Revised

Fish Passage Barriers Study Plan
for
Energy Northwest's Packwood Lake Hydroelectric Project
FERC No. 2244
Lewis County, Washington

Submitted to

ENERGY NORTHWEST
People · Vision · Solutions

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TABLE OF CONTENTS

Section | Title | Page
-------|-------|------
1.0 | INTRODUCTION | 1
1.1 | Study Plan Goals and Objectives | 1
2.0 | AGENCY AND TRIBE RESOURCE GOALS AND OBJECTIVES | 1
2.1 | Forest Service Resource Management Goals | 1
2.2 | USFWS Resource Management Goals | 2
2.2.1 | General Goals | 2
2.2.2 | Goals for Aquatic Ecosystems | 2
2.2.3 | Goals for Endangered, Threatened and Proposed Species | 3
2.3 | WDFW Resource Management Goals | 3
2.3.1 | Wild Salmonid Policy | 4
2.3.2 | WDFW Draft Hydroelectric Project Assessment Guidelines | 4
3.0 | EXISTING INFORMATION AND NEED FOR ADDITIONAL INFORMATION | 4
3.1 | Existing Information | 4
3.2 | Need for Additional Information | 4
4.0 | NEXUS BETWEEN PROJECT OPERATIONS AND EFFECTS ON RESOURCES | 5
5.0 | STUDY AREA AND METHODS | 5
5.1 | Study Area | 5
5.2 | Methodology | 5
5.2.1 | Fish Bearing Determination | 6
5.2.2 | Fish Passage Determination | 6
5.2.3 | Stream Simulation Determination | 9
5.2.4 | Habitat Assessment | 10
5.2.5 | Analysis of Hall Creek | 11
5.2.6 | Analysis of Snyder Creek | 11
5.2.7 | Analysis of Art Lake Creek | 12
5.2.8 | Analysis of Lake Creek | 12
5.3 | Products | 12
5.4 | Consistency with Generally Accepted Scientific Practice | 12
6.0 | CONSULTATION WITH AGENCIES, TRIBES AND OTHER STAKEHOLDERS | 12
7.0 | PROGRESS REPORTS, INFORMATION SHARING, AND TECHNICAL REVIEW | 13
8.0 | SCHEDULE | 13
9.0 | LEVEL OF EFFORT AND COST | 13
10.0 | LITERATURE CITED | 14
LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-1</td>
<td>Level A Culvert Analysis</td>
<td>7</td>
</tr>
<tr>
<td>5-2</td>
<td>Level B Culvert Analysis</td>
<td>8</td>
</tr>
<tr>
<td>5-3</td>
<td>Stream Simulation Model/No Slope Model</td>
<td>9</td>
</tr>
</tbody>
</table>

LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-1</td>
<td>Criteria Used to Assign Habitat Quality Modifiers (HQM) to Rearing and Spawning Habitat</td>
<td>11</td>
</tr>
<tr>
<td>9-1</td>
<td>Level of Effort</td>
<td>13</td>
</tr>
</tbody>
</table>

APPENDICES

<table>
<thead>
<tr>
<th>Appendix</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hall Creek and Snyder Creek Fish Passage</td>
</tr>
<tr>
<td>2</td>
<td>Interim Report Lake Creek Anadromous Barrier Analysis</td>
</tr>
</tbody>
</table>
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. 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.

The source of water for the Project, Packwood Lake, is a natural lake 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.

1.1 Study Plan Goals and Objectives

The goal of this study is to identify barriers to fish passage from Project facilities such as roads, trails, pipelines and the tailrace. Analysis of the drop structure is covered in a separate study.

Objectives of the Packwood Lake Hydroelectric Project Fish Passage Barriers study include:

1. Determine impacts to fish migration and connectivity from project facilities and operations.
2. Include in this evaluation all species present and life stages that are appropriate at the particular barrier.
3. Scope of this study is to evaluate Project-related barriers including, but not limited to the following: roads, trails, pipelines and tailrace.

2.0 AGENCY AND TRIBE RESOURCE GOALS AND OBJECTIVES

The USDA Forest Service, U.S. Fish and Wildlife Service (USFWS), and the Washington Department of Fish and Wildlife (WDFW) requested this study (USDA Forest Service 2005, USFWS 2005, WDFW 2005). Their resource management goals and objectives were provided by the agencies and are presented below.

2.1 Forest Service Resource Management Goals

As stated by the Forest Service, management direction for aquatic resources is contained in a variety of laws, policy and management plans. The Gifford Pinchot National Forest Land and Resource Management Plan (1990), as amended by the Northwest Forest Plan in 1994, provides the management direction for all of the National Forest System lands and their associated resources directly affected by or within the vicinity of the Packwood Lake Hydroelectric Project. The Aquatic Conservation Strategy (ACS), a core component of the Northwest Forest Plan, provides management direction aimed at maintaining or restoring the ecological health and function of watersheds and the aquatic ecosystems contained within them. ACS objectives most applicable to this issue are:
Objective 1 – Maintain and restore the distribution, diversity, and complexity of watershed and landscape-scale features to ensure protection of the aquatic systems to which species, populations, and communities are uniquely adapted.

Objective 2 – Maintain and restore spatial and temporal connectivity within and between watersheds. Lateral, longitudinal, and drainage network connections include floodplains, wetlands, upslope areas, headwater tributaries, and intact refugia. These network connections must provide chemically and physically unobstructed routes to areas critical for fulfilling life history requirements of aquatic and riparian-dependent species.

Objective 9 – Maintain and restore habitat to support well-distributed populations of native plant, invertebrate, and vertebrate riparian-dependent species.

2.2 USFWS Resource Management Goals

The USFWS seeks the accomplishment of several resource goals and objectives through the relicensing process for the Project. Their study plan request includes the following description of the goals that apply to this study.

2.2.1 General Goals

1. Ensure that protection, mitigation and enhancement measures are commensurate with Project effects and help meet regional fish and wildlife objectives for the basin.
2. Recover federally proposed and listed species.
3. Conserve, protect, and enhance the habitats for fish, wildlife, and plants that continue to be affected by the Project.
4. Ensure that once the licensing process is complete, there is an adaptive management plan to allow the use of new information or new management strategies over the term of the license, bringing us closer to the desired level of protection for fish and wildlife resources. The adaptive approach is particularly appropriate where there are insufficient data and/or biological uncertainties about those measures that will be most effective for meeting ecosystem goals and objectives.

2.2.2 Goals for Aquatic Ecosystems

1. Protect, enhance, or restore, diverse high quality aquatic and riparian habitats for plants, animals, food webs, and communities in the watershed and mitigate for loss or degradation of these habitats.
2. Maintain and/or restore aquatic habitat connectivity in the watershed to provide movement, migration, and dispersal corridors for salmonids and other aquatic organisms and provide longitudinal connectivity for nutrient cycling processes.
3. Restore naturally reproducing stocks of native anadromous and resident fish to historically accessible riverine habitat, using stocks that are native to the Cowlitz River basin where feasible, with priority given to the restoration of listed native stocks.

4. Provide an instream flow regime that meets the spawning, incubation, rearing, and migration requirements of wild salmonids and other resident fish and amphibian species, throughout the project area.

5. Meet or exceed federal and state regulatory standards and objectives for water quality in the basin.

6. Minimize current and potential negative project operation effects on water quality and downstream fishery resources.

2.2.3 Goals for Endangered, Threatened and Proposed Species

1. Reduce project effects on bald eagles, spotted owls, and other threatened, endangered, and proposed species.

2. Explore opportunities for potential protection, mitigation and enhancement measures for threatened, endangered, and proposed species.

