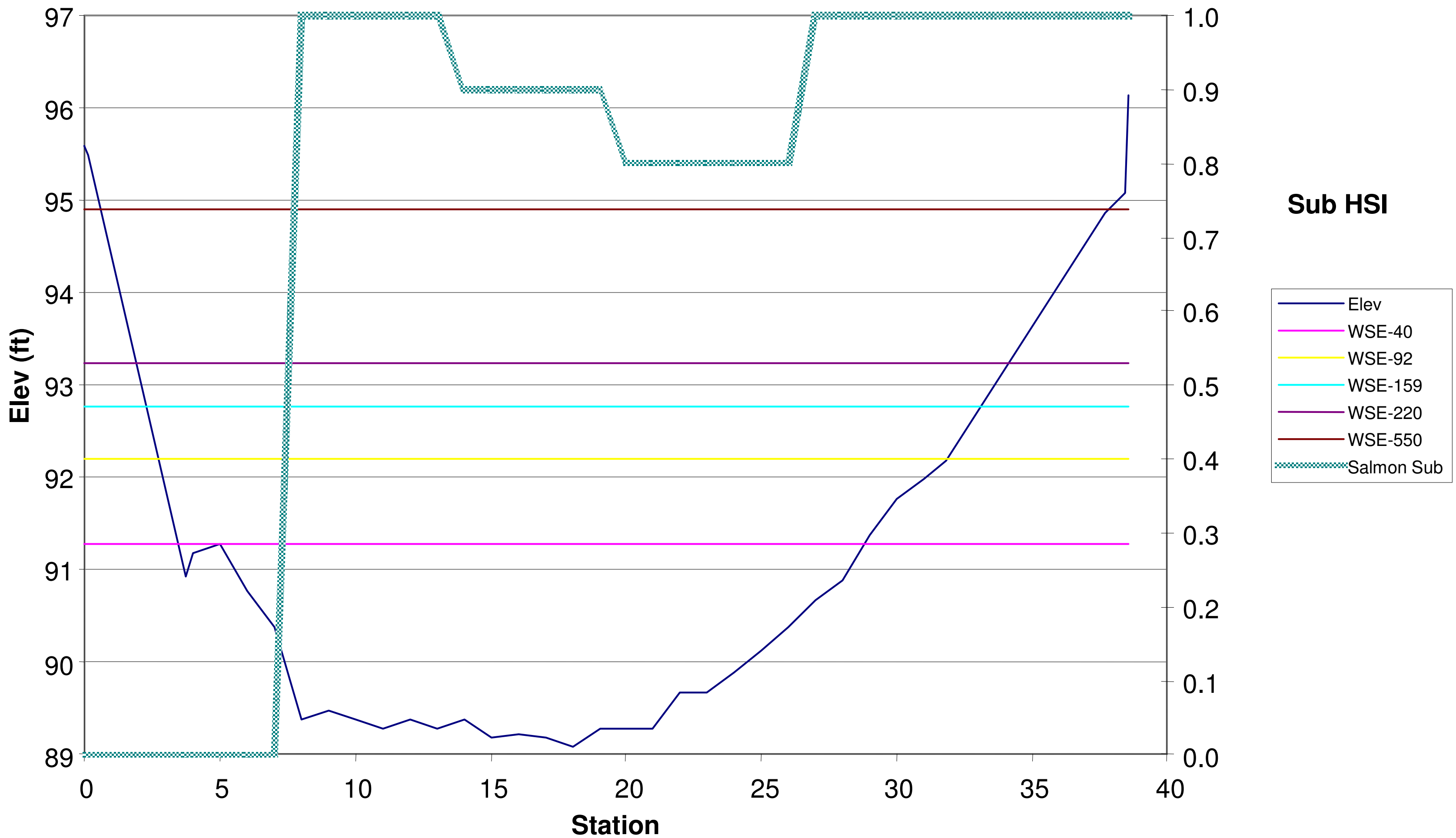


Table 4.3-8
Summary of Bed Elevation and Water Surface Elevations for Tailrace Instream Flow Study, Packwood Hydroelectric Project, Transect 8

