Geomorphology and Habitat of the Tailrace Slough Study Report for Energy Northwest's Packwood Lake Hydroelectric Project FERC No. 2244 Lewis County, Washington

Submitted to

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1.0 INTRODUCTION

Energy Northwest operates the Packwood Lake Hydroelectric Project (Project) near the town of Packwood in Lewis County, Washington. On November 12, 2004 Energy Northwest filed a Notice of Intent (NOI) to file an application for a new license to operate the Project. Energy Northwest also concurrently filed with the Federal Energy Regulatory Commission (FERC) and the resource agencies, a Pre-Application Document (PAD), containing existing, relevant, and reasonably available information describing the existing environment and the potential effects of Project facilities and operations. Additional studies were requested to supplement information contained in the PAD (NOAA Fisheries 2005, USFWS 2005).

Energy Northwest, in consultation with tribes and agencies, developed and implemented a study to evaluate the geomorphology of the tailrace slough (Watershed GeoDynamics 2005). This report provides results for the geomorphology of the tailrace slough and surrounding areas.

1.1 Project Area and Study Area

1.1.1 Project Area

Energy Northwest’s Packwood Lake Hydroelectric Project, FERC No. 2244, received its initial license in 1960. The majority of the Project is located in the Gifford Pinchot National Forest, east of the town of Packwood (Figure 1.1). 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.

Figure 1.1 – Project Location.
The source of water for the Project, Packwood Lake, is situated at an elevation of approximately 2,857 feet above mean sea level (MSL), about 1,800 feet above the powerhouse. Water discharged from the Project is released to the Cowlitz River via a tailrace channel. Power from the Project is delivered over an 8,009-foot 69 kV transmission line to the Packwood substation.

### 1.1.2 Study Area

The study area includes the tailrace slough from a point 500 feet upstream of the end of the lined tailrace downstream into the Cowlitz River to the end of the Project boundary (from approximately the point labeled A33 to the point labeled A39 on Figure 1.2).

For clarification, the following terminology is used in this report:

- **Tailrace** – refers to the lined portion of the tailrace
- **Tailrace slough** – refers to the channel between the end of the lined tailrace to the current confluence with the Cowlitz River side channel (approximately 250 feet downstream).
- **Cowlitz River** – river channel and side channels that are supplied with Cowlitz River flow from upstream.

### 2.0 STUDY GOALS AND OBJECTIVES

The goals and objectives of this study, as provided in the study plan, are to obtain a description of the physical habitat present in the tailrace slough; the geomorphology of the point bar at the end of the tailrace; and the likely changes in the point bar and tailrace slough over the duration of the license, including:

1. Likely physical changes to the tailrace slough over the course of the license (natural processes);

2. Potential for development (residential or industrial) of area surrounding the tailrace slough; and

3. Potential for Energy Northwest to undertake activities to stabilize (i.e. rip rap, grading) or otherwise modify the tailrace and its entrance into the slough over the course of the license.
Figure 1.2 – Tailrace Slough Study Area
3.0 METHODS

3.1 Geomorphic Analysis

An analysis of the Cowlitz River and tailrace channel changes through time in the vicinity of the tailrace slough was made from historical aerial photographs of the area. Table 3.1 lists the aerial photographs used in this analysis.

<table>
<thead>
<tr>
<th>Date</th>
<th>Approx. Cowlitz River Flow (cfs)</th>
<th>Photo</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/15/59</td>
<td>2,250</td>
<td>EFM-36-99</td>
<td>B/W from UW map library</td>
</tr>
<tr>
<td>5/24/66</td>
<td>2,120</td>
<td>2109-2110 4-14-5-55</td>
<td>B/W from WDOT</td>
</tr>
<tr>
<td>4/25/73</td>
<td>996</td>
<td>2110 4-12-10-82</td>
<td>B/W from WDOT</td>
</tr>
<tr>
<td>8/11/81</td>
<td>728</td>
<td>2110 4-12-17-159</td>
<td>B/W from WDOT</td>
</tr>
<tr>
<td>5/11/93</td>
<td>3,560</td>
<td>2000-2109 4-12-29-239</td>
<td>B/W from WDOT</td>
</tr>
<tr>
<td>7/27/99</td>
<td>3,090</td>
<td>SW-C-99 50-125-56</td>
<td>Color from WDNR</td>
</tr>
<tr>
<td>2003</td>
<td>unknown</td>
<td>composite</td>
<td>B/W ortho-photo base (GIS)</td>
</tr>
</tbody>
</table>

The location of the wetted channel and the location of the high flow channel (determined by change from mature upland/riparian vegetation to sparse or no vegetation) was marked on acetate overlays to each photo. In addition, the location of permanent landmarks such as the Skate Creek Bridge, roads, the airstrip, and the tailrace were marked on the overlays to assist with overlaying years and comparing changes through time. Acetate overlays were reduced or enlarged as necessary to bring them to a common scale for comparison. The aerial photographs are not ortho-rectified, and therefore are subject to distortion in areas away from the center of each photograph. Since the objective of this study is to determine the relative position and movement of the river in the area of the tailrace slough and not precise river position, no orthorectification or adjustments for distortion during the reduction/enlargement process were made.