3. If bull trout are discovered within the Cowlitz River basin, gain a better understanding on bull trout population trends, migration, habitat loss, present usage and continuing impacts as related to the Project.

In addition, an overarching USFWS goal for the new licensing of the Project is to succeed in having the Commission include as license conditions, protection, mitigation and enhancement measures that sustain normal ecosystem functional processes including geomorphic, hydrologic and hydraulic patterns, and water chemical and physical parameters. Maintaining and improving these functional processes throughout the term of the new license will, in turn, provide the habitat to support healthy fish and wildlife populations.


2.3 WDFW Resource Management Goals

The goal of WDFW’s management policy is no net loss of existing or potential habitat production. The upper basin of the Cowlitz River is the site of reintroduction efforts for Endangered Species Act listed salmon species. WDFW Resource Management goals related to the reintroduction effort (Cowlitz Settlement Agreement) are cited by WDFW (2005) because the listed species need to be considered in the evaluation of fish passage related to this Project’s facilities. Goals directly applicable to the Project include:
2.3.1 **Wild Salmonid Policy**

The objectives of fish access and passage under the WDFW Wild Salmonid Policy (1995b) include: 1) to ensure salmonids are protected from injury or mortality from diversion into artificial channels or conduits; 2) to ensure natural fish passage barriers are maintained where necessary, to maintain biodiversity among and within salmonid populations and other fish and wildlife.

The goal of the Wild Salmonid Policy is to: 1) remove existing barriers, prevent creation of new barriers, to ensure that usable or restorable habitat is accessible to wild salmon, and screen all water diversions with state-of-the-art facilities designed to comply with current regional protection criteria. Achieve **No Net Impact** for each species affected by hydropower projects through a combination of: 1) project improvement measures to ensure high survival rate; and 2) compensation/mitigation for unavoidable impacts.

2.3.2 **WDFW Draft Hydroelectric Project Assessment Guidelines**

The Washington Department of Fish and Wildlife Draft Hydroelectric Project Assessment Guidelines (WDFW 1995a) explain the management goals of the WDFW regarding hydropower projects. Studies are outlined to gather information necessary to assess potential impacts of a hydroelectric project on fish and wildlife and their habitats.

3.0 **EXISTING INFORMATION AND NEED FOR ADDITIONAL INFORMATION**

3.1 **Existing Information**

A preliminary draft assessment of fish passage barriers from the tailrace flume crossing over Hall Creek and the culvert passage of Snyder Creek under the tailrace were prepared (EES Consulting 2005) with a subsequent presentation of the results to agency representatives on January 21, 2005. The preliminary draft assessment demonstrated that there is no fish passage barrier created by the flume over Hall Creek. However, the preliminary information developed for Snyder Creek was not sufficient to make an informed assessment on fish passage related to the culvert under the tailrace. The final report of the preliminary assessments is provided in Appendix 1. The drop structure has been determined to be an upstream barrier; it is also a downstream barrier with the exception of when spill events occur.

There are a series of barriers that have been documented on Lake Creek. An interim report of the potential barrier at RM 1.03 on Lake Creek is provided as Appendix 2. Additional data will be collected when a planned release of higher flows at the drop structure occurs in the spring of 2006.

3.2 **Need for Additional Information**

Preliminary results showed potential culvert blockage on Snyder Creek. The engineering drawings provided did not show the size of the actual culvert. The 4.6 ft. vertical drop on Snyder
Creek also should be evaluated as a potential fish barrier. More information must be collected to determine if Snyder Creek is passable for all fish for all life stages at most flows.

Potential fish passage barriers may also exist where streams, such as Art Lake Creek, cross Project facilities such as the pipeline or the Pipeline Access Road. Information is needed to determine what streams may be impacted by these Project facilities, and if the facilities have created fish passage barriers.

If additional data collection and analysis indicates that the falls/chute complex on Lake Creek at RM 1.03 is not a barrier at all flows, the next upstream barrier to anadromous salmonid migration will be determined. Another barrier (a bedrock falls approximately 25 ft in height) is located at RM 1.95.

4.0 NEXUS BETWEEN PROJECT OPERATIONS AND EFFECTS ON RESOURCES

The Packwood Lake Hydroelectric Project has project structures that may impede fish passage. Potential fish passage concerns have been expressed for Hall Creek, Snyder Creek, and Art Lake Creek.

5.0 STUDY AREA AND METHODS

5.1 Study Area

The Snyder Creek culvert that crosses below the tailrace and the culvert for Art Lake Creek will be studied. A review will be made of Project facilities such as the pipeline and Pipeline Road to determine if there are other streams to which analysis should apply. The tailrace channel and the drop structure are addressed in separate study plans (see Geomorphology and Habitat of the Tailrace Slough, Engineering Study Related to Barrier Replacement on the Tailrace, and Fish Population Characterization Near the Drop Structure).

A fish passage study is underway on a potential barrier on Lake Creek at RM 1.03; if further examination indicates that this is not a barrier at all flows, then another potential barrier (bedrock falls) at RM 1.95 will be examined.

5.2 Methodology

Evaluation of culverts for fish passage will follow the protocol set forth in WDFW’s fish passage guidelines entitled “Washington Department of Fish and Wildlife Passage Barrier and Surface Water Diversion Screening Assessment and Prioritization Manual” (TAPPS 2000), and the “Design of Road Culverts for Fish Passage” (Bates 2003) document. The primary purpose of the former manual is to provide guidance on how to identify and prioritize culverts, dams, and fishways that impede fish passage. This protocol is widely accepted throughout Washington and many local, state, and federal agencies and other groups have or are currently utilizing it. The protocol provides a standard method of data collection across the state, a means to prioritize fish barriers for replacement across differing jurisdictions, and a single database depository. Anadromous access, the amount of usable habitat, the habitat quality throughout all reaches, and
additional barriers (human-made and natural) should be verified via downstream and upstream checks to provide a higher level of data confidence. When assessing natural waterfalls for fish passage the protocol recommended in Powers and Orsborn (1985) should be used, modified to reflect resident fish leaping and swimming capabilities. Passage will be assessed for all species and life stages present.

The first step at each potential barrier site is to identify the feature as either a culvert, fishway, or dam. When applicable, Energy Northwest will obtain additional information for each feature as described below.

5.2.1 Fish Bearing Determination

A determination will be made at each site as to whether the waterway is fish bearing. To make this assessment, waterways will be evaluated to determine if they:

1. Are WDNR-mapped type 1-4 waterways;
2. Have documented presence of fish through visual observation, electrofishing, or verification by local biologists;
3. Are water courses having ordinary high water widths greater than 0.60 meters (m) and gradients less than 20%; or

If none of the above criteria is met, the waterway is assessed as non-fish bearing. If any of these criteria are met, but fish presence is questionable, then the waterway is evaluated as unknown for fish presence. Using the WDFW criteria, fish presence at each site is evaluated as potential presence, if the habitat above were made accessible. The barrier assessment is not necessarily intended to identify whether or not fish are currently using the habitat. If some of these criteria are met, Energy Northwest will determine if fish are present below the existing barrier.

5.2.2 Fish Passage Determination

Within the TAPPS manual protocol, there are three categories for fish passability: passable, impassable, or unknown. The protocol has been designed to assess fish passability for all juvenile through adult salmonid life stages. Partial barriers were rated as a percentile of the degree of passability (0%, 33%, 67%, 100%); impassable status does not always indicate a barrier to all fish species or life stages.