WSE (ft) Discharge (cfs) Station	*Elevation (ft)*	*Substrate*	*HSI Value Salmon*	*HSI Value Steelhead*	*91.28 40 Depth(ft)*	*92.2 102.21 Depth(ft)*	*92.76 159 Depth(ft)*	*93.23 220 Depth(ft)*	*94.91 550 Depth(ft)*
0	95.58	88.9	0	0					
0.1	95.5	88.9	0	0					
3.7	90.93	88.9	0	0	0.35	1.27	1.83	2.3	3.98
4	91.18	88.9	0	0	0.1	1.02	1.58	2.05	3.73
5	91.28	88.9	0	0	0	0.92	1.48	1.95	3.63
6	90.78	88.9	0	0	0.5	1.42	1.98	2.45	4.13
7	90.38	88.9	0	0	0.9	1.82	2.38	2.85	4.53
8	89.38	65.7	1	1	1.9	2.82	3.38	3.85	5.53
9	89.48	65.7	1	1	1.8	2.72	3.28	3.75	5.43
10	89.38	65.7	1	1	1.9	2.82	3.38	3.85	5.53
11	89.28	65.7	1	1	2	2.92	3.48	3.95	5.63
12	89.38	65.7	1	1	1.9	2.82	3.38	3.85	5.53
13	89.28	65.7	1	1	2	2.92	3.48	3.95	5.63
14	89.38	67.8	0.9	0.86	1.9	2.82	3.38	3.85	5.53
15	89.18	67.8	0.9	0.86	2.1	3.02	3.58	4.05	5.73
16	89.23	67.8	0.9	0.86	2.05	2.97	3.53	4	5.68
17	89.18	67.8	0.9	0.86	2.1	3.02	3.58	4.05	5.73
18	89.08	67.8	0.9	0.86	2.2	3.12	3.68	4.15	5.83
19	89.28	67.8	0.9	0.86	2	2.92	3.48	3.95	5.63
20	89.28	67.6	0.8	0.72	2	2.92	3.48	3.95	5.63
21	89.28	67.6	0.8	0.72	2	2.92	3.48	3.95	5.63
22	89.68	67.6	0.8	0.72	1.6	2.52	3.08	3.55	5.23
23	89.68	67.6	0.8	0.72	1.6	2.52	3.08	3.55	5.23
24	89.88	67.6	0.8	0.72	1.4	2.32	2.88	3.35	5.03
25	90.13	67.6	0.8	0.72	1.15	2.07	2.63	3.1	4.78
26	90.38	67.6	0.8	0.72	0.9	1.82	2.38	2.85	4.53
27	90.68	56.7	1	1	0.6	1.52	2.08	2.55	4.23
28	90.88	56.7	1	1	0.4	1.32	1.88	2.35	4.03
29	91.38	56.7	1	1		0.82	1.38	1.85	3.53
30	91.78	56.7	1	1		0.42	0.98	1.45	3.13
31	91.98	56.7	1	1		0.22	0.78	1.25	2.93
31.8	92.18	56.7	1	1		0.02	0.58	1.05	2.73
37.7	94.87	56.8	1	1					0.04
38.45	95.08	56.8	1	1					
38.55	96.14	56.8	1	1					