3.2 Tailrace Cross Sections and Grain Size Characterization

Cross sections of the tailrace and slough between the bridge over the tailrace (A33/B28 on Figure 1.2) and the downstream end of the project boundary (A39/B35 on Figure 1.2) were measured on April 26-27 and May 4-5, 2006 using a tripod, laser level and survey rod. Distance along each transect was determined using a tape. Cross sections extended on both sides of the tailrace between approximately the base of the large berm around Teal Lake and the base of the rip rap levee along the Cowlitz River channel. Cross sections along the slough (downstream of the end of the concrete tailrace) extended from a position far enough southeast of the Cowlitz River to be past evidence of former channel positions, across the road parallel to the channel and to the base of the rip rap levee along the Cowlitz River. A water surface elevation in Teal Lake was also shot for comparison with the Cowlitz River and tailrace water surface elevations.

Cross sections were placed every 50 feet along the lined portions of the tailrace and the unlined tailrace slough channel (from bridge over the tailrace through the slough to the confluence with
the Cowlitz River). Man-made and natural features were noted, including: rip rap, levees, roads, side channels, and the historic Cowlitz River channel migration zone (abandoned channels). Partial cross sections were spaced 100 feet apart along the Cowlitz River channel between the existing outlet of the tailrace slough and the downstream end of the Project boundary. GPS points were taken at the endpoints of each cross section, as well as several mid-points of the cross sections to provide data to produce a map of cross section locations. Cross section data was plotted in Excel to produce graphs.

Thalweg measurements at each cross section were used to plot a longitudinal profile from the downstream end of the original tailrace as indicated on the project boundary map (points labeled A39/B35 on Figure 1.2), through the river and tailrace slough area, and 500 feet into the lined portion of the tailrace (to approximately the point labeled A33/B28 on Figure 1.2).

The grain size distribution of sediment at each cross section was visually estimated. Pebble counts (100+ clasts) were made across the channel at five locations within the existing tailrace slough on October 18, 2006 during low water. Pebble counts were taken on traverses across the entire channel that had been wetted during the surveying in April/May and included material on the banks (rip rap and sand bars) up to the normal full tailrace water level.

The location of old river channels, rip rap, roads and other man-made features were marked on recent aerial photographs of the area. Information about the current disposition of rip rap levees was also noted, including the size of rip rap and types of vegetation growing in the rip rap. We also attempted to obtain information about rip rap placement (year, reason, amount, agency). The length, slope, top and bottom width and height were obtained from the cross sections and available drawings on permit applications.

### 3.3 Ownership, Zoning, and Development Plans

Property ownership, zoning and development plans that are likely to affect the point bar and tailrace slough area were reviewed. The following information was collected:

- Property ownership data from Lewis County
- Local zoning information from Lewis County
- The homeowner’s association representative was contacted to request plans for development of the private lots near the tailrace.

Although Energy Northwest reviewed the potential for development of the area surrounding the slough, this area is private property and is currently being developed for residential use by others. Energy Northwest will maintain the property associated with the tailrace, however it has no control over the activities of Lewis County and other property holders in the slough area.
4.0 RESULTS

4.1 Geomorphic Analysis

The Cowlitz River is a glacial river with a high sediment load. The channel is very active in the area of the Project tailrace. Figure 4.1 shows the varying locations of the Cowlitz water surface (solid lines) and the edge of the active flood flow channel (dashed lines) from 1959 through 2003 (channel positions in each of the air photo years are included in Appendix 1). Figure 4.2 shows the annual peak flow recorded at the Cowlitz River near Packwood gage. Large-scale channel changes can be correlated with high peak flow events; the green bars indicate years when aerial photographs are available.

The Cowlitz River channel location is fixed upstream of the tailrace at the Skate Creek road bridge, but is unconfined and free to migrate across the flood plain downstream of the bridge. Between 1959 (prior to Project construction), 1966, and 1973, the river channel upstream