A Level A analysis will be completed for initial barrier determination of culverts, and if barrier status cannot be determined at this level, a Level B analysis will be initiated (see Level A and B analysis flow charts, Figures 5-1 and 5-2, below). Based on the Level B analysis, the barrier status of a culvert is unknown if there is a grade break within the culvert, a downstream control point is inaccessible, or the culvert is submerged. The downstream control is typically the head of the first riffle downstream of the culvert, where measurements must be taken for the Level B analysis. If there is a wetland or large pond downstream of the culvert, then the downstream control is inaccessible.
If the stream is not used by chum salmon, and the water level difference up and downstream of the dam is greater than 0.30 m, then the dam is a barrier.

Surveying is used to obtain the culvert length and slope and all other measurements. Photographs are taken and site location is recorded using a GPS receiver, if feasible. If GPS is not feasible, the location will be marked on 7.5 minute quad maps and location determined through GIS or other appropriate model.

**Figure 5-1. Level A Culvert Analysis**
BARRIER ANALYSIS – LEVEL B

Level B Applicability:
Is there a grade break in the culvert? Is the culvert tidally influenced? Is the downstream control inaccessible?

Any
Yes
Barrier Status is Unknown

No to all
Collect the information in Table 3b

Calculate the High Fish Passage Design Flow

Calculate the Depth and Velocity using Manning’s Equation

Does the Calculated Depth and Velocity meet the Criteria for Trout in WAC 220-110-070?

Yes
The culvert is Passable

No
Do a Backwater Analysis

Is the Culvert Backwatered to the Upstream End of the Culvert?

No
The Culvert is a Barrier

Yes

Does the Calculated Depth and Velocity at the Upstream End of the Culvert meet the Criteria for Trout in WAC 220-110-070?

Yes
The Culvert is Passable

No
The Culvert is a Barrier

Figure 5-2. Level B Culvert Analysis
5.2.3 **Stream Simulation Determination**

A discrepancy exists between the TAPPS manual protocol determination of a fish barrier and the WDFW stream simulation design for installing fish passable culverts. In order to address this discrepancy (explained in the next paragraph) and in addition to the measurements taken following the TAPPS manual protocol, measurements are also taken for the WDFW stream simulation model on culverts that satisfy certain requirements (see Figure 5-3). The stream simulation model is “a design method used to create or maintain natural stream processes in a culvert. Stream simulation is based on the principle that, if fish can migrate through the natural channel, they can also migrate through a man-made channel that simulates the stream channel” (Bates 2003).

![Stream Simulation Mode/No Slope Model](image)

**Abbreviations:**
- Sculv = Slope of culvert
- Sch = Slope of Channel
- Wcb = Width of culvert bed
- Wch = Width of backfull channel

**Figure 5-3. Stream Simulation Model/No Slope Model**
According to the TAPPS manual protocol, a culvert is considered passable if it has streambed material throughout, and the ratio of the diameter of the culvert to the toe width of the stream is 75% or greater. However, a culvert that is determined passable by the TAPPS manual protocol may not meet the specifications required of the WDFW stream simulation design criteria. To determine whether an existing culvert meets the stream simulation criteria, the bankfull channel width and the slope of the streambed are measured in comparison with the existing culvert diameter and slope. The culvert bed diameter should be 1.2 times the bankfull channel width, plus 2 feet; and the slope ratio of the stream to the culvert should be no greater than 1.25 (see Figure 5-3).

### 5.2.4 Habitat Assessment

For each culvert that is determined to be a fish passage barrier, it is necessary to perform a physical habitat assessment to prioritize the barrier for correction. The physical habitat assessment quantifies the amount of spawning and rearing habitat available to each salmonid species present or presumed to occur at the site. A priority index (PI) rating is generated for each barrier through a Priority Index Model created by WDFW. The PI is based on cost, species utilization, and habitat gain. The habitat gain is 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) are assigned to each reach within the survey (Table 5-1). 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 in square meters). Table 5-1 summarizes the criteria for rearing and spawning habitat.

The full physical survey methodology will be utilized, as this provides the most reliable information about the habitat upstream of the barrier. Habitat measurements will be measured on 30 m sections of 160 m sections if the total stream length is less than 1.6 km. However, habitat measurements will be completed on 60 m sections of 320 m sections if the total stream length is greater than 1.6 km. It is 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 will be used to measure total distance while walking upstream, and will use a laser level to obtain stream gradient readings.
### Table 5-1. Criteria Used to Assign Habitat Quality Modifiers (HQM) to Rearing and Spawning Habitat.

<table>
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<th>Habitat Condition</th>
<th>HQM Value</th>
<th>Rearing Habitat Criteria</th>
<th>Spawning Habitat Criteria</th>
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<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

### 5.2.5 Analysis of Hall Creek

Hall Creek has been evaluated and found not to be a barrier to fish passage (see Appendix 1). Maintenance of stream processes by transport of large woody debris was examined and determined not to be an issue. The habitat upstream of the flume is a marsh with little large wood. A culvert where Hall Creek crosses under Snyder Road is located approximately one-half mile upstream of the marsh. No large wood can pass downstream of this culvert. This information was confirmed with the agencies during a site visit on July 19, 2005.

### 5.2.6 Analysis of Snyder Creek

The culvert where Snyder Creek crosses under the tailrace will be examined and a determination made as to whether it is passable using criteria described in Section 5.2.2 of this study plan. The habitat will be examined and a determination made concerning fish presence above the culvert.

Based on discussions with the agencies at the Snyder Creek crossing on July 19, 2005, instream and riparian habitat surveys will be conducted on lower Snyder Creek to its confluence with Hall Creek and the slough area adjacent to the tailrace in order to quantify the habitat in those areas to determine if rerouting Snyder Creek into the slough is a desirable option. The feasibility of constructing a tailrace siphon under Snyder Creek also will be examined. A determination will be made as to the best and most effective means of correcting a potential passage problem at this site.
5.2.7 **Analysis of Art Lake Creek**

The culvert on the Pipeline Road will be examined and a determination made as to whether it is a barrier to fish migration. If it is determined to be a barrier, a survey will be conducted to the next barrier downstream of the culvert, and the stream will be electrofished or snorkeled to determine if fish are present in that reach.

If fish are found in the sampled reaches, the following will be 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.

5.2.8 **Analysis of Lake Creek**

A fish passage study is underway on a potential barrier on Lake Creek at RM 1.03 (see Appendix 2); if further examination indicates that this is not a barrier at all flows, then another potential barrier (bedrock falls) at RM 1.95 will be examined. Powers and Orbsorn (1985) will be used, excluding Fish Condition Factor. A planned release from the drop structure is tentatively scheduled for June 2006 so that surveys can be conducted at a flow of at least 100 cfs.

5.3 **Products**

The products of the Fish Passage Barriers study will be draft and final reports discussing the results of the barrier analysis. Preliminary data will be reviewed by the resource agencies and tribes. Draft and final study results will be provided to the resource agencies and tribes for review and comment.

5.4 **Consistency with Generally Accepted Scientific Practice**

The survey protocol proposed is essentially the same as specified by the Forest Service, USFWS, and WDFW in their requests. Justification of the study protocols is given in Section 5.2 for each study proposed.

6.0 **CONSULTATION WITH AGENCIES, TRIBES AND OTHER STAKEHOLDERS**

Energy Northwest will consult with an Environmental Engineer from the WDFW Habitat Program throughout this study process to evaluate potential fish passage concerns.

Energy Northwest initiated agency consultation in December 2003. A Water Quality and Aquatic Resources Committee was formed in March 2004. Representatives include Energy Northwest, EES Consulting, WDFW, USFWS, NOAA Fisheries, Department of Ecology, the Forest Service, the Cowlitz tribe, and the Yakama Nation. Updates will be provided and draft and final reports will be provided to the agencies and tribes for review and comment.
7.0 PROGRESS REPORTS, INFORMATION SHARING, AND TECHNICAL REVIEW

Technical reports, including the draft and final Fish Passage Barriers study reports will be shared with agencies, tribes, and stakeholders. Energy Northwest and its consultant will report on the methods, progress, and results of the study at the Water Quality and Aquatic Resources Committee meetings.