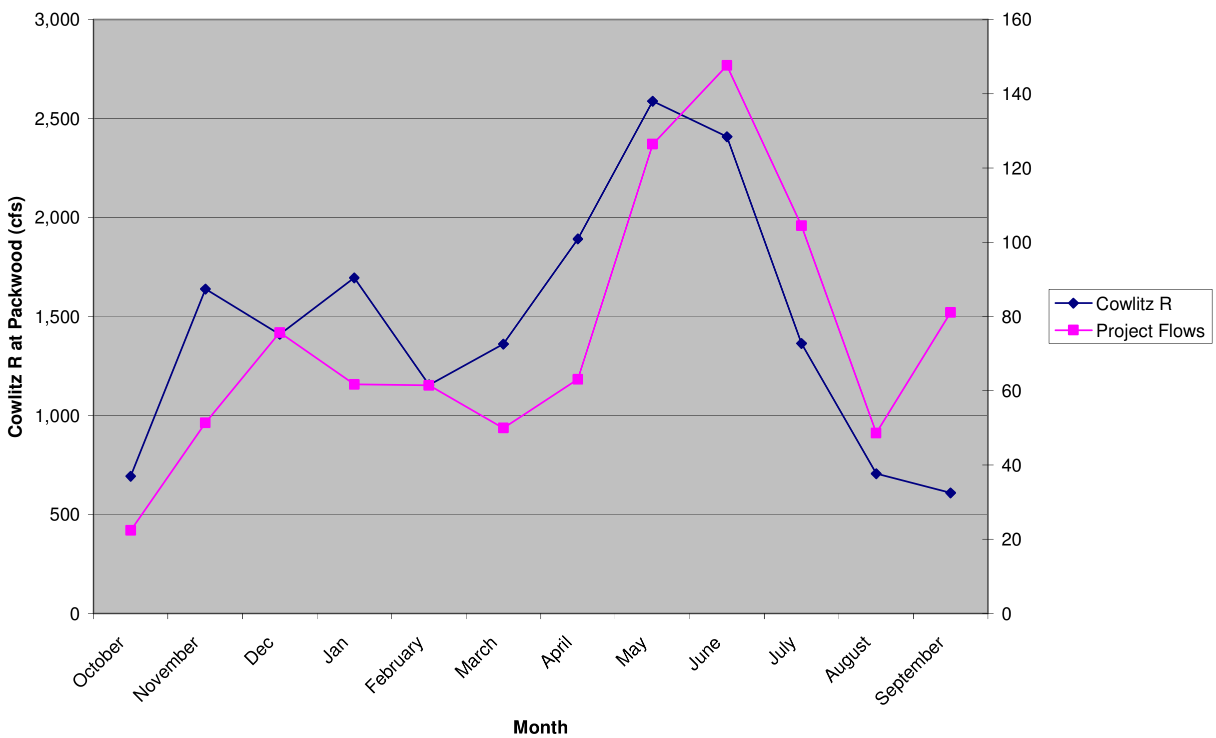
4.4 Upper Cowlitz River and Project Flows and Effects on Target Species

4.4.1 Cowlitz River and Project Flows

EES Consulting previously reviewed upper Cowlitz River and Project flows for the period 2000 – 2004 in order to determine when redds were most susceptible to dewatering. These figures are included as Appendix D.

Monthly mean flows for the Cowlitz River at Packwood and the Project for the years 2000 – 2004 are presented in Figure 4.5-1.

Figure 4.4-1 Mean Monthly Flows, Cowlitz R and Packwood Lake Project, 2000 - 2004



Project flows generally follow Cowlitz River flows, with one notable exception. Project flows in September are higher than would be expected due to scheduled Project shutdown and maintenance in October. After September 15, the Project is not required to hold lake elevation to 2857.0 +/- 0.5 ft MSL. The Project typically runs to full capacity after September 15 in order to lower Packwood Lake to the lowest elevation allowed (El 2849.0 ft MSL) to prepare for the annual shutdown. The process allows the project to create margin in order to minimize overtopping spills during the shutdown. This results in higher project discharge flows than would be normal, based on natural lake inflows, for that period in September.

4.4.2 Effects of Flows on Target Species

EES Consulting examined the effects of flows on spawning and incubation of target species, with an objective of evaluating the effects of planned Project shutdowns on incubating eggs in the tailrace slough. Below is a summary of expected impacts on target species with the current scheduled outage in October.

Coho Salmon

- Peak spawning occurs in January and February.
- Cowlitz River flows decrease in February before increasing again in March.
- Project shutdown as scheduled **will not impact coho salmon redds**

Cutthroat Trout

- Peak spawning occurs in January and February.
- Cowlitz River flows decrease in February before increasing again in March.
- Project shutdown as scheduled **will not impact cutthroat trout redds**

Steelhead Trout

- Peak spawning occurs in April and May.
- Cowlitz River flows peak in June and begin to decrease until September.
- Project shutdown as scheduled **will not impact steelhead trout redds**

Rainbow Trout

- Peak spawning occurs from mid- May until the end of June
- Cowlitz River flows peak in June and begin to decrease until September
- Project shutdown as scheduled **will not impact rainbow trout salmon redds**

Spring Chinook Salmon

- Peak spawning is from August– September
- Cowlitz River and Project flows are highest in May and June, decreasing through September
- Project shutdown as scheduled **potentially impacts Spring Chinook salmon incubating eggs, depending upon tailrace slough configuration**.

