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1.0 INTRODUCTION

Energy Northwest’s Packwood Lake Hydroelectric Project, FERC No. 2244 (Project), received its initial license in 1960. The majority of the Project is located in the Gifford Pinchot National Forest (Figure 1-1). 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, and powerhouse with a 26,125 kW turbine generator. Project and controlled release flows to lower Lake Creek go through a screened intake. When lake elevation exceeds 2858.5 ft Mean Sea Level (MSL), water spills over the drop structure. There is no upstream fish passage and downstream fish passage only occurs during spill events.

The source of water for the Project, Packwood Lake, which pre-existed the Project, is situated at an elevation of approximately 2,857 ft 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.
During the period May 1 through September 15, Packwood Lake is maintained at approximately elevation (2,857 feet MSL). During the remainder of the year, the existing FERC license allows lowering the lake level not more than eight feet below the summer lake level down to an elevation of 2,849 feet MSL.

Figure 1-2 is a photograph of the drop structure; Figure 1-3 is a diagram of the drop structure; and Figure 1-4 is a plan view of the stilling apron.
Figure 1-4
Plan View of the Stilling Apron
1.1 Goals and Objectives

This study characterized the abundance, distribution, movement, and structure of the fish communities and available habitat that are potentially impacted by the Packwood Lake Hydroelectric Project drop structure.

The objective of the Fish Population Characterization Near the Drop Structure (Fish Characterization) study was to provide the stakeholders with information to assess potential drop structure impacts on fish populations in Project affected waters to allow them to make informed decisions on the management of the fish communities near the drop structure.

Specific study goals included the following:

1. Determine the location of the first fish passage barrier waterfall downstream of the drop structure, thereby delineating the isolated reach of Lake Creek. The isolated reach was defined here as the reach from the drop structure downstream to the first barrier waterfall.
2. Determine the amount of suitable spawning and rearing habitat available for rainbow and cutthroat trout and other fish species within the isolated reach.
3. Determine the fish species present within the isolated reach.
4. Determine the population size and age/size structure of all fish species within the isolated reach.
5. Determine upstream migration timing (spawning, foraging, and other movement) of rainbow and cutthroat trout and other fish species within the isolated reach.

2.0 STUDY AREA AND METHODS

As identified in the study plan, the study area was to be that portion of Lake Creek between the uppermost natural barrier to resident fish and the drop structure. The first natural barrier was identified to be 1464 feet downstream of the drop structure which is located at RM 5.4. This location is consistent with earlier physical habitat surveys conducted by EES Consulting in 2004 (EES Consulting 2004), which indicated that the barrier was approximately 1,200 feet below the drop structure.

2.1 Methodology

List of 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, ESA 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 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 PacificCorp. 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 seven 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 playing an integral role in all environmental components of relicensing efforts by EES 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 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.

- **Brian Johnson, EES Consulting, Inc. Field Biologist**

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

  Mr. Johnson presently is the field lead for spawner surveys for Energy Northwest’s relicensing of the Packwood Lake Hydroelectric Project. He both conducts and handles the field logistics of survey crews covering the Cowlitz River, Hall Creek, Snyder Creek, and Lake Creek. He is skilled at species and redd identification, 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.

  He has done additional fisheries field work throughout Washington State, Oregon, and California over the past 15 years.

- **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 all 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 Packwood Lake Hydroelectric Project. 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 the spawning Chinook population in the Methow and Okanogan river basins.

### 2.1.1 Analysis of Barrier to Upstream Passage

The protocol entitled, “Analysis of barriers to upstream fish migration. An investigation of the physical and biological conditions affecting fish passage success at culverts and waterfalls” (Powers and Orsborn 1985), was utilized to determine the location of the first barrier waterfall downstream of the drop structure. This protocol was modified to exclude the Fish Condition
Factor based on the recommendation of Pat Powers and his use of the protocol over the past 20 years (Powers, 2005). The barrier evaluation started immediately downstream of the drop structure and progressed downstream. The first potential fish passage barrier waterfall encountered was evaluated. Because this waterfall was determined to be a fish passage barrier, the survey ended at this point, (approximately RM 5.13). Species analysis began at this point.

It is important to note that Powers and Orsborn (1985) identify swimming speeds and leaping abilities for anadromous fish; however, this report does not address the leaping ability of resident rainbow and cutthroat trout. Bell (1991) lists swimming speeds for cutthroat trout, but not for rainbow trout. Energy Northwest proposed using the cutthroat trout cruising, sustained and darting speeds for both rainbow and cutthroat trout. As an alternative to creating leaping curves, EES Consulting used as criteria for resident salmonids a barrier height of 4 feet and suggests that a vertical falls in this range be considered a barrier for these species. Fish of this size were observed by EES Consulting leaping unsuccessfully at the falls/chute complex at RM 1.03 at released flows from the drop structure of 3 cfs, 17 cfs, and 35 cfs. Due to accretion between the drop structure and RM 1.03, flows at the site were higher. Maximum vertical leap of these fish into the falls did not exceed 1.5 feet.

### 2.1.2 Quantification of Rearing and Spawning Habitat

WDFW’s “Fish Passage Barrier Assessment and Prioritization Manual” of the Technical Applications Division (TAPPS 2000) was used to quantify spawning and rearing habitat. This protocol is widely accepted throughout Washington, and many local, state, and federal agencies and other groups have used, or are currently utilizing, the protocol. The protocol provides a standard method of data collection across the state and a means to prioritize fish passage barriers. The Priority Index Model portion of this protocol has been used in this study.

Although this protocol is usually used to assess manmade fish blockages, it is appropriate to use the Priority Index Model portion upstream of a natural fish passage barrier. The physical habitat assessment quantifies the amount of spawning and rearing habitat available to each salmonid species present at the site.

The model generates a priority index (PI) rating that is based on species utilization and habitat gain. The habitat gain was determined by measuring gradient, stream-wetted and ordinary high-water widths, substrate composition, riffle-to-pool-to-rapid ratios, juvenile abundance, canopy cover, instream cover, flow, temperature, and spring water influence. In order to identify the productive capability of the stream for the PI Model, Habitat Quality Modifiers (HQM) were assigned to each reach within the survey area (Table 2-1). The HQM rating is used as a multiplier of the habitat area to obtain H in the PI model (H = habitat quality modifier x habitat area in square meters).

The production potential of the stream was determined as square meters available for spawning and rearing habitat. The full physical survey methodology was utilized, as this provides for the most reliable information about the habitat upstream of the barrier.
Habitat was measured on 30 m sections of 160 m sections since the total stream length was less than 1.6 km. Three sites were established in the approximately 300 m section of stream above the first barrier. It was not necessary for the purpose of this study to perform an assessment of the downstream channel to determine if there are any fish passage barriers present. A hip chain was used to measure the total distance while walking upstream. Stream gradient was determined by the use of a laser level.

Once all data was collected and organized, the HQM value was applied to both wetted width and bankfull width numbers for all reaches related to both spawning and rearing habitat. A total amount of rearing and spawning habitat was derived for both wetted width and bankfull width criteria.