Energy Northwest will provide copies of the reports to interested stakeholders for review. A review period of 30 days will be provided for stakeholder comment on draft reports, after which Energy Northwest and its consultant will take review comments into consideration when making revisions and producing a final report.

8.0 SCHEDULE

Data collection efforts will be initiated in 2005 as soon as the parties reach agreement. The planned overtopping of the drop structure is tentatively scheduled for June 2006. The study will be completed in 2006. The draft Fish Passage Barriers study report will be completed and distributed to the resource agencies and tribes following completion of the field effort, no later than September 30, 2006.

9.0 LEVEL OF EFFORT AND COST

This study will require use of hip chain, measuring tape, laser level, and other equipment. The fish passage barrier and Priority Index assessments will consist of two person crews. Table 9-1 reflects estimated person hours to conduct the studies on Snyder, Art Lake and Lake creeks. An additional day of effort for a team of two to assess other potential barriers is included in the estimate.

Additional costs include equipment purchase and rental, mileage, travel and per diem costs. Ten hour days are assumed for field work. When possible, other activities will be scheduled concurrent with this study to maximize efficiency. For example, work on the entrainment study or fisheries activities associated with the lake will be scheduled simultaneously with the upstream migration seining when feasible. Travel costs are reduced to reflect this assumed combination of field effort. Total estimated costs for this study are $25,446.

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<td>Draft Report</td>
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<td>Final Report and Project Management</td>
<td>3</td>
<td>48</td>
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Preliminary studies conducted in 2004 cost approximately $10,440.
10.0 LITERATURE CITED


14
APPENDIX 1

Final Hall Creek and Snyder Creek Fish Passage
FINAL

HALL CREEK AND SNYDER CREEK
FISH PASSAGE

Prepared for:

Energy Northwest

Prepared by:

EES Consulting

July 27, 2005
FINAL

HALL CREEK AND SNYDER CREEK
FISH PASSAGE

SECTION 1: INTRODUCTION

The Packwood Lake Hydroelectric Project (Project) includes a tailrace channel that crosses over Snyder and Hall creeks. The goal of this study was to establish if the tailrace channel impacts fish migration and channel connectivity, and to establish whether the tailrace channel is a barrier to fish and/or has a negative impact on channel connectivity.

Project Operation

Lake Creek is located at the outlet of Packwood Lake and flows to the northwest approximately 5.3 miles to the upper Cowlitz River where it enters at approximately River Mile (RM) 129.2. Water used to produce power for the Project is diverted from Lake Creek at approximately elevation 2857 ft MSL and delivered to the powerhouse at about elevation 1057 ft MSL. Generation water is returned to the upper Cowlitz River via a tailrace channel which carries water about 6,700 ft from the powerhouse to where it joins the Cowlitz River at approximately RM 125.2.

Both Hall Creek and Snyder Creek cross under the tailrace (see Figure 1). Snyder Creek enters a vertical drain in a stilling basin on the upstream side of the tailrace; it exits via a horizontal culvert encased in concrete on the downstream side into a small basin attached to a channel that eventually drains into Hall Creek. The tailrace flume is suspended for 360 ft over Hall Creek, which passes underneath the flume in a marshy area.

SECTION 2: METHODS

EES Consulting, Inc., on behalf of Energy Northwest, surveyed Snyder Creek and Hall Creek in the immediate vicinity of the tailrace channel and flume in 2004. In the case of Hall Creek, the span under the flume was measured (vertically and horizontally); for Snyder Creek, the drain, grate, upstream and downstream water surface elevations, and downstream control were surveyed. Photographs were taken of both areas.
Figure 1 – Snyder Creek and Hall Creek Stream Crossings
SECTION 3: RESULTS

3.1 Hall Creek

EES Consulting, Inc. surveyed passage at both the upstream and downstream side of the flume where it crosses Hall Creek. Upstream of the flume, Hall Creek enters a marsh and extends laterally for over 50 feet. Hall Creek passes under the flume in a 36-ft section where depths range between 2.5 ft and 3.1 ft. At the time of the survey, the water surface elevation of Hall Creek was the same as the bottom of the flume. The calculated area under the flume at this location was approximately 100 ft$^2$, (36 ft in width X average depth of 2.8 ft). Even if the water depth were to increase so that it backed up onto the flume, there would still be 100 ft$^2$ of passage with relatively evenly-distributed, laminar flow under the flume; there would not be any velocity barriers. In addition, there were other areas where Hall Creek passed under the flume with clearance. Photos 1 and 2 portray the flume where it spans Hall Creek. Figure 1 shows the location of Hall Creek relative to the project powerhouse and tailrace.

Photo 1. Hall Creek upstream of flume.
3.2 **Snyder Creek**

Snyder Creek originates from Snyder Lake and enters a vertical drain on the upstream side of the tailrace (see Figure 1). The drain is covered by a grate, with openings as large as 9.6 in X 6 in. At the time of the survey, the grate was covered with 1.23 ft of water (see Photos 3 and 4).
Below the grate, the creek drains vertically 4.65 ft before connecting with a concrete-encased culvert which extends across and underneath the tailrace. The water surface elevation on the upstream side (i.e., above the drain) was only 0.27 ft higher than the downstream side of the drain; a riffle immediately downstream of the culvert opening is the hydraulic control for the opening (see Photos 5 and 6). Figures 2 and 3 show the Snyder Creek drain in plan and profile view, respectively.

Photo 5. Riffle acting as control for pool, downstream side of tailrace.
Photo 6. Downstream entrance of culvert on Snyder Creek, below tailrace.

Figure 2 – Snyder Creek Plan View Drawing
Currently, most of the culvert is filled with sediment passing down Snyder Creek and through the grate. Only the top 6 – 8 inches is currently clear and all flow is directed towards the top of the opening. A deep pool exists immediately downstream of the crossing with a hydraulic control 0.16 ft below the downstream water surface elevation.

**SECTION 4: DISCUSSION**

### 4.1 Hall Creek

Hall Creek is passable at all flows. The area that Hall Creek drains is extremely low gradient. Hall Creek tends to inundate a wide area laterally. However, Hall Creek does have a main channel and its thalweg, where it crosses under the tailrace flume, is over 3.0 ft in depth on the date of the survey. With a cross-sectional area of 100 ft$^2$, the opening under Hall Creek can easily accommodate fish passage at much higher flows without creating any velocity barriers to fish under these conditions. The natural resource agencies have questioned whether or not the flume prevents recruitment of large wood from upper to lower Hall Creek. Consultation with Energy Northwest personnel indicates that they have never observed large wood resting on the upstream side of the flume.

### 4.2 Snyder Creek

The openings in the grate upstream of the flume vary in size, with the largest ones measuring 9.6 in X 6 in. Openings of this size would probably allow passage of coho salmon. Given the size of Snyder Creek, it is unlikely that Snyder Creek would support Chinook salmon.

Energy Northwest has agreed to survey the Snyder Creek vertical drain using methods described in Section 5.2.2 of the Fish Passage Barriers study for the relicensing of the Packwood Lake Hydroelectric Project (Energy Northwest 2005).
SECTION 5: CONCLUSION

In conclusion, the tailrace flume does not impede fish passage at Hall Creek. Fish passage is currently undetermined in Snyder Creek.