Based on this assessment, Project shutdown in October has the potential to negatively impact incubating Spring Chinook salmon eggs deposited in the tailrace slough, if the tailrace slough is receiving inadequate flow from the Cowlitz River to support spawning and is entirely dependent on water from the project tailrace.

4.5 Evaluation of Tailrace Slough Flows on Spawning Chinook Salmon Eggs

4.5.1 Calculation of Flows for Analysis

Under the current operational regime, Spring Chinook salmon incubating eggs are the most susceptible to dewatering and desiccation. EES Consulting, in consultation with Dr. Hal Beecher of WDFW, analyzed the impacts on incubating eggs during the months of July, August, September and October. For purposes of this analysis, the years 2003 – 2006 were used, and the monthly 20%, 50%, and 80% flow exceedance values were examined for the Cowlitz River, tailrace slough and Project flows (J Blum, personal communication with Dr. H.A. Beecher, WDFW, May 3, 2007). Exceedance values are calculated by sorting the monthly flows in order. The highest evaluated flow is the 20% exceedance flow, which is greater than 80% of the flows. The median flow is the 50% exceedance flow, while the 80% exceedance flow is only higher than 20% of the measured flows during that period of time for the Cowlitz River, tailrace slough, and the Project.

The following analysis was conducted:

1. The monthly 20%, 50%, and 80% flow exceedance values were calculated for the Cowlitz River at Packwood and the Project flows. Years were grouped from 2003 – 2006 for the flow exceedance values, and 2006 was run independently as well. 2006 was run separately because the study was conducted in that year, and the regression analyses were developed for flow conditions in 2006.
2. The proportion of the Cowlitz River diverted to the tailrace slough was calculated using *Equation (1)*.
3. The Project flow was then added to the amount of water from the Cowlitz River to arrive at a total tailrace slough flow.
4. The proportion of the total tailrace slough flow diverted through the left channel was calculated using *Equation (2).*

Note: Flow conditions in the tailrace slough have changed every year. Since 2004, the tailrace slough configuration has changed four times: in the fall 2004; in the fall 2005; in the fall 2006, and in the spring 2007. In 2004, 2006 and 2007, Cowlitz River flows configured the tailrace slough as to make it dependent upon the Project in low flow conditions. In 2005, however, a much larger percentage of the Cowlitz River was diverted into the slough, and it was not dependent upon the Project at all in the fall. Appendix E shows photos of the tailrace slough after the November 2006 flood event.

Tables 4.5-1 – 4.5-4 summarize the flows used to analyze potential spawning areas of Transects 1 – 4, 6, and 8.

Table 4.5-1
Flow Exceedance Values (in cfs) for July 2003 – 2006, Cowlitz River and Tailrace Slough

% Exceedance	*2003-2006*				*2006*			
	Cowlitz River	*Slough*	*Plant*	*Left Channel*	*Cowlitz River*	*Tailrace Slough* [1/]	*Plant*	*Left Channel*
10%	1,560	115	141	163	2460	231	188	319
20%	1,350	88	122	118	1940	164	135	204
30%	1,180	66	113	89	1490	106	123	137
40%	1,120	58	95	64	1340	86	122	117
50%	1,020	45	84	42	1160	63	111	84
60%	921	32	76	22	1080	53	94	59
70%	846	23	64	1	1020	45	86	43
80%	691	2	56	0	939	35	58	7
90%	590	0	52	0	878	27	58	0

[1/] Waters from the Cowlitz River; does not include Project flows.

Table 4.5-2
Flow Exceedance Values (cfs) for August 2003 – 2006, Cowlitz River and Tailrace Slough

% Exceedance	*2003-2006*				*2006*			
	Cowlitz River	*Slough*	*Plant*	*Left Channel*	*Cowlitz River*	*Tailrace Slough* [1/]	*Plant*	*Left Channel*
10%	820	19	67	1	695	3	56	0
20%	698	3	54	0	684	2	47	0
30%	660	0	49	0	660	0	45	0
40%	633	0	45	0	656	0	45	0
50%	601	0	43	0	629	0	44	0
60%	539	0	42	0	611	0	44	0
70%	499	0	41	0	601	0	43	0
80%	466	0	37	0	588	0	42	0
90%	436	0	0	0	500	0	32	0

[1/] Waters from the Cowlitz River; does not include Project flows.