<table>
<thead>
<tr>
<th>Habitat Condition</th>
<th>HQM Value</th>
<th>Rearing Habitat Criteria</th>
<th>Spawning Habitat Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good to Excellent</td>
<td>1</td>
<td>Rearing habitat is stable and in a normal productive state with all components functional</td>
<td>Spawning gravel patches have ≤ 16% fine particle sizes that are &lt; 0.85mm in diameter</td>
</tr>
<tr>
<td>Fair</td>
<td>2/3</td>
<td>Rearing habitat shows moderate/widespread signs of instability and/or disturbance known to reduce productive capability (one or more habitat components missing or significantly reduced presence)</td>
<td>Spawning gravel patches/riffles show moderate/widespread signs of instability (scour/filling) and/or &gt; 16% and ≤ 21% fine particle sizes &lt; 0.85mm in diameter</td>
</tr>
<tr>
<td>Poor</td>
<td>1/3</td>
<td>Rearing habitat shows signs of major/widespread disturbance likely to cause major reductions in its production capabilities (two or more habitat components missing or severely reduced presence)</td>
<td>Spawning gravel patches/riffles show major/widespread signs of instability (scour/filling) and/or &gt; 21% and ≤ 26% fine particle sizes &lt; 0.85mm in diameter</td>
</tr>
<tr>
<td>No Value</td>
<td>0</td>
<td>Rearing habitat severely disturbed so that production capabilities are without value to salmonids at this time</td>
<td>Spawning gravel patches with &gt; 26% fine particle sizes &lt; 0.85mm in diameter</td>
</tr>
</tbody>
</table>

Sources: USFWS 2005 and USDA Forest Service 2005

The variety in costs, amounts of habitat gain, and species utilizing potential project sites throughout Washington State can make the characterization and prioritization of corrections to fish passage barriers complex. The WDFW Fish Passage Inventory process uses a Priority Index model to consolidate the many factors which affect a project’s feasibility (expected passage improvement, production potential of the blocked stream, fish stock health, etc.) into a manageable framework for developing prioritized lists of projects. The result is a numeric indicator giving each project’s relative priority that includes production benefits to both anadromous and resident salmonid species adjusted for sympatric species interactions (species complexes). The Priority Index (PI) for each barrier is calculated as follows:
\[ PI = \sum_{all\ species}^{4} \sqrt[4]{(BPH) \times MDC} \]

Where:

\( PI \) = Fish Passage Priority Index

- Relative project benefit considering cost.
- The PI is actually the sum (all species) of individual PI values, one of which is calculated for each species present in a stream (e.g., \( P_{\text{coho}} \) is added to \( P_{\text{chum}} \) to obtain \( P_{\text{all species}} \)).
- The quadratic root in the equation is used because it provides a more manageable number and represents a geometric mean of factors used.

\( B \) = Proportion of passage improvement

- Proportion of fish run expected to gain access due to the project (passability after project minus passability before project); gives greater weight to projects providing a greater margin of improvement in passage.
- Barriers are assumed to be partial and have a value of 0.67. Modifications to this approach can be applied with advanced levels of expertise.

\( P \) = Annual adult equivalent production potential per m\(^2\)

- Estimated number of adult salmonids that can potentially be produced by each m\(^2\) of habitat annually.
- The values (adults/m\(^2\)) are species specific; Chinook salmon = 0.016, chum salmon = 1.25, coho salmon = 0.05, pink salmon = 1.25, sockeye salmon = 3.00, steelhead = 0.0021, bull trout/Dolly Varden = 0.0007, searun cutthroat trout = 0.037, resident cutthroat/rainbow trout = 0.04, brook trout = 0.04, and brown trout = 0.0019.

\( H \) = Habitat gain in m\(^2\)

- Measured/calculated from physical survey; gives greater weight to projects which will make greater amounts of habitat available.
- Spawning area values used for species complexes normally limited by spawning habitat (sockeye, chum, and pink salmon) and rearing area values used for species complexes normally limited by rearing habitat [(coho salmon, searun cutthroat, Chinook salmon, and
steelhead) and (resident cutthroat/rainbow trout and bull trout/Dolly Varden) and (brook and brown trout).}

- When more than one species within a species complex is present H is modified to reflect sympatric interactions among species with similar freshwater life histories. The result is a reduction of single species habitat area values when competing species coexist.

**M = Mobility Modifier**

- Accounts for benefits to each fish stock for increased mobility (access to habitat being evaluated); gives greater weight to projects that increase productivity of species that are highly mobile and subject to geographically diverse recreational and commercial fisheries by providing access to habitat currently limited productivity.

  2 = Highly mobile stock subject to geographically diverse recreational and commercial fisheries (anadromous species).

  1 = Moderately mobile stock subject to local recreational fisheries (resident species).

  0 = Increased mobility of stock would have negative or undesirable impacts on productivity or would be contrary to fish management policy. By default, exotic salmonid such as brook trout and brown trout are assigned a 0 value unless they are the only salmonid species present in the system.

**D = Species Condition Modifier**

- Representations of status of species present; gives greater weight to less healthy species as listed in the *Washington State Salmon and Steelhead Stock Inventory (SASSI)* report (WDF et al. 1993) and *Washington Salmonid Stock Inventory, Bull Trout/Dolly Varden* (WDFW 1997). In the absence of a SASSI assignment, stock condition should be estimate using the best available information.

  3 = Condition of species considered critical.

  2 = Condition of species considered depressed or stock of concern.

  1 = species not meeting the conditions for 2 or 3.

**C = Cost Modifier**

- Representation of projected cost of project; gives greater weight to less costly projects.

  3 = incremental funds needed ≤ $100,000.

  2 = incremental funds needed >$100,000 and ≤$500,000.
1 = incremental funds needed >$500,000.

- All barriers receive a cost modifier value of 2 until engineering evaluations are completed.

The information from the fish passage priority index that resides in the fish passage and screening database is shown in Table 2-2.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>B= Proportion of passage improvement. Values can range between 0.1 and 1.0. This value is based on the % Passability estimate made for barrier features. A total barrier would have a value of 1 indicating a 100% improvement in fish passage if the barrier were corrected. Based on current barrier assessment methodologies input values should be; 0% passable = 1.0, 33% passable = 0.67, 67% passable = 0.33. These values can vary between species for a given barrier reflecting different swimming strengths.</td>
</tr>
<tr>
<td>P</td>
<td>P= annual adult equivalent production potential per m². Values are species specific. This is a read only field with the values being programmed into the form.</td>
</tr>
<tr>
<td>H</td>
<td>H= gain in production habitat (m²) above barrier. This value is taken from the adjusted production area table in the habitat assessment spreadsheet.</td>
</tr>
<tr>
<td>M</td>
<td>M=mobility modifier. Values include; 2 (anadromous species), 1 (resident species), and 0 (species whose increased mobility would have negative impacts to native species such as brook trout and brown trout). Default values have been programmed into the form. They can be changed if conditions require.</td>
</tr>
<tr>
<td>D</td>
<td>D= stock condition modifier. Valid entries include; 3 (stock status critical), 2 (stock status depressed or of concern), or 1 (stock status not meeting the conditions for 2 or 3).</td>
</tr>
<tr>
<td>C</td>
<td>C=cost modifier. Valid entries include; 3 (estimate project cost $100,000), 2 (estimated project costs &gt;$100,000 and &lt;$500,000, or 1 (estimated project costs &gt;$500,000).</td>
</tr>
<tr>
<td>PI Species</td>
<td>Species specific PI value. Read only, calculated by form.</td>
</tr>
<tr>
<td>PI Total</td>
<td>Sum of all species specific PI values. Read only, calculated by form.</td>
</tr>
</tbody>
</table>

2.1.3 Fisheries Investigations

Electrofishing was conducted following procedures identified by Reynolds (1996), which are commonly employed by fisheries biologists. Electrofishing was performed during non-spill periods to ensure the safety of the field crew.