SECTION 6: LITERATURE CITED


APPENDIX 2

Interim Report - Lake Creek Anadromous Barrier Analysis
INTERIM REPORT
LAKE CREEK
ANADROMOUS BARRIER ANALYSIS

Prepared for
Energy Northwest

Prepared by
EES Consulting

JULY 2005
SECTION 1: INTRODUCTION

In accordance with the Cowlitz River Project settlement agreement of August 10, 2000, anadromous fish are being reintroduced into the upper Cowlitz River above Barrier, Mossyrock, and Cowlitz Falls dams via the trap-and-haul of adults. The target species under this agreement are Chinook and coho salmon and steelhead trout. Sea-run cutthroat trout are also transported and released above the dams (City of Tacoma 2000). With this reintroduction strategy, there is the potential for these species to utilize lower Lake Creek. Because there are no current data on species utilizing either lower Lake Creek or the tailrace slough, Energy Northwest requested that EES Consulting conduct electrofishing, snorkeling, and/or spawner surveys to verify the presence and relative abundance of anadromous salmonids as well as rainbow trout, cutthroat trout, lamprey, and sucker (EES Consulting, 2005).

An integral part of the Lake Creek instream flow study is a physical habitat survey of Lake Creek in its entirety. A probable anadromous barrier (a 25 ft falls) exists at RM 1.95 and has been noted by the USDA Forest Service (1995) and Wieman (2004). Lucas (WDFW 1992) also identified this as the probable end of anadromous fish distribution and cited three independent surveys to support his conclusions including a WDFW foot survey, and surveys conducted by Bryant and Kray.

EES Consulting noted a chute/falls complex that has the potential to be a barrier to upstream migration of anadromous fish at RM 1.03. Energy Northwest, in consultation with EES Consulting, the tribes and natural resource agencies, discussed the feasibility of analyzing this chute against established, published criteria and evaluating its potential as an anadromous barrier. This report summarizes the results of that evaluation.

Three anadromous fish species that would attempt to migrate upstream in Lake Creek are spring Chinook and coho salmon and steelhead trout. Chinook and coho salmon have been observed spawning below the chute/falls complex in 2004; steelhead trout have not been seen to date (latest survey July 12, 2005).

SECTION 2: METHODS

EES Consulting surveyed the falls/chute complex at RM 1.03 at three separate flows in 2004. Lake Creek flows are regulated by the Packwood Lake Hydroelectric Project plus additional accretion from tributaries downstream. Measurements were taken of the barrier at base, middle, and high calibration flows for the Lake Creek instream flow study.
Cross sectional measurements were taken at lip (crest) of the falls/chute, in the middle section of the chute, and near the top of the chute. The longitudinal profile of the falls/chute complex was surveyed using a Topcon auto level and stadia rod and extended from the plunge pool at the base of the falls approximately 50 ft upstream of the lower end of the barrier. To define the profile, EES Consulting surveyed gradient breaks along the thalweg of the profile. Although measurements were not taken every foot, they adequately defined the longitudinal profile for purposes of this analysis.

Detailed photographs and a video were taken of the falls/chute complex at flows of 46 cfs, 25 cfs and 11 cfs as measured at the downstream gage (releases of 33 cfs, 13 cfs and 3 cfs at the outlet structure, respectively). Velocities were taken at the falls crest, mid-channel in the chute, and near the top of the chute.

2.1 Survey of Potential Barriers

There are numerous boulder cascades, turbulent cascades, multiple falls and chutes present in Lake Creek below the intake structure. A total of 11 falls and 23 chutes were noted by the USDA Forest Service (1993) during its survey, and these were verified by EES Consulting in 2004. A chute/falls complex located at RM 1.03 has the potential to preclude upstream passage of anadromous salmonids. This chute was evaluated by EES Consulting for Energy Northwest.

Upstream passage potential was analyzed for steelhead trout, the species with the greatest leaping ability among the anadromous fish present in the upper Cowlitz River system, as well as Chinook and coho salmon, which are known to utilize Lake Creek for spawning. The barrier was analyzed according to its height, horizontal distance, plunge pool exit conditions, crest depth and velocities, landing zone conditions and chute velocities ranging from flows of 3 cfs to 33 cfs as released from the project drop structure (i.e., flows at the barrier from approximately 11 – 46 cfs). EES Consulting then used the criteria established in Powers and Orsborn (1985), including leaping ability, to assess passage, as agreed to in consultation with the agencies and tribes.

Several factors are important to evaluate when determining passage success at barriers: 1) the plunge pool (fish entrance zone); 2) landing conditions (fish exit zone) and 3) the barrier itself (fish passage zone) (Powers and Orsborn 1985). White water and turbulence are also important to evaluate when assessing barriers. Jackson (1950) noted turbulence deflects a swimming fish from its course, causing it to expend energy resisting upwellings, eddies, entrapped air and vortices, which in turn make it impossible for a fish to use its swimming power effectively (Powers and Orsborn 1985). Factors influencing the fish entrance, passage and exit zones are summarized below and are derived from Powers and Orsborn (1985). Additional information was obtained from R2 Consultants and Ichthyological Associates, Inc (2000).
Fish Entrance Zone

A good takeoff pool is essential if fish are to leap effectively to any height. If the turbulent pool conditions, created from the falling water impacting the shallow pool, prevent a good takeoff, a relatively low fall my act as a total barrier (Powers and Orsborn 1985). In addition, air bubbles are created by the mixture of air and water as the falling water impacts the surface and entrain large quantities of air. When this occurs, the leaping height attained by fish attempting to leap the barrier is much less than the recorded maximum at other passable falls because of the reduced attraction flow (Stuart 1964). As stated in R2 Consultants and Ichthyological Associates, Inc (2000): “A pool which is deep enough to absorb the falling water will result in the formation of a well-defined standing wave relatively close to the falls from which a fish can leap. A shallow plunge pool will result in highly turbulent conditions which produce difficult leaping conditions for fish. A shallow plunge pool will also result in the formation of the standing wave further downstream of the falls.” This results in a greater leaping distance, since fish usually leap from the standing wave towards the barrier crest. In addition, the air bubbles created by the falls under these conditions greatly reduce the propulsive power of a fish’s tail, resulting in smaller leaps (Stuart 1964). Aaserude (1984) concluded that two conditions should be satisfied to provide optimum leaping conditions in the plunge pools:

1. Depth of penetration of the falling water should be less than the depth of the plunge pool (turbulent pool conditions disorient fish and the standing wave is reduced and moved downstream).
2. Depth of the plunge pool must be greater than or equal to the length of the fish attempting to pass (if the depth less than length of fish, propulsive power of fish’s tail may be reduced for leaping).

Stuart (1964) also states that the depth of the plunge pool should be at least 1.25 times the falls height in order to create optimal leaping conditions for fish. Any waterfall that is steep enough to accelerate flow to violent white water should be considered a total barrier to upstream fish passage (Powers and Orsborn 1985).

Fish Passage Zone

Analysis of Falls

One type of passage barrier is a falls. When the change in water surface elevation between pools exceeds the leaping height of the species in question, the falls is considered a barrier. For Pacific salmon and steelhead, the highest calculated leap from a level pool is 10.9 ft for steelhead. Falls where a change in water surface elevation is in excess of 11 ft can be considered a barrier (Powers and Orsborn 1985). Bruce Crawford (WDFW), however, observed steelhead jumping the Kalama Falls at the upper Kalama River Hatchery on a regular basis, with the occasional, younger (3 year old) Chinook salmon also jumping the falls. The falls is twelve feet in height on the upper Kalama
River. It is his opinion that a jump of approximately 13 feet is closer to the true height that a steelhead can jump (Email to H. Beecher, WDFW, February 25, 2005).