Table 4.5-3
Flow Exceedance Values (cfs) for September 2003 – 2006, Cowlitz River and Tailrace Slough

% Exceedance	*2003-2006*				*2006*			
	Cowlitz River	*Slough*	*Plant*	*Left Channel*	*Cowlitz River*	*Slough*	*Plant*	*Left Channel*
10%	1190	67	213	185	570	0	199	108
20%	616	0	153	64	551	0	153	64
30%	544	0	104	17	510	0	95	9
40%	496	0	82	0	484	0	57	0
50%	447	0	54	0	447	0	39	0
60%	395	0	46	0	422	0	38	0
70%	354	0	41	0	402	0	37	0
80%	298	0	36	0	387	0	36	0
90%	253	0	0	0	354	0	31	0

Table 4.5-4
Flow Exceedance Values (cfs) for October 2003 – 2006, Cowlitz River and Tailrace Slough.
All values are in cfs

% Exceedance	2003-2006				2006			
	Cowlitz River	*Slough*	*Plant*	*Left Channel*	*Cowlitz River*	*Slough*	*Plant*	*Left Channel*
10%	1660	128	11	51	582	0	34	0
20%	1140	61	0	0	370	0	0	0
30%	825	20	0	0	340	0	0	0
40%	611	0	0	0	325	0	0	0
50%	529	0	0	0	306	0	0	0
60%	454	0	0	0	294	0	0	0
70%	372	0	0	0	274	0	0	0
80%	328	0	0	0	271	0	0	0
90%	294	0	0	0	255	0	0	0

4.5.2 Analysis of Spawning and Incubation Flows

4.5.2.1 Left Channel Transects

EES Consulting analyzed substrate composition of the calibration transects at the 20%, 50%, and 80% exceedance flows for the months and years already discussed. In order for the substrates to be considered viable for spawning, water depth needed to be ≥ 0.5 ft over the substrate at the given flow. EES Consulting then ran a sensitivity analysis to determine the protection level afforded by decreasing flows over the substrate. For incubating eggs to be protected, the depth of water over the substrate needed to be ≥ 0.1 ft.

Table 4.5-5 summarizes those spawning flows analyzed in the left channel of the tailrace slough. Transects 1 – 4 and 6 were analyzed. During much of the time, including all of August and October, flows in the Cowlitz River were so low as to not contribute to the tailrace slough. These flows are natural and are not affected by the Project. During this period of time, the Project would need to be running at 90 cfs (see Equation 2) just to contribute 1 cfs to the left channel. This exceeds the mean monthly project flows from August through October (see Figure 4.5-1).

Table 4.5-5
Spawning Flows (cfs) Analyzed in Left Channel, Tailrace Slough (Transects 1-4, 6)

July	*2003 - 2006*	*2006*		*September*	*2003 – 2006*	*2006*
%Exceedance	*Flow*	*Flow*		*%Exceedance*	*Flow*	*Flow*
20%	118	204		20%	64	64
50%	42	84		50%	0	0
80%	0	7		80%	0	0
August	*2003 - 2006*	*2006*		*October*	*2003 – 2006*	*2006*
%Exceedance	*Flow*	*Flow*		*%Exceedance*	*Flow*	*Flow*
20%	0	0		20%	0	0
50%	0	0		50%	0	0
80%	0	0		80%	0	0

Table 4.5-6 summarizes the percent exceedance, the spawning flow associated with that flow, and the flows that corresponded to protecting from 50% to 100% of the incubating eggs at the spawning flow in the left channel of the tailrace slough.

4.5.2.2 Tailrace Slough Immediately below the Tailrace

EES Consulting analyzed Project flows that directly affected the habitat immediately below the tailrace (Transect 8). Table 4.5-7 summarizes those spawning flows analyzed. Table 4.5-8 summarizes the percent exceedance, the spawning flow associated with that flow, and the flows that corresponded to protecting from 50% to 100% of the incubating eggs at the spawning flow in the left channel of the tailrace slough.