Given that the habitat and species data collected for the Fish Characterization Below the Drop Structure Report will be incorporated into the Fish Species Distribution and Composition Study Report (completion April 2007); an effort was made to be consistent with the protocol employed on the other stream reaches. Three 30 m study sites (SS) were surveyed in the approximately 1464-foot section of stream below the drop structure on August 23, 2006. The entire isolated reach was electrofished during October, 2006 and again in May/June, 2007. Stream sections were isolated by using block nets. The field crew leap-frogged the block nets while moving upstream through the isolated reach.
The following information was recorded:

1. stream section captured
2. species
3. fork length (mm)
4. weight (gm)
5. Note of visible deformities or injuries, and eggs or milt present.

The multiple pass removal method was utilized. In addition, scales from a representative sample of the fish collected were selected and analyzed to determine ages of the fish. All fish were returned to the reach they were captured in, downstream of the block net.

In addition to other data analysis, a graph, by species, is included depicting weight and fork length. These graphs, along with scale analysis, will aid in the determination of age/year classes for the various fish species present.

2.1.4 Determination of Upstream Migration Timing (spawning, foraging and other movement) of Rainbow and Cutthroat Trout and Other Fish Species Within the Isolated Reach

In order to determine the upstream migration timing of rainbow, cutthroat, and other fish species potentially present in the isolated reach, the stilling apron area at the outlet pipe was sampled using a fyke net continuously from early July thru mid-October, 2006 and gill netted in March, 2007. Given the ability of fyke nets to retain captured fish, the net was checked every time a biologist came to the lake for any reason, (approximately twice per week). The dimensions of the stilling apron made seining techniques inefficient due to the amount of area that could not be netted correctly. Gill nets were also considered. However, because of the increased requirements related to maintenance and observation, it was determined that the use of a fyke net would be most efficient and least harmful. All captured fish were released immediately downstream of the stilling apron in suitable resting habitat. Visual counts of all fish in the apron area were made on each trip to provide additional information on fish species present below the drop structure.

2.1.5 Fish Presence Information in the Vicinity Upstream of the Drop Structure

A separate entrainment study is being conducted for the Project. Please see Packwood Lake Entrainment Study Report.

2.1.6 Literature Review of Potential Injury to Fish Below the Drop Structure During Spills

A literature review was conducted to determine the potential for injury or mortality to those fish that could pass over the drop structure during spill events. This information has been compared with the physical characteristics of the drop structure, depth of pools, distance of fall, etc. to determine the potential for injury if fish were to be swept over the drop structure during a spill event (Appendix B).
3.0 RESULTS

3.1 Analysis of Upstream Barrier

A barrier falls exists 1464 feet below the drop structure. The barrier was surveyed as a vertical falls of 11.80 ft as measured at a baseflow release of 3.5 cfs at the drop structure (Figure 3-1). This falls exceeds the leaping capability for rainbow trout and other resident fish found in Lake Creek. (Figures 3-1 and 3-2).

Figure 3-1
11.80 Ft. Barrier Falls Located 1464 Feet Below the Drop Structure
3.2 Quantification of Rearing and Spawning Habitat

Three 30 m study sites were surveyed in the approximately 1464-foot section of stream below the drop structure on August 23, 2006. Gradients ranged from 1.37% at SS1, (nearest the drop structure) to 3.63% at SS3, (just above the barrier). A distinct habitat break existed near SS2. A higher gradient (6.23%), much coarser substrate and short steep habitat units made this reach distinct. Spawning gravel at all 3 sites comprised less than 5% of the total substrate. Rearing habitat and cover were variable throughout the sites. Table 3-1 displays all the variables measured to adequately input habitat gain into the Priority Index Model. The associated substrate code is displayed in Appendix A.
Table 3-1
Rearing and Spawning Habitat Data for Lake Creek Below the Drop Structure

<table>
<thead>
<tr>
<th>Study Site #1</th>
<th>Gradient %</th>
<th>Spawning Gravel %</th>
<th>Rearing Habitat %</th>
<th>Instream Cover %</th>
<th>Canopy Cover %</th>
<th>Water Temp. (C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.37%</td>
<td>5%</td>
<td>70%</td>
<td>5%</td>
<td>1%</td>
<td>17.0</td>
</tr>
<tr>
<td>Distance (ft)</td>
<td>Unit Distance (ft)</td>
<td>Habitat</td>
<td>Substrate</td>
<td>Wetted Width (ft)</td>
<td>Bank Full Width (ft)</td>
<td></td>
</tr>
<tr>
<td>0-16</td>
<td>16</td>
<td>Glide</td>
<td>86.7</td>
<td>16.6</td>
<td>27.0</td>
<td></td>
</tr>
<tr>
<td>16-32</td>
<td>16</td>
<td>Run</td>
<td>68.6</td>
<td>17.9</td>
<td>32.0</td>
<td></td>
</tr>
<tr>
<td>32-98</td>
<td>66</td>
<td>Pool</td>
<td>65.7</td>
<td>20.6</td>
<td>38.0</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Study Site #2</th>
<th>Gradient %</th>
<th>Spawning Gravel %</th>
<th>Rearing Habitat %</th>
<th>Instream Cover %</th>
<th>Canopy Cover %</th>
<th>Water Temp. (C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6.23%</td>
<td>1%</td>
<td>30%</td>
<td>30%</td>
<td>20%</td>
<td>17.0</td>
</tr>
<tr>
<td>Distance (ft)</td>
<td>Unit Distance (ft)</td>
<td>Habitat</td>
<td>Substrate</td>
<td>Wetted Width (ft)</td>
<td>Bank Full Width (ft)</td>
<td></td>
</tr>
<tr>
<td>0-16</td>
<td>16</td>
<td>Glide</td>
<td>86.8</td>
<td>8.0</td>
<td>30.5</td>
<td></td>
</tr>
<tr>
<td>16-82</td>
<td>66</td>
<td>Run</td>
<td>86.7</td>
<td>16.6</td>
<td>34.5</td>
<td></td>
</tr>
<tr>
<td>82-98</td>
<td>16</td>
<td>Cascade</td>
<td>86.7</td>
<td>22.7</td>
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<tr>
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<th>Spawning Gravel %</th>
<th>Rearing Habitat %</th>
<th>Instream Cover %</th>
<th>Canopy Cover %</th>
<th>Water Temp. (C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3.63%</td>
<td>0%</td>
<td>70%</td>
<td>35%</td>
<td>8%</td>
<td>16.0</td>
</tr>
<tr>
<td>Distance (ft)</td>
<td>Unit Distance (ft)</td>
<td>Habitat</td>
<td>Substrate</td>
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<td>Bank Full Width (ft)</td>
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</tr>
<tr>
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<tr>
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<tr>
<td>21-31</td>
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<td>Run</td>
<td>86.9</td>
<td>24.3</td>
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<tr>
<td>31-73</td>
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<td>Glide</td>
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<td>51.3</td>
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<td>73-90</td>
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<td>86.7</td>
<td>29.0</td>
<td>38.8</td>
<td></td>
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3.2.1 Calculation of Fish Passage Priority Index

Once all data was collected and organized, the HQM value was applied to both wetted width and bankfull width numbers for all reaches related to both spawning and rearing habitat. A total amount of rearing and spawning habitat was derived for both wetted width and bankfull width criteria. Total wetted width and bankfull width habitat for rearing in the isolated reach was determined to be 395.0 m$^2$ and 797.6 m$^2$ respectively. Wetted width for spawning habitat was determined to be 9.1 m$^2$ and bankfull width for spawning was calculated to be 19.6 m$^2$ for the entire isolated reach (Tables 3-2 and 3-3).