In many cases, the actual distance the fish must leap is greater than the vertical drop between pools. Unless the water is falling vertically, some horizontal component of the leap will be required for successful passage. Assuming that the plunge pool and landing conditions are satisfied, the following conditions assess passage at waterfalls (from Table 8, Powers and Orsborn 1985):

1. If the change in water surface elevation > the height the fish can leap, it is an elevational barrier.
2. If the change in water surface elevation < the height the fish can leap, two analyses can be conducted:
   a. If the horizontal distance from the crest to the standing wave > horizontal leap at the highest point of the leap, it can either be passable or a horizontal distance barrier.
   b. If the horizontal distance from the crest to the standing wave < horizontal leap at the highest point of the leap, it is passable.

Analysis of Chutes

Another type of barrier is a chute. Powers and Orsborn (1985) states that by definition, the flow must be supercritical down the chute (Froude number is greater than unity). At the start of the chute the flow will pass through critical depth and then into a transition zone of varied flow for some distance before uniform flow is established. If the chute length is shorter than the transition length required to reach normal depth, uniform flow cannot be attained.

The mean velocity of turbulent uniform flow in chutes can be expressed by the following equation:

\[ V = (1.49/n)(R)^{0.67}(Sp)^{0.5} \]

where \( V \) = mean velocity (ft/sec), \( n \) = empirical roughness coefficient, \( R \) = hydraulic radius in ft and \( Sp \) = passage slope.

The \( n \) value for smooth bedrock is 0.025 – 0.030; the hydraulic radius was calculated by using the HYDSIM submodule of RHABSIM (by Thomas R. Payne and Associates), and the slope was calculated from the change in bed elevation and horizontal distance from the top to the bottom of the chute.

The conditions for analyzing a chute are listed below and come directly from Powers and Orsborn (1985), assuming that plunge pool requirements, landing conditions and depth of flow are sufficient.
Table 1. Chute conditions, given that plunge pool requirements, landing conditions, and depth of flow are sufficient (Powers and Orsborn 1985).

<table>
<thead>
<tr>
<th>Condition</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 If the Velocity of the water &gt; Fish speed</td>
<td>Velocity Barrier</td>
</tr>
<tr>
<td>2 The velocity of the water &lt; fish speed</td>
<td></td>
</tr>
<tr>
<td>Length of the slope &gt; distance the fish can swim</td>
<td>Distance/velocity barrier</td>
</tr>
<tr>
<td>Length of the slope &lt; distance the fish can swim</td>
<td>Passable</td>
</tr>
</tbody>
</table>

**Classification of Barriers**

Powers and Orsborn (1985) assign a degree of passage difficulty rating (from 1 to 10, with 10 being the most difficult) that is independent of barrier height and velocity. The rating is based on the following assumptions:

1. The differential elevation and water velocities are within the swimming and leaping capabilities of the species in question.
2. At higher swimming speeds (> 9 ft/s) leaping is more energetically efficient than swimming (Blake 1983 as cited in Powers and Orsborn 1985).
3. Fish will be attracted to the area of highest momentum (flow x velocity) when migrating upstream; therefore, if multiple paths are present the fish may try to ascend the one with the highest attraction which will be created by the highest combination of drop, velocity, and discharge. **[Note: This is not always the case, in that Dr. Beecher (WDFW) observed steelhead passage at the waterfall on the Little Klickitat River near the confluence of Bowman Creek during 1991. In this instance, he watched steelhead ascend a small chute to the side of the main waterfall that carried the bulk of the flow; here fish were able to move to a lateral area of reduced flow (H. Beecher letter to L. Vigue, WDFW, April 1, 2005)].**
4. Turbulent flow (for white water) with surges, boils, and eddies make it difficult for fish to orientate themselves and make full use of their swimming power.

In the case of the barrier in question at RM 1.03, Powers and Orsborn (1985) would consider it a compound barrier, consisting of both a falls and a chute.

**Vertical Distance.** According to Powers and Orsborn (1985), the curved trajectory of a fish leaping a falls can be best described as a projectile motion (see Figure 1, from Powers and Orsborn 1985). The leap can be divided into two components: vertical (y axis) and horizontal (x axis). Vertical distance represents the height a fish must leap in order to reach the top of the falls, and was calculated by subtracting the water surface elevation (WSE) of the plunge pool at each flow from the crest elevation of the barrier. The crest elevation is not always the highest elevation along the longitudinal profile, but the point which provided a resting area for the fish (R2 Consultants and Ichthyological Associates, Inc 2000).
**Horizontal Distance.** The leap of a fish must be of sufficient length as to allow it to clear the horizontal distance between the plunge pool and the crest elevation. As stated by R2 Consultants and Ichthyological Associates, Inc (2000), “This distance may be relatively short, such as at falls where water free-falls down to the plunge pool below. However, many bedrock waterfalls and most boulder cascades possess a steeply inclined face over which water flows at high velocities before striking the water. If the horizontal distance of a barrier is too long, then a falls which has a height which a fish can normally leap will still be a total barrier.”

EES Consulting determined the horizontal distance the fish was required to travel by subtracting the position of the base of the falls from the horizontal position of the crest with the resting area.

**Fish Landing Zone**

When fish leap at waterfalls, often the landing conditions near the crest are such that the fish may be swept back by high velocities or unable to propel themselves in water depths less than their body depths, where they are not totally submerged. The following factors should be evaluated when assessing landing conditions:

1. The depth of flow where the fish lands must be equal to or greater than the depth of the fish (generally considered to be 1.0 ft for steelhead).
2. The velocity where the fish lands should be within the range of the sustained swimming speed for the species in question. [Note: Dr. Beecher qualifies this statement: “Leaping fish can often be swimming in air during a leap. They may land in a burst speed effort and so continue upstream through water that exceeds sustained swimming speed. Using the assumption that fish cannot exceed sustained swimming speed upon landing may lead to incorrect classification of a barrier” (H. Beecher letter to L. Vigue, WDFW, April 1, 2005)].
3. The velocity and depth should be analyzed under a range of fish migration flows (Powers and Orsborn 1985).

### 2.1 Fish Condition

The ability of a fish to leap and swim is dependent upon its condition. Powers and Orsborn (1985) distinguish three different coefficient of fish condition \( C_{fc} \) based on the following definitions (Table 2):

<table>
<thead>
<tr>
<th>( C_{fc} )</th>
<th>Fish Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00</td>
<td>Bright: fresh out of salt water or still a long distance from spawning grounds; spawning colors not yet developed.</td>
</tr>
<tr>
<td>0.75</td>
<td>Good: in the river for a short time; spawning colors apparent but not fully developed; still migrating upstream.</td>
</tr>
<tr>
<td>0.50</td>
<td>Poor: in the river for a long time; full spawning colors developed and fully mature; very close to spawning grounds</td>
</tr>
</tbody>
</table>
Figures 1 and 2 (Figures 7 and 8 in Powers and Orsborn 1985) show the leaping ability of steelhead trout and Chinook and coho salmon with C_{fc} 1.00 and 0.75, respectively. Table 3 shows the leaping and swimming capabilities of steelhead trout in excellent, good (from R2 Consultants and Ichthyological Associates, Inc 2000) and poor conditions. Table 4 gives the leaping and swimming capabilities of Chinook and coho salmon (from Powers and Orsborn 1985). [Note: per agency consultation with P. Powers, WDFW, fish condition should no longer be considered a factor influencing the ability of a salmon or trout to negotiate a barrier, since the biological urge to spawn may override the physical condition of the fish. As a result, the tables and figures are retained with C_{fc} values < 1.0 but are not used in the subsequent analysis].