Table 4.5-6
Spawning Flows (cfs) and the Incubation Flows (cfs) that Protect Spawnable Chinook Salmon Substrate in the Left Channel of the Tailrace Slough

				Incubation Flow (cfs) and % protection of spawnable substrate						
Month	*Period*	*% Exceedance*	*Spawning Flow (cfs)*	*100%*	*95%*	*90%*	*80%*	*70%*	*60%*	*50%*
July	2003-2006	20%	118	85	37	27	14	10	4	1
		50%	42	15	10	5	3	1	1	1
		80%	0	0	0	0	0	0	0	0
	2006	20%	204	115	91	70	45	18	12	5
		50%	84	35	20	16	12	6	3	1
		80%	7	1						
August	2003-2006	20%	0	0						
		50%	0	0						
		80%	0	0						
	2006	20%	0	0						
		50%	0	0						
		80%	0	0						
September	2003-2006	20%	64	25	17	14	11	5	2	1
		50%	0	0						
		80%	0	0						
	2006	20%	64	25	17	14	11	5	2	1
		50%	0	0						
		80%	0	0						
October	2003-2006	20%	0	0						
		50%	0	0						
		80%	0	0						
	2006	20%	0	0						
		50%	0	0						
		80%	0	0						

Table 4.5-7
Spawning Flows (cfs) Analyzed Immediately Below the Tailrace (Transect 8)

July % Exceedance	*2003 - 2006 Flow*	*2006 Flow*		*September % Exceedance*	*2003 – 2006 Flow*	*2006 Flow*
20%	122	135		20%	153	153
50%	84	113		50%	54	39
80%	56	58		80%	36	34
August % Exceedance	*2003 - 2006 Flow*	*2006 Flow*		*October % Exceedance*	*2003 – 2006 Flow*	*2006 Flow*
20%	153	153		20%	0	0
50%	54	39		50%	0	0
80%	36	34		80%	0	0

4.5.3 Flows Required to Maintain Incubating Eggs

Table 4.5-6, shown in the previous section, shows the 20%, 50% and 80% flow exceedance values for the months and years examined, and the level of protection for potentially incubating eggs at various flow levels.

Table 4.5-9 back calculates the amount of flow required from the Cowlitz River and/or the Project to provide the 100% level of protection of incubating eggs. For purposes of this analysis, EES Consulting bracketed the amount of flow required in 25% increments (e.g., when the Cowlitz River provided 100%, 75%, 50%, 25% and no water for the left channel, with the Project providing the complementary component). For example, if the 20% exceedance flow for the 2003 – 2006 September period were 64 cfs in the left channel of the tailrace slough, 25 cfs would be required in order to afford 100% protection of those eggs. This level could be achieved by the Cowlitz River at Packwood having a flow of 1,533 cfs, with no Project contribution. On the other hand, if the flow in the Cowlitz was less than 625 cfs, the Project providing a flow of 112 cfs would afford the same level of protection. In the areas between these two extremes, the Project could contribute 84 cfs if the Cowlitz River flows were at least 887 cfs. Conversely, if the Project was producing power with 56 cfs, the Cowlitz River flow would need to be at least 1,102 cfs in order to provide 100% protection of incubating eggs.

Table 4.5-8
Spawning Flows (cfs) and the Incubation Flows (cfs) that Protect Spawnable Chinook Salmon Substrate Immediately Below the Project Tailrace (Transect 8)

				Incubation Flows to Protect % of Eggs						
Month	*Period*	*% Exceedance*	*Spawning Flow (cfs)*	*100%*	*95%*	*90%*	*80%*	*70%*	*60%*	*50%*
July	2003-2006	20%	122	80	35	20	13.7	3.8	1	
		50%	84	50	30	20	8.8	2.7	1	
		80%	56	30	20.6	15.5	4.7	1.5		
	2006	20%	135	95	79	49	18	4	1	
		50%	113	80	35	20	13.7	3.8	1	
		80%	58	30	20.6	15.5	4.7	1.5		
August	2003-2006	20%	54	30	20.6	15.5	4.7	1.5		
		50%	43	20	11.1	10	3.3	1		
		80%	37	20	11.1	10	3.3	1		
	2006	20%	47	30	20.6	15.5	4.7	1.5		
		50%	44	30	20.6	15.5	4.7	1.5		
		80%	42	20	11.1	10	3.3	1		
September	2003-2006	20%	153	110	108	106	76	18	5	1
		50%	54	30	20.6	15.5	4.7	1.5		
		80%	36	20	11.1	10	3.3	1		
	2006	20%	153	110	108	106	76	18	5	1
		50%	39	20	11.1	10	3.3	1		
		80%	34	17	9.7	4.8	2	1		
October	2003-2006	20%	0							
		50%	0							
		80%	0							
	2006	20%	0							
		50%	0							
		80%	0							