<table>
<thead>
<tr>
<th>Study Site</th>
<th>Wetted Width Rearing Habitat (M2)</th>
<th>Modifier</th>
<th>Modified Rearing Value</th>
<th>Wetted Width Spawning Habitat (M2)</th>
<th>Modifier</th>
<th>Modified Spawning Value</th>
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</thead>
<tbody>
<tr>
<td>1</td>
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<td>124.3</td>
<td>8.88</td>
<td>0.67</td>
<td>5.92</td>
</tr>
<tr>
<td>2</td>
<td>44.22</td>
<td>0.67</td>
<td>29.5</td>
<td>1.47</td>
<td>0.33</td>
<td>0.49</td>
</tr>
<tr>
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<td>0.33</td>
<td>44.3</td>
<td>0.00</td>
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<table>
<thead>
<tr>
<th>Study Site</th>
<th>Wetted Width Rearing Habitat (M2)</th>
<th>Modifier</th>
<th>Modified Rearing Value</th>
<th>Wetted Width Spawning Habitat (M2)</th>
<th>Modifier</th>
<th>Modified Spawning Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>1.00</td>
<td>224.48</td>
<td>16.03</td>
<td>0.67</td>
<td>10.69</td>
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<tr>
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<td>61.48</td>
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<td>0.33</td>
<td>1.02</td>
</tr>
<tr>
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<td>96.49</td>
<td>0.00</td>
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</table>

<table>
<thead>
<tr>
<th>Reach</th>
<th>Reach Length (M)</th>
<th>Modified Rearing Wetted Width Value (M2)</th>
<th>Wetted Width Rearing Habitat Available (M2)</th>
<th>Modified Spawning Wetted Width Value (M2)</th>
<th>Wetted Width Spawning Habitat Available (M2)</th>
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<tr>
<td>1.0</td>
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<td>4.1</td>
<td>109.5</td>
<td>0.2</td>
<td>5.2</td>
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<tr>
<td>2.0</td>
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<td>0.02</td>
<td>3.9</td>
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<tr>
<td>3.0</td>
<td>33.8</td>
<td>1.5</td>
<td>49.9</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>395.0</td>
<td>Total</td>
<td>9.1</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Reach</th>
<th>Reach Length (M)</th>
<th>Modified Rearing Bankfull Width Value (M2)</th>
<th>Bankfull Width Rearing Habitat Available (M2)</th>
<th>Modified Spawning Bankfull Width Value (M2)</th>
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<tr>
<td>1.0</td>
<td>26.4</td>
<td>7.5</td>
<td>197.7</td>
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<td>491.2</td>
<td>0.03</td>
<td>8.1</td>
</tr>
<tr>
<td>3.0</td>
<td>33.8</td>
<td>3.2</td>
<td>108.7</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
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<td>Total</td>
<td>797.6</td>
<td>Total</td>
<td>17.6</td>
<td></td>
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</tbody>
</table>

Once wetted and bankfull width data was determined, the following calculation was applied to establish the Priority Index:
The values used in this calculation were as follows:

**Species used for calculations:** Rainbow Trout (Note: only rainbow trout were observed during investigations for this study as well as the Fish Distribution and Species Composition Surveys).

**B = Proportion of Passage Improvement:** Barriers are assumed to be partial and assigned a value of 0.67.

**P = Annual adult equivalent production potential per m²:** 0.04 for rainbow trout

**H = Habitat Gain in m²:** Rearing area values are used for species complexes normally limited by rearing habitat (resident rainbow). From Table 3-2.
- Wetted width rearing (m²): 395.0
- Bankfull width rearing (m²): 797.6

**M = Mobility Modifier:** 1 = Moderately mobile stock subject to local recreational fisheries (resident species)

**D = Species Condition Modifier:** 2 = Conditions of species considered depressed or stock of concern

**C = Cost Modifier:** All barriers receive a cost modifier of 2 (incremental funds needed >$100,000 and ≤ $500,000) until engineering evaluations are completed.

**CALCULATED PI :**
- Wetted Width: 2.55
- Bankfull Width: 3.04

### 3.3 Fisheries Investigations

Fish presence information was gathered during the rearing and spawning habitat evaluation on August 23, 2006. Given that the habitat and species data collected for the Fish Characterization Below the Drop Structure Report will be incorporated into the Fish Species Distribution and Composition Report (2007); an effort was made to be consistent with the protocol employed on other stream reaches during the August survey. Two electrofishing passes were made at each site. A total of 5 rainbow were captured, (3 at SS1, 2 at SS2). The fish ranged in length from 40 mm to 140 mm and in weight from 1.0 g to 28.0 g. Scale samples were collected from all fish and fish were released unharmed. No visible disease or physical abnormalities were noted. Figure 3-3 displays the length versus weight ratio of fish captured during the August 2006 analysis.
The entire 1464 foot reach was surveyed for fish presence on October 17 and 18, 2006. Reaches between 150 and 200 feet were segmented using block nets and two electrofishing passes were made. A total of 12 rainbow were captured measuring between 70 mm and 165 mm and weighing between 3.7 g and 39.5 g. All fish were captured in the upper 340 feet of the 1464 foot reach above the distinct habitat break mentioned in the rearing and spawning habitat section. A majority of the fish were captured in the lower gradient pools and glide that define the upper area of this reach. Scale samples were collected from all fish and fish were released unharmed. No visible disease or physical abnormalities were noted. Figure 3-4 displays the length versus weight of fish captured during the October 2006 analysis.
The entire reach was surveyed for a second time on May 30 and June 12, 2007. The downstream half of the reach was surveyed on May 30 and the upstream half on June 12. Between the two surveys, a large release of approximately 280 cfs was conducted for a gravel movement study. A total of 47 rainbow trout were captured measuring between 50 mm and 220 mm and weighing between 4 g and 120 g. Seventy percent of the rainbow trout were captured above the habitat break during the June 12 survey. A majority of the fish were captured in the lower gradient pools and glide that define the upper area of this reach. Scale samples were collected from all fish and fish were released unharmed. No visible disease or physical abnormalities were noted. Figure 3-5 displays the length versus weight of fish captured during the May/June 2007 analysis. Figure 3-6 displays a scatter plot with a line of best fit for all fish captured during the August, October and May/June surveys.
Figure 3-5
Length vs. Weight of Rainbow Captured in May/June 2007
Energy Northwest chose to further analyze rainbow trout spawning activity in the isolated section below the drop structure during May and June, 2007. Four surveys were conducted concurrent with likely spawn timing for resident rainbow trout in Lake Creek. Two surveys were done in late May and two in early June, 2007. No spawning fish or redds were observed during any of the surveys.

Scales were collected from a representative sample of rainbow trout in the isolated reach below the drop structure. The scales were analyzed and aged by the WDFW scale analysis lab in Olympia, Washington.