Table 3. Leaping and swimming capabilities for steelhead trout in excellent (bright) condition. Leaping and performance values assume that no air is entrained in the water (sources: Powers and Orsborn 1985; Bell 1990). Table from R2 Consultants and Ichthyological Associates, Inc (2000).

<table>
<thead>
<tr>
<th>Description</th>
<th>Excellent Condition C_{fc} = 1.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Height, 80° Trajectory</td>
<td>10.8 ft</td>
</tr>
<tr>
<td>Maximum Horizontal Distance, 80° Trajectory</td>
<td>8 ft</td>
</tr>
<tr>
<td>Maximum Height, 60° Trajectory</td>
<td>8.0 ft</td>
</tr>
<tr>
<td>Maximum Horizontal Distance, 60° Trajectory</td>
<td>19 ft</td>
</tr>
<tr>
<td>Maximum Height, 40° Trajectory</td>
<td>4.5 ft</td>
</tr>
<tr>
<td>Maximum Horizontal Distance, 40° Trajectory</td>
<td>22 ft</td>
</tr>
<tr>
<td>Maximum burst swimming speed</td>
<td>26.5 ft/s</td>
</tr>
<tr>
<td>Maximum prolonged swimming speed</td>
<td>13.7 ft/s</td>
</tr>
<tr>
<td>Maximum sustained swimming speed</td>
<td>4.6 ft/s</td>
</tr>
<tr>
<td>Maximum swimming distance, water velocity = 10 ft/sec</td>
<td>83 ft</td>
</tr>
</tbody>
</table>

Table 4. Leaping and swimming capabilities for Chinook and coho salmon in excellent (bright), Leaping and performance values assume that no air is entrained in the water (sources: Powers and Orsborn 1985; Bell 1990).

<table>
<thead>
<tr>
<th>Description</th>
<th>Excellent Condition C_{fc} = 1.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Height, 80° Trajectory</td>
<td>7.6 ft</td>
</tr>
<tr>
<td>Maximum Horizontal Distance, 80° Trajectory</td>
<td>5 ft</td>
</tr>
<tr>
<td>Maximum Height, 60° Trajectory</td>
<td>5.8 ft</td>
</tr>
<tr>
<td>Maximum Horizontal Distance, 60° Trajectory</td>
<td>13 ft</td>
</tr>
<tr>
<td>Maximum Height, 40° Trajectory</td>
<td>3.2 ft</td>
</tr>
<tr>
<td>Maximum Horizontal Distance, 40° Trajectory</td>
<td>15 ft</td>
</tr>
<tr>
<td>Maximum burst swimming speed</td>
<td>22.4 ft/s</td>
</tr>
<tr>
<td>Maximum prolonged swimming speed</td>
<td>10.8 ft/s</td>
</tr>
<tr>
<td>Maximum sustained swimming speed</td>
<td>3.4 ft/s</td>
</tr>
<tr>
<td>Maximum swimming distance, water velocity = 10 ft/sec</td>
<td>62 ft</td>
</tr>
</tbody>
</table>

The burst speed of steelhead trout (26.5 ft/second) is given above for fish in excellent condition. It is important to note that the values of fish speeds suggested by Bell (1990) are for fish swimming in water without entrained air. When swimming in white water,
the density of the water/air mixture will be reduced and detract from the propulsive power of the fish’s tail, reducing its speed (Powers and Orsborn 1985).

SECTION 3: RESULTS AND DISCUSSION

3.1 Fish Condition

EES Consulting has observed many anadromous salmonids in both Lake Creek and the tailrace slough during 2004 (Chinook and coho salmon; see Lake Creek Spawner Survey report (EES Consulting, 2005) for details. All fish observed would have been classified as Ce0.50 (poor) in that they already had been in the river a long time and trucked to the Skate Creek Bridge in Packwood; all were in spawning colors or had begun to fungus-up; with many of them physically deteriorating; and all were on or within a mile of the spawning grounds. Fish condition, per agency consultation with P. Powers of WDFW, should be excluded from the analysis. As a result, all species will be analyzed as if in excellent condition (Ce1.00).

3.2 Description of Potential Barrier

This potential barrier is classified as a compound falls and complex chute. The barrier is composed completely of bedrock. It has a total height (water surface elevation [WSE] of the plunge pool to WSE of the crest) of 9.32 ft as measured at the low flow release with an average gradient in the chute of over 41%. The upper half of this barrier is a very steep, narrow, twisting chute with measured velocities at the middle flow release of over 14 ft/s. The water is very shallow in the chute (< 0.4 ft), is fully entrained with air, and changes direction at the base, and there is a curved alignment of the chute (Appendix A Photo 3). There is no resting area in the chute, nor is there a place for fish to re-orient themselves before attempting to swim or leap the chute. At the flows observed, there is only one possible route through this compound barrier, although the chute has two flow streams. At higher flows, the hydraulics of the chute may change. Figure 3 shows the bed profile and various WSEs of this barrier.

3.2 Passage Analysis

Photos of the chute at low, middle and high flows are included in Appendices A, B and C respectively.

Plunge Pool

Exit conditions for steelhead trout and Chinook and coho salmon can be considered good at all flows (see Photo 1 in each of the Appendices A, B and C). Although the surface of the plunge pool is highly turbulent, the depth of the pool is over 5 ft at the low flow and the depths increase with additional discharge (Table 5). Several smaller fish (approximately 12” in length) were observed attempting to jump into this falls, but were not successful.
Table 5. Depth of plunge pool at measured flows

<table>
<thead>
<tr>
<th>Flow</th>
<th>Depth (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>5.54</td>
</tr>
<tr>
<td>Middle</td>
<td>5.81</td>
</tr>
<tr>
<td>High</td>
<td>6.02</td>
</tr>
</tbody>
</table>

*Vertical Distance*

Steelhead salmon with $C_{fc}$ 1.00 would be able to leap 10.8 ft at an 80° angle (the angle with the highest leap; Powers and Orsborn 1985). Steelhead have been observed leaping 12 ft at Kalama Falls. Chinook and coho salmon leaping in excellent condition would be able to achieve a leap of 7.6 ft since the lip of the falls immediately above the plunge pool is only 4.3 ft. All species would be able to leap these falls.

Although the lip of the falls immediately above the plunge pool is only 4.3 ft in elevation above the plunge pool WSE, there is no resting or landing zone available at the top of this falls. The water is fully entrained with air, reducing the propulsion effectiveness of the fish’s tail, reducing the effective speed of the fish. As defined by Powers and Orsborn (1985), a good fish landing (i.e., exit) zone would have velocities where the fish lands within the sustained swimming speed of that species. Table 6 summarizes velocity measurements taken at the falls crest. The minimum velocity (at base flow) was 8.30 ft/s, which exceeds the sustained swimming speeds of steelhead trout and Chinook and coho salmon in excellent condition (as shown in Tables 3 and 4), but not the burst swimming speeds of 26.5 ft/s (steelhead) and 22.4 ft/s (Chinook and coho) for these species.

Therefore, the total vertical distance to be leaped would need to be 9.32 feet to clear both the falls and the chute. This vertical distance exceeds the leaping capabilities of Chinook and coho salmon in excellent condition. Although steelhead trout in excellent condition have the ability to exceed the vertical component of the barrier, consideration must be given to the horizontal component.

*Horizontal Distance*

As mentioned above, the lip of the falls immediately above the plunge pool is only 4.3 ft above the plunge pool WSE; however, there is no resting or landing zone available at the top of this falls. Measured velocities (Table 6) exceed the sustained swimming speeds for steelhead trout and Chinook and coho salmon in excellent condition (as shown in Tables 3 and 4), but not the burst speed of either species. The water is fully entrained with air, reducing the propulsion effectiveness of the fish’s tail and the effective capabilities of the fish. The only way for fish to make it past the falls and the chute would be to leap the horizontal distance from the plunge pool at the bottom of the barrier to the top of the barrier (explanation of chute characteristics are given below).