Table 4.5-9
Cowlitz River at Packwood and Project Flows Required to Protect 100% of Spring Chinook Spawning Habitat in the Left Channel of the Tailrace Slough[1/]

Month	*Period*	*% Exceedance*	*Flow (cfs)*		*Percent Protected*	*Cowlitz*	*Cowlitz*	*Project*	*Cowlitz*	*Project*	*Cowlitz*	*Project*	*Project*
			Spawning	*Incubation*		***100%***	***75%***	***25%***	***50%***	***50%***	***25%***	***75%***	***100%***
July	2003-2006	20%	118	85	100%	2,018	1,682	44	1,345	87	843	152	175
				37	95%	1,630	1,390	31	1,151	62	911	93	124
				27	90%	1,549	1,330	28	1,110	57	891	85	114
				14	80%	1,444	1,251	25	1,058	50	864	75	100
				10	70%	1,412	1,227	24	1,041	48	856	72	96
				4	60%	1,363	1,190	22	1,017	45	844	67	90
				1	50%	1,339	1,172	22	1,005	43	838	65	87
		50%	42	15	100%	1,452	1,257	25	1,062	51	866	76	101
				10	95%	1,412	1,227	24	1,041	48	856	72	96
				5	90%	1,371	1,196	23	1,021	45	846	68	91
				3	80%	1,355	1,184	22	1,013	44	842	67	89
				1	70%	1,339	1,172	22	1,005	43	838	65	87
				1	60%	1,339	1,172	22	1,005	43	838	65	87
				1	50%	1,339	1,172	22	1,005	43	838	65	87
		80%	0	0									
July	2006	20%	204	115	100%	2,261	1,864	52	1,466	103	1,069	155	206
				91	95%	2,067	1,718	45	1,369	90	1,020	136	181
				70	90%	1,897	1,591	40	1,284	79	978	119	159
				45	80%	1,695	1,439	33	1,183	66	927	100	133
				18	70%	1,477	1,275	26	1,074	52	872	78	104
				12	60%	1,428	1,239	25	1,050	49	860	74	98
				5	50%	1,371	1,196	23	1,021	45	846	68	91
		50%	84	35	100%	1,614	1,378	31	1,143	61	907	92	122
				20	95%	1,493	1,287	27	1,082	53	876	80	106
				16	90%	1,460	1,263	26	1,066	51	868	77	102
				12	80%	1,428	1,239	25	1,050	49	860	74	98
				6	70%	1,380	1,202	23	1,025	46	848	69	92
				3	60%	1,355	1,184	22	1,013	44	842	67	89
				1	50%	1,339	1,172	22	1,005	43	838	65	87
		80%	0	0		0							0

Table 4.5-9
Cowlitz River at Packwood and Project Flows Required to Protect 100% of Spring Chinook Spawning Habitat in the Left Channel of the Tailrace Slough[1/]

Month	*Period*	*% Exceedance*	*Flow (cfs)*		*Percent Protected*	*Cowlitz*	*Cowlitz*	*Project*	*Cowlitz*	*Project*	*Cowlitz*	*Project*	*Project*
			Spawning	*Incubation*		***100%***	***75%***	***25%***	***50%***	***50%***	***25%***	***75%***	***100%***
August	2003-2006	20%	0	0		0							0
		50%	0	0		0							0
		80%	0	0		0							0
	2006	20%	0	0		0							0
		50%	0	0		0							0
		80%	0	0		0							0
September	2003-2006 and 2006	20%	64	25	100%	1,533	1,318	28	1,102	56	887	84	112
				17	95%	1,468	1,269	26	1,070	52	870	78	103
				14	90%	1,444	1,251	25	1,058	50	864	75	100
				11	80%	1,420	1,233	24	1,045	49	858	73	97
				5	70%	1,371	1,196	23	1,021	45	846	68	91
				2	60%	1,347	1,178	22	1,009	44	840	66	88
				1	50%	1,339	1,172	22	1,005	43	838	65	87
October	2003-2006	20%	0	0		0							0
		50%	0	0		0							0
		80%	0	0		0							0
	2006	20%	0	0		0							0
		50%	0	0		0							0
		80%	0	0		0							0

[1/] Based upon analysis of Transects 1 – 4 and 6 and channel configuration as measured during summer 2006.