All rainbow trout sampled for scales during electrofishing efforts (n=11) in the isolated reach were determined to be either 1 or 2 year old fish. All fish captured via netting efforts immediately below the drop structure (n=45), were determined to be either 3 or 4 year old fish with the exception of one 2 year old. Figure 3-7 graphically displays the age comparison between rainbow collected during electroshocking efforts, rainbow captured immediately below the drop structure (likely overtopped fish) and fish collected at the Packwood intake during the entrainment study.
Figure 3-7
Age Comparison Between Rainbow Trout Collected in Lower Lake Creek, Likely Overtopped Rainbow and Rainbow Collected at the Packwood Intake

3.4 Determination of Upstream Migration Timing

Capture devices were to be put in place in the stilling apron in February 2006. Due to heavy snow and high flows creating overtopping events through June, the net was put in place in mid-July. Several overtopping events occurred in May and June 2006. Prior to and after the net was put in place in July, many rainbow (up to 20 at one time), approximately 200 to 300 mm in size, were observed near the net orienting themselves directly into the current from the outflow pipe. These fish were located in an area that could not be covered by the fyke net due to the dimensions of the stilling apron (Figure 3-8).

A fyke net was used to capture fish potentially attempting an upstream migration near the drop structure. The fyke net consisted of a 3 ft.x3 ft mouth with a 10 ft. long tapered collection area and two 15 ft. long wings used as a guidance mechanism. Initially, several configurations were used to determine the optimal location for capturing fish. It was determined that orienting the mouth of the fyke net so that it was directly in the current of the outflow pipe from the lake was the best option. Figure 3-8 displays the location of the fyke net. The net was fished continuously in this location from mid-July until a large flood in early November, 2006. One
rainbow trout measuring 220 mm was captured in the net over the four and a half month period the trap was in place.

A supplemental gill netting effort immediately below the drop structure took place on March 28 and 29, 2007. A total of 43 rainbow were captured during the 24 hour set. These fish ranged in length from 205 mm to 290 mm and from 75 g to 210 g in weight. It is important to note that these fish had been observed for several weeks below the drop structure after a series of overtopping events associated with high inflows to Packwood Lake. Twenty two of the rainbow captured were mortalities.

![Figure 3-8](image)

Primary Netting Location Below Packwood Lake Drop Structure

3.5 Literature Review of Potential Injury to Fish Below the Drop Structure During Spills

A literature review was conducted to determine the potential for injury or mortality to those fish that could pass over the drop structure during spill events. This information has been compared with the physical characteristics of the drop structure, depth of pools, distance of fall, etc. to determine the potential for injury if fish were to be swept over the drop structure during a spill event (Appendix B).
4.0 DISCUSSION

The location of the fish passage barrier was determined to be at approximately 1464 ft (446 m) downstream of the drop structure. The upper 328 ft (100 m) of the isolated reach produced 35 of the 59 fish captures. This appears to be a result of a significant habitat break, which occurs approximately 350 ft (107 m) downstream from the drop structure. Gradient increases at this break from between approximately 1.5% to over 6%. Habitat units transition from primarily deep, slow moving runs, glides and pools to mainly cascades and plunge pools. Substrates become coarse and the overall available quality habitat for rainbow trout is significantly diminished (Table 3-1).

Rainbow trout were the only species observed in the section of lower Lake Creek below the drop structure. No cutthroat trout or any other species was observed. It is very likely that rainbow trout are the only fish species present given the comprehensive nature of the data collected during this study and the fact that rainbow trout are the only species known to exist in the upstream sources to lower Lake Creek, Packwood Lake and its tributaries (Fish Distribution and Species Composition Report).

Gravel for rainbow trout spawning is scarce in the reach below the drop structure (Table 3-1). This condition likely existed before the project and would be expected as a result of Packwood Lake absorbing the gravel deposited from the tributaries upstream. This limited amount of spawning habitat has a direct relationship to the small resident population of rainbow trout present in the area.

There was a significant difference in size between the fish observed orienting themselves into the flow immediately below the drop structure and those captured via electrofishing downstream. The rainbow trout in the stilling apron ranged from 200-300 mm while the fish captured downstream ranged from 40 mm to 165 mm with only three fish captured over 200 mm. The lengths of the fish captured downstream of the drop structure correspond well with fish observations in lower Lake Creek below the established barrier for this study. These observations will be further discussed in the Fish Species Composition and Distribution Report. It is likely that the larger fish observed immediately below the drop structure moved downstream as a result of overtopping events in May and June, 2006 and the large flood in November, 2006. These rainbow were observed directly in front of the outflow pipe likely attempting to return to Packwood Lake. Given the appreciable difference in mean size between the two groups and the similarity in size between the fish immediately below the drop structure and fish captured in Packwood Lake, it is likely that a rainbow population utilizing only lower Lake Creek has been established that is distinct from the Packwood Lake population. Figure 4-1 displays the size comparison between lower Lake Creek resident rainbow trout, likely overtopped Packwood Lake rainbow trout and fish captured in gill netting efforts in Packwood Lake. There is a very strong length correlation between the likely overtopped fish and the residents captured in Packwood Lake.
The differences in habitat (Table 3-1) and the associated differences in the amount of forage available create divergent growth rates in rainbow trout between nutrient rich Packwood Lake and this section of lower Lake Creek. Size differences between rainbow trout in this section of lower Lake Creek and sections further downstream are discussed in the Fish Species Distribution and Composition Report.

The assertion that a majority of the fish occupying the reach below the drop structure during certain times of year are Packwood Lake fish that have been re-routed as a result of overtopping events is further illustrated by the second full reach shocking effort in May and June, 2007. A total of 47 rainbow trout were captured during the two survey days. Nine were observed during the May 30 portion of the survey and the other 38 were captured during the June 12 survey after the overtopping event for the gravel movement study had occurred. Fish were likely displaced from Packwood Lake as a result of the overtopping event. Given that Packwood Lake is fully seeded, (see Fish Species Distribution and Composition Report), the occasional supplementation of a very small number of the lake’s population into the isolated reach of lower Lake Creek could potentially assist in expanding the rainbow trout population below the drop structure.

Scale data was collected from rainbow trout captured in the isolated section of lower Lake Creek, fish captured immediately below the drop structure and fish collected at the Packwood intake.
As Figure 3-7 shows, there is a distinct age difference between fish captured in lower Lake Creek and those immediately below the drop structure and at the intake. All of the rainbow trout captured during electroshocking efforts in lower Lake Creek were 1 or 2 year old fish. Eighty-five percent of the fish collected immediately below the drop structure and at the Packwood intake were 3 or 4 year old fish. These age classifications add credence to the likelihood that a large majority of the fish collected immediately below the drop structure were actually Packwood Lake resident rainbow trout that had been relocated as a result of high flows.

Spill events such as those that occur during overtopping at the Packwood drop structure can potentially cause injury to fish (Appendix B). None of the fish captured during netting efforts or visually observed had any injuries consistent with those that would occur during a fall related to overtopping at the drop structure.

There is no evidence from netting and spawning data to indicate that any timed upstream migration of resident rainbow trout occurs in the section of lower Lake Creek below the drop structure. Given the adequate amount of rearing habitat in the isolated section (Table 3-1), resident rainbow trout may rear in the reach for one to two years prior to migrating downstream over the barrier at the lower end of the reach in search of better quality habitat for feeding and spawning purposes. The Fish Distribution and Species Composition Study documents much higher populations of resident rainbow trout in the sections of lower Lake Creek further downstream. Some of these may be rainbow that relocated from the section below the drop structure in search of higher quality habitat downstream.