This potential compound barrier consists of a falls and complex chute. Although the total length of this barrier is approximately 55 ft in length, the portion of interest extends from
the base of the falls to the crest elevation immediately above the chute. This portion of the barrier is 26 ft long. This value exceeds the maximum horizontal leaping distance (assuming a 40° leap) of 22 ft for steelhead trout in excellent condition and the maximum horizontal leaping distance for Chinook and coho salmon of 15 ft in excellent condition.

<table>
<thead>
<tr>
<th>Table 6. Velocities (ft/s) at the lip of the falls at measured flows.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow</td>
</tr>
<tr>
<td>Low</td>
</tr>
<tr>
<td>Mid</td>
</tr>
<tr>
<td>High</td>
</tr>
</tbody>
</table>

* Measurement not at same location due to safety concerns

At the flows observed, the creek has stayed within the bedrock channel at the falls. Observations of higher flows have not yet occurred to determine if there is an alternative channel for fish migration (Figure 4).

**Chute Conditions**

Under all flow conditions that were evaluated, the upper half of this chute is steep and very narrow. Flow conditions in the chute ranged from measured velocities of 7.9 ft/s at low flow to 14.08 ft/s at middle flow. Velocities were so high at the high flow that they could not be effectively measured. However, using Equation 1 in Powers and Orsborn (1985), velocities would approach 25.3 ft/s using a Manning’s n of 0.030 (Table 7).

<table>
<thead>
<tr>
<th>Table 7. Velocities (ft/s) in the main portion of the chute at measured flows.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow</td>
</tr>
<tr>
<td>Low</td>
</tr>
<tr>
<td>Mid</td>
</tr>
<tr>
<td>High</td>
</tr>
</tbody>
</table>

* Not measurable; Velocity calculated from Equation 1.

As stated in Powers and Orsborn (1985), swimming speeds are predicated upon having depth of at least 1.0 feet for salmon and steelhead and there being no air entrained in the water. In this chute, water is approximately 0.2 – 0.4 feet in depth and the water is completely entrained with air (see Appendix A, Photos 2 and 3; Appendix B, Photo 2; and Appendix C, Photos 2 and 3). The steepness of the chute as well as the high velocities can be observed in Appendix A, Photo 4; Appendix B, Photo 3, and Appendix C, Photo 4. This portion of the chute is significantly entrenched (Figure 5).
None of the conditions required for fish to migrate this chute is present at this location. The depth of the water at the chute is less than 1.0 ft, so the fish’s body is partially uncovered which reduces swimming effectiveness and the water is totally entrained with air (see Appendix C, Photo 2). Further, Powers and Orsborn (1985) state that any waterfall that is steep enough to accelerate flow to violent white water should be considered a total barrier to upstream fish passage. Because of these high chute velocities (> 9 ft/s), the fish would ascend this barrier by leaping (Powers and Orsborn 1985). However, there is no zone within the chute that would allow a fish to leap (depth of water inadequate; fully air-entrained water; turbulent white water associated with high velocities). The fish would need to leap from the plunge pool at the base of the falls to the crest elevation, a distance (26 ft) and height (9.3 ft) outside the leaping ability for all salmonids, including steelhead in excellent condition. Velocities measured at the main portion of the chute are less than steelhead burst speed at all flows evaluated; Chinook and coho salmon burst speeds are greater than the velocities measured at the low and middle flows, but are less than the velocities calculated at the highest flow measurement. Given the high velocities, fully air-entrained water, and depth, passage through the chute would be highly problematic.

Crest Conditions

The crest of this barrier is approximately 7.2 ft in width. Average crest velocities were somewhat lower than those velocities noted in the chute and ranged from 4.8 ft/s to 7.0 ft/s (Table 8). These velocities exceed the sustained swimming speeds of steelhead trout and Chinook and coho salmon in excellent condition while being less than the burst speed for these species. Depths were sufficient for passage at all flows noted (i.e., they exceeded the minimum depth of 1.0 ft required for upstream passage). Figure 7 shows the cross-sectional profile of the crest, which can also be viewed in Appendix A, Photo 4; Appendix B, Photo 3; and Appendix C, Photo 4.

<table>
<thead>
<tr>
<th>Table 8. Velocities (ft/s) at the crest at measured flows.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow</td>
</tr>
<tr>
<td>Low</td>
</tr>
<tr>
<td>Mid</td>
</tr>
<tr>
<td>High</td>
</tr>
<tr>
<td><strong>(1)</strong> Measurement not at same location due to safety concerns</td>
</tr>
</tbody>
</table>

SECTION 4: CONCLUSIONS

Based upon the results of this analysis, the compound falls/chute barrier at RM 1.03 on Lake Creek may be considered an impassible barrier to upstream migration to anadromous fish at the range of flows examined. However, higher flows have not been evaluated at this location and ambiguities regarding the most applicable criteria cause uncertainty in this assessment. Energy Northwest has proposed a planned release from the drop structure in spring 2006 pending coordination with the power schedules and
potential impacts to anadromous fish. This release flow cannot be fully controlled, however, a flow of approximately 100 cfs will be released if sufficient inflows enter Packwood Lake.

Energy Northwest recommends that final resolution of the status of this potential barrier be deferred until an additional observation at the higher release flow can be made. In the interim, the criteria used to determine whether this is a potential barrier will be refined.

Although anadromous spawner surveys conducted in 2004 and 2005 are not conclusive, the results are consistent with the surveys on Lake Creek conducted to date. Both Chinook and coho salmon have been observed migrating and spawning in Lake Creek. All spawning activity has been documented below RM 1.03, although several of the surveys have extended upstream to nearly the previously-acknowledged barrier at RM 1.95 (EES Consulting 2005). The area above RM 1.03 also lacks spawning substrates of proper size, with the first substantial suitable substrates noted approximately 100 yards below this location. A Chinook redd was found at the site of this gravel bar, and no spawning activity has been observed upstream of this site.
Figure 1. Leaping curves for steelhead trout
(From Powers and Orsborn 1985; Figure 7)

![Graph showing leaping curves for steelhead trout.]

Figure 2. Leaping curves for Chinook and coho salmon
(From Powers and Orsborn 1985; Figure 8)

![Graph showing leaping curves for Chinook and coho salmon.]

Figure 3. Falls/Chute Complex Long. Profile at RM 1.03

Figure 4. Mouth of Chute Profile
SECTION 5: LITERATURE CITED


Bell, M 1990. Fisheries handbook of engineering requirements and biological criteria. Fish Passage Development and Evaluation Program, Army Corps of Engineers. North Pacific Division, Portland, OR.


APPENDIX A

COMPOUND FALLS/CHUTE AT RM 1.03

LOW FLOW PHOTOS
Photo 1. Plunge pool and lip of falls at middle flow

Photo 2. Chute at low flow.
Photo 3. Mid chute complex, low flow.
Photo 4. Top of chute, low flow.
APPENDIX B

COMPOUND FALLS/CHUTE AT RM 1.03

MIDDLE FLOW PHOTOS
Photo 1. Plunge pool and lip of falls at middle flow

Photo 2. Mid chute at middle flow
Photo 3. Top of chute at middle flow
APPENDIX C

COMPOUND FALLS/CHUTE AT RM 1.03

HIGH FLOW PHOTOS
Photo 1. Plunge pool and lip of falls at high flow

Photo 2. Lower part of chute, high flow
Photo 3. Chute at high flow

Photo 4. Top of chute at high flow