5.0 DISCUSSION

The results of the tailrace spawning surveys, habitat use and presence surveys and the Tailrace Slough Instream Flow study were examined. Records of Project operations and its effects on salmonid habitat within the tailrace were also reviewed and analyzed to determine potential impacts on spawning salmonids in this area.

As stated several times in this report, the tailrace slough is a complex, dynamic environment that may remain stable or change many times during the course of a year. The analysis presented in this report represents a type of analysis that could be performed to analyze the effects of the Project, and reflects conditions as present during the summer 2006. Since then, the tailrace slough channel has changed twice and it is certain that it will change many more times in the future. As a result, the numerical values cited in this report are no longer valid for the tailrace slough.

In some years, the Cowlitz River does not provide much or any water to the tailrace slough during spawning periods, especially in late August – October for Spring Chinook salmon. Project flows typically mirror conditions in the upper Cowlitz River; in these instances, unless the Project flows are sufficient to provide an attractant flow, Project operations will not likely attract fish for spawning. If this hypothesis holds, then Project flows are not required for protection of incubating eggs in this scenario, because the tailrace slough would be dry without the Project. It is important to acknowledge that the Project tailrace discharge is ordinarily a very small percentage of the overall Cowlitz River flows. Accordingly, the Cowlitz River exerts a much greater influence on the entire area's available spawning habitat than Project tailrace outflows.

Energy Northwest may consider changing the timing of the annual outage. However, it is likely that any changes in scheduling the outage will depend upon instream flow and timing in Lake Creek as well as lake level requirements of Packwood Lake. Results from the Lake Creek instream flow and fisheries investigations and possible changes in lake level requirements would need to be reviewed and integrated with the results of this study before any decision could be made on options for protecting incubating eggs in the tailrace slough area.

6.0 LITERATURE CITED

Bovee, K.D. 1982. A Guide to Stream Habitat Analysis Using the Instream Flow Incremental Methodology. Instream Flow Information Paper #12. U.S. Fish & Wildlife Service, Fort Collins, Colorado.

EES Consulting. 2004. Draft Study Plan, Lake Creek Instream Flow Study and Habitat Assessment, 401 Water Quality Certification. Prepared for Energy Northwest, For the Packwood Lake Hydroelectric Project (FERC No. 2244). Bellingham, WA. June 2004.

EES Consulting. 2007a. Packwood Lake Hydroelectric Project (FERC No. P-2244), Anadromous Salmonid Habitat and Spawner Survey Report. Bellingham, WA. April 2007.

EES Consulting. 2007b. Draft, Lake Creek Instream Flow Study Report for Energy Northwest's Packwood Lake Hydroelectric Project, FERC No. 2244, Lewis County, Washington. Prepared for Energy Northwest. Bellingham, WA June 2007.

EES Consulting, 2005. Revised Tailrace Slough Instream Flow Study Plan for Energy Northwest's Packwood Lake Hydroelectric Project. Bellingham, WA. August 22, 2005.

Morlock, S.E. 1996. Evaluation of Acoustic Doppler Current Profiler Measurement of River Discharge. U.S. Geological Survey, Water Resources Investigations Report 95-4218. Indianapolis Indiana.

Payne, T.R. 2003. The Influence of Multiple Calibration Velocity Sets on the PHABSIM Habitat Index. IFIM Users Workshop. Ft. Collins, CO. June 2003.

Trihey, E.W., and David Wegner. 1981. Field Data Collection Procedures for Use with the Habitat Simulation System of the Instream Flow Group. U.S. Fish and Wildlife Service, Fort Collins, Colorado

Washington Department of Fish and Wildlife and Washington Department of Ecology (WDFW/WDOE). 2004. Instream Flow Guidelines Update. Olympia WA. April 2004.