5.0 GOALS AND OBJECTIVES

5.1 Goals

1. Determine the location of the first fish passage barrier waterfall downstream of the drop structure, thereby delineating the isolated reach of Lake Creek. The isolated reach was defined here as the reach from the drop structure downstream to the first barrier waterfall.

   • A barrier falls exists 1464 feet below the drop structure. The barrier was surveyed as a vertical falls of 11.80 ft as measured at a baseflow release of 3.5 cfs at the drop structure.

2. Determine the amount of suitable spawning and rearing habitat available for rainbow and cutthroat trout and other fish species within the isolated reach.

   • Spawning and rearing habitat was quantified at three 30 m study sites in the section of lower Lake Creek below the drop structure (Table 3-1).

3. Determine the fish species present within the isolated reach.

   • The only fish species observed during the Fish Population Characterization Near the Drop Structure Study was rainbow trout.
4. **Determine the population size and age/size structure of all fish species within the isolated reach.**

- The population of resident rainbow in the reach of lower Lake Creek below the drop structure appears to be quite small. Sixty four rainbow trout were captured during electrofishing efforts in the reach below the drop structure. Another 47 rainbow were collected in gill netting efforts immediately below the drop structure. A large portion of the fish collected during netting immediately below the drop structure were much larger in size than the fish collected further downstream in the reach and were observed to be oriented directly into the fish flow. Many of these fish are likely residents of Packwood Lake that were directed over the drop structure during overtopping events. During electroshocking efforts downstream of the drop structure, 95% of the rainbow were under 160 mm versus 98% of the fish collected at the drop structure being over 200 mm.

As Figure 3-7 shows, there is a distinct age difference between fish captured in lower Lake Creek and those immediately below the drop structure and at the intake as well. All of the rainbow trout captured during electroshocking efforts in lower Lake Creek were 1 or 2 year old fish. Eighty five percent of the fish collected immediately below the drop structure and at the Packwood intake were 3 or 4 year old fish. These age classifications add credence to the likelihood that a large majority of the fish collected immediately below the drop structure were actually Packwood Lake resident rainbow trout that had been relocated as a result of high flows.

5. **Determine upstream migration timing (spawning, foraging, and other movement) of rainbow and cutthroat trout and other fish species within the isolated reach.**

- There is no evidence from netting and spawning data to indicate that any timed upstream migration of resident rainbow trout occurs in the section of lower Lake Creek below the drop structure. Given the adequate amount of rearing habitat in the isolated section (Table 3-1), resident rainbow trout may rear in the reach for one to two years prior to migrating downstream over the barrier at the lower end of the reach in search of better quality habitat for feeding and spawning purposes.

No cutthroat trout or any other species were observed.

5.2 **Objectives**

1. **Provide the stakeholders with information to assess potential drop structure impacts on fish populations in Project affected waters to allow them to make informed decisions on the management of the fish communities near the drop structure.**

- Comprehensive habitat mapping, fish species presence and abundance assessments and barrier analysis were conducted to define the 1464 ft reach of lower Lake Creek below the drop structure.
6.0 REFERENCES


Powers, P.D. 2005. Personal communication with WDFW staff.


Appendix A

Substrate Code
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<th>Description</th>
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<th>Substrate Code</th>
</tr>
</thead>
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<td>&lt;2</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Sand</td>
<td>&lt;2</td>
<td></td>
</tr>
<tr>
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<td>0.1-0.5</td>
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<td>Medium Gravel</td>
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<td>0.5-1.5</td>
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<td>Large Gravel</td>
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</tr>
<tr>
<td>9</td>
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Ex. Primary Substrate – 70% Boulder (8)
Secondary Substrate – 30% Bedrock (9)
Substrate Code = 89.7
Appendix B

Fish Injury Related to Spill Events Literature Review
DRAFT

Literature Review:
Potential Injury to Fish Below the Drop Structure During Spills

Fish Population Characterization Near the Drop Structure Study
For
Energy Northwest’s Packwood Lake Hydroelectric Project
FERC No. 2244
Lewis County, WA

Submitted to:

EES Consulting
1155 North State St., Suite 700
Bellingham, WA 98225

Submitted by:
D. Brady Green
D. B. Green Environmental Consulting, LLC
707 Cedar Creek Lane
Bellingham, WA 98229-1900
PH/FAX: 360-738-6496
E-Mail: bgreen5645@aol.com

November 9, 2006
1.0 INTRODUCTION

A literature review was conducted to determine the potential for injury or mortality to those fish that could pass over the drop structure on Packwood Lake during spill events. This review was conducted in accordance with the “Fish Population Characterization Near the Drop Structure Study Plan,” Item 5.2.6, which states: “A literature review will be conducted to determine the potential for injury or mortality to those fish that could pass over the drop structure during spill events. This information will be compared with the physical characteristics of the drop structure, depth of pools, distance of fall, etc., to determine the potential for injury if fish were to be swept over the drop structure during a spill event.”

The Packwood Lake concrete drop structure and stilling basin dimensions are shown in Figures 1-1, 1-2, and 1-3. Figure 1-1 is a photograph of the drop structure during a spill event in November, 2006; Figure 1-2 is a diagram of the drop structure; and Figure 1-3 is a plan view of the stilling basin.

Prior to construction of the drop structure in 1964 there was no permanent man-made barrier to fish movement between Packwood Lake and the upper 1464 feet of lower Lake Creek. Since then the drop structure has been a barrier to fish migration (upstream and downstream) except when high flows spill over the top and fish pass downstream. Due to the natural barrier 1464 feet below the current drop structure location, fish below this point would not have been permitted passage to the lake prior to drop structure installation.

The drop structure weir is 14 feet high and 80 feet across. Fish passing downstream over the weir during a spill would fall a maximum of 10.5 feet to the water surface below into the stilling apron, which is 3.5 feet deep. The height above the weir crest up to the top of the wing walls, on each side, of the spillway is 12.5 feet. The total spill capacity of the Packwood Lake spillway and drop structure is about 1000 square feet above the weir and between the wing walls.

There is a 24-inch valve that provides an instream flow of approximately 3 to 3.5 cfs to lower Lake Creek. However, because the flow through this pipe is screened at the intake structure, the only way for fish to migrate from Packwood Lake downstream to lower Lake Creek is over the weir during spill events.

Spill over the drop structure begins when the water level exceeds the top of the spillway crest at elevation 2858.52 ft MSL. The amount of water (in cfs) passing the drop structure’s 80-foot wide rectangular weir opening increases with increasing lake elevation. Flow over the drop structure is driven by the lake elevation which in turn is a function of the constantly changing natural inflow to the lake and the amount of water diverted for power generation. Spill over the drop structure is uncontrolled because there are no flash boards or spillway gates.
The primary fish species of concern in Packwood Lake is rainbow trout (*Oncorhynchus mykiss gairdneri*). These fish appear to be more closely related to Eastern Washington redband trout than to the coastal rainbow trout (Lucas and Chilcote 1982). Behnke (2002) indicates that the inland form of redband trout inhabits small, cool streams and rivers and lakes, live 3-10 years, and those inhabiting larger bodies of water often grow to 18 inches and 3 pounds. All forms of redband trout are part of the rainbow trout species *Oncorhynchus mykiss* (Behnke 2002).

Currently, any recruitment of fish from Packwood Lake into the isolated reach of Lake Creek below the drop structure, down to the next barrier located approximately 1464 feet downstream, is dependent on periodic spill events. The drop structure is too high to allow fish passage, and the fish flow valve is screened; thus it is a complete barrier to upstream fish migration.

Fish surveys conducted downstream from the drop structure in 1993, and from 2004 to the present, indicate the presence of adult and juvenile resident forms of rainbow trout (*O. mykiss*) in this reach of Lake Creek (USFS 1993, EES Consulting 2006).
Figure 1-2
Diagram of the Drop Structure
Figure 1-3
Plan View of the Stilling Basin
2.0 METHODS

The literature search included investigation of a variety of information sources that are considered pertinent to fish migration injury related to dams. Internet searches were made using various information search websites (Google, AOL, Alltheweb, etc.), US Army Corps of Engineers web sites (e.g., Walla Walla District). Various technical books, journals and reports on these topics were also reviewed.

3.0 RESULTS

3.1 Overview

The majority of the studies on dam-related fish migration injury were conducted in the Columbia River system on larger hydroelectric dams. These studies focused primarily on juvenile salmon mortality and injury due to entrainment or collision during downstream migration.

Much of the pertinent research on the effects of dams and reservoirs on fish has been focused on juvenile salmonids as they migrate from their natal waters to the ocean (Adams et. al 2001). There is a consensus that migration hazards (e.g., time of travel, predators, etc.) associated with mainstem dams are a leading factor in the mortality of smolts as they migrate downriver in the Columbia River system (National Research Council 1996). The portion of the research dealing with fish injury during spill events is from the Columbia River basin and focuses on salmon and steelhead.

According to Odeh and Haro (2000) any evaluation of fish passage structures requires an understanding of the target fish’s migratory and swimming behavior as well as hydraulics and habitat preferences. Odeh and Haro (2000) identify the following five major components, and their functions, that must be taken into consideration for successful fish passage systems: 1) the immediate reach of the waterway served by the passage structure, 2) the entrance to a fishway or bypass, 3) the passage structure itself, 4) the passage structure’s exit, and 5) the reach below where fish exit. These considerations should be useful for evaluating the potential for injury to fish from the drop structure on Packwood Lake.

Although the main focus of this inquiry is on the potential impacts to fish passing over the drop structure at Packwood Lake, the evaluation should also include consideration of the fish behaviors (e.g., spawning migration, searching for food, escaping predation) that occur in Packwood Lake fish populations that might bring fish close enough to be swept over the drop structure and be subjected to possible injury.

The biological consequences of entrainment by power plants are influenced by the species of fish involved, the manner in which they are physically affected, and their ecological role (Goodyear 1977). The relative importance of each of these factors is both species and site specific and is affected by the size and design of the power plant,
associated facilities, and structures (Goodyear 1977). Mathematical models were used by Goodyear to estimate percentage loss of populations of aquatic organisms that are entrained by power plants located on rivers, streams, lakes and reservoirs. These models may be useful to estimate the percentage loss or injury due to the Project’s drop structure. These models require knowledge of average concentration of fish in Packwood Lake, the flow in the lake, and the flow over the spillway.

Movement, behavior, and passage routes of radio-tagged emigrating steelhead smolts were evaluated at Wanapum Dam on the Columbia River to determine the proportional usage of various downstream passage routes fish took at that hydroelectric project (Royer et al. 2000). The evaluation found that 34% of the steelhead smolts used spillway passage.

A radio telemetry study conducted at the Lower Saranac Hydroelectric Project to assess effectiveness of the project’s bypass system passing steelhead trout smolts found that, out of five possible downstream passage routes, 12% of the steelhead passed over the spillway during a spill event (Simmons 2000).

At Packwood Lake, the only downstream passage route is currently to pass over the spillway.

Naughton et al. (2006) reported finding head and body injuries while investigating fallback injuries at dams in Columbia River sockeye. Head injury in chinook salmon and steelhead has been observed in fishways of the Columbia River dams since the 1970s (Gustason et al. 1997).

No injury studies were found that specifically involved rainbow trout, cutthroat trout or redband trout. However, steelhead are the same species as rainbow and redband trout, and are related to cutthroat trout. Results from these studies involving steelhead may be applicable to *O. mykiss* in the Packwood Lake – Lake Creek system.

### 3.2 Factors To Consider

Although the Packwood Lake intake structure is screened, and the drop structure does not involve turbines, the types of fish injuries that might occur may be similar to those found with turbines (OTA 1995). Fish injuries, however, would be expected to much less severe.

Causes of injury to fish at the Packwood Drop Structure could potentially come from these four factors:

1) Mechanical
2) Pressure
3) Cavitation
4) Shearing
Downstream passage of juveniles can cause impingement, bruising, scale loss (descaling), and stress (Chapman et al. 1991). The probability of a fish being injured or killed is a complicated function of characteristics of the fish (species, age, length, mass, condition), and behavior (Cada et al. 1997). Other important injury factors include: collision velocity, fish swimming speed and behavior, fish orientation, water velocity, distribution of fish, whether they are randomly, or passively, or attempting to resist moving across the drop structure (Cada et al. 1997).

Fish swimming speed and ability is a function of body size (Quinn 2005). The size and age of fish would seem to be a determining factor in assessing the potential for a fish in Packwood Lake to be near enough to the drop structure to be at risk of going over the spillway. A larger adult fish feeding near the structure would be better able to handle the approach velocities of the downstream flow near the weir and swim away than smaller fish, especially fry. [Note: fisheries investigations conducted to date for the Fish Distribution and Species Composition study indicate the presence of larger fish in the vicinity of the intake structure.]

For the purpose of evaluating the Packwood Lake drop structure fish injuries can be grouped into the following general areas:

1. Mechanical injury
2. Predation
3. Water Flow and Spill
4. Fish behavior

3.2.1 Mechanical Injury

The most likely form of injury to fish going over the Packwood Lake drop structure, and associated features, during a spill is some form of mechanical injury. Injury could result when fish come in contact with some part of the concrete weir spillway, one of the sloped concrete braces, or the bottom of the apron below. The risk of fish hitting the sloped concrete braces would be expected to be much less than other features and objects, since these structures tend to split the water flow going over the weir and concentrate flow more towards the middle of each section of the stilling apron. Damage to fish could range from abrasion (loss of scales and mucous) to more serious injury, such as contusions and internal bleeding.

Major factors that would affect the seriousness of mechanical injury to fish at the Packwood Lake drop structure are:

- Amount of flow or spill over the weir
- Distance of the fall or drop
- Pool depth
- Fish characteristics (e.g., species, age, size, condition)
- Type of contact with hard surfaces (e.g., direct hit, glancing blow)
The amount of flow or spill over the weir is dependent on the lake level, which is primarily dependent upon the amount of tributary inflow and project power production. Spill occurs when lake elevation reaches 2858.52 ft and overtops the drop structure. A rating curve exists for the drop structure (see Lake Drawdown and Ramping Rate Plans, Energy Northwest 2006). For example, a lake elevation of 2859.70 ft MSL results in a spill of 311 cfs.

During a spill the maximum fall, or drop, that a fish would be subjected to would be about 10.5 feet into the apron pool, about 3.5 feet deep. Entrance velocities can be calculated using the formula:

\[ V = \sqrt{2GH} \]

where

- \( V \) = Velocity
- \( G \) = 32.2
- \( H \) = 10.5

Using this formula, the entry velocity would be 26 ft/sec. With a spill depth of 0.2 feet (a spill of 311 cfs), the spill would not reach the apron floor. At a spill depth of 0.75 feet (associated with a spill of 600 cfs), the spill would reach the floor, but it would be gentle.

The larger the size of the fish the greater the body mass. Therefore, it would be expected that the larger the fish going over the drop structure, the greater the risk of the fish hitting some portion of the drop structure, one of the sloped concrete braces, or the bottom of the stilling basin, and the harder the impact would be to the fish.

3.2.2 Predation

After being stunned, or injured, by the fall over the drop structure, fish may have an increased susceptibility to predation. Avian predation on yearling and older trout by great blue herons (\textit{Ardea herodias}), common mergansers (\textit{Mergus merganser}), river otters (\textit{Lutra Canadensis}), and mink (\textit{Mustela vison}) was found to be significant (Griffith 1993). Common merganser broods consumed significant numbers of wild coho salmon fry in a Vancouver Island stream (Wood 1987). Larger trout in Lake Creek, found downstream from the drop structure, may prey on smaller trout that go over the drop structure and are stunned. Larger cutthroat trout are known to be piscivorous (Quinn 2005).

Packwood Lake, and most of Lake Creek downstream from the dam, is within the Gifford Pinchot National Forest and is a relatively remote and wild area. Avian species such as common mergansers, ospreys (\textit{Pandion haliaetus}) and bald eagles (\textit{Haliaeetus leucocephalus}), observed in the Packwood Lake area, could fish in the area downstream of the drop structure; fish that are stunned, or injured, could be more attractive prey than fish in Packwood Lake.
3.2.3 Water Flow and Spill

See Section 3.2.1 “Mechanical Injury” for estimated spill velocities that would affect fish going over the Packwood Lake drop structure.

In reservoirs, fish are often lost from surface discharges over dam spillways. Fish loss is more common over modern concrete spillways with laminar flow at the top than over a drop-board spillway with turbulent, noisy flow. This loss varies by species (Summerfelt 1993).

The vertical distribution of fish in a waterbody generally will show the largest number of downstream migrants in the top half depth, although this is altered by factors such as sunlight, water temperature, fish size, species and day or night (Bell 1991).

Dissolved gas can become supersaturated at depth can injure or kill fish below larger dams (Muir et al. 1996). However, the scale of the Project’s drop structure (e.g., 10.5 ft drop at spill and the typical overtopping flows of approximately 50-100 cfs), would not be expected to form the conditions in the creek for gas bubble trauma to occur with these trout. Gas supersaturation conditions are more prevalent from spill over much larger dams, like those on the Columbia River.

3.2.4 Fish Behavior, Migration and Territoriality

According to McKeown (1984) there are three major types of fish migrations:
1) Alimental – for food procurement,
2) Climatic – for reaching a region of better climate
3) Gametic – for reproduction.

Other biological as well as physical factors play a role in determining direction, distance and timing of freshwater migration (McKeown 1984).

The most common types of migration pattern exhibited by fish moving entirely within freshwater are seasonal return movements to spawning areas and usually involves an upstream migration of spawning adults and a subsequent return to downstream feeding areas (McKeown 1984). Displacement of young or subordinate adults to feeding areas usually occurs downstream (McKeown 1984). Genetic as well as environmental factors seem to be important in determining direction and type of migration pattern followed (McKeown 1984).

Movement of fish over a spillway may be related to defending a territory. The ability to establish and hold a territory is largely dependent on body size, with larger fish being dominant in most encounters (Griffith 1993).

McKeown (1984) indicated that Northcote and co-workers (Kelso et al. 1981; Northcote and Kelso 1981) found genetic and rheotropic responses of rainbow trout fry in water currents. They found that in order to maintain trout populations above impassable
waterfalls, emerging fry need to respond with a positive rheotaxis. Likewise, emerging trout fry from inlet and outlet streams of a lake used later by the adult fish must possess an appropriate and opposite rheotaxis in order to arrive at the lake.

Currents are usually thought of as being capable of transporting adult fish, or at least providing cues to which adult fish may respond for desirable rheotropism, and may also be useful to movements of fish eggs or young larvae (McKeown 1984). Emanuel and Dodson (1979) have shown that currents may provide directional cues for migrating male rainbow trout and that olfactory stimuli from females’ ovarian fluid regulate the rheotropic response.

Rheotropic responses of rainbow trout appear to be affected by temperature and illumination (Kelso et al. 1981). An enhanced rheotaxis has been observed in rainbow trout in response to decreased prey abundance both in the field (Slaney 1972) and in laboratory experiments (Slaney and Northcote 1974).

The movement of fish throughout the day is not uniform (Bell 1991). The time of day when the spill occurs, length of spill and water temperature are other factors to consider. It is generally believed that photoperiod is the primary cue that triggers migration, although flow, temperature, and social interactions can also influence it (Godin 1982).

Fish that go over the Project’s drop structure and end up in Lake Creek below would be expected to eventually find a place where they can maintain a position in the stream. Some fish would probably try to swim upstream until they are blocked by the drop structure. Eventually these fish would try to find a suitable habitat somewhere downstream. They would have to compete with resident fish with already established territories for food and space.

All of the migration behaviors described above could be expected to occur in the Packwood Lake system and, to some degree or another, could influence whether, or not, fish end up going over the drop structure.

4.0 SUMMARY

The risk of fish going over the drop structure from Packwood Lake only occurs when there is a spill. Spill events occur on a sporadic basis and fish would be vulnerable to going over the drop structure only if they were in the vicinity. The ability of individual fish to swim away from the spillway is size-dependent, with smaller fish, especially fry, being least able to swim out of the flow going towards the structure. Healthy larger, or adult fish, should be able to swim out of the current going toward the drop structure and get away.

With the existing Project drop structure, some kind of mechanical injury is the most likely type of injury that could occur to fish going over the structure during a spill. The distance a fish would fall, 10.5 feet (less at higher flows), is much lower than typical
spillways on the much larger Columbia River dams and spillways, where most of the research on fish passage injury has taken place.

Scale and mucous loss and bruising injuries would be the most likely types of mechanical injuries that fish would receive during a spill. This could occur during a fall if a fish hits part of the weir or the base of the stilling apron. (Figures 1-1, 1-2 and 1-3).

The risk of hitting a part of the structure is related to the volume and velocity of a spill over the weir. It would be expected that the larger the flow volume, and greater the water velocity, the greater the chance a fish would be forced at a greater velocity towards the bottom of the stilling apron, or against a hard surface (e.g., sloped concrete brace, large woody debris, ice). The risk of fish hitting the sloped concrete braces would be expected to be much less than other features and objects, since these structures tend to split the water flow going over the weir and concentrate flow more towards the middle of each section of the stilling apron. The risk and the severity of these mechanical injuries are related to a number of factors, many of them biological, (species, age class, swimming speed, etc.).

Indirect effects to fish that go over the drop structure are less clear. If the fish are stunned from the fall then they could be more vulnerable to downstream predation from avian, mammalian, and fish predators. These fish would also compete for food and space with existing lower Lake Creek resident fish populations with already established territories.

Rainbow trout fry that emerge from Packwood Lake and its tributaries, and migrate downstream due to their natural rheotropic responses, may be more vulnerable than adult fish to being swept over the drop structure, if present in the vicinity of the structure.

5.0 LITERATURE CITED


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US. Army Corps of Engineers.  Walla Walla District web site: www.nww.usace.army.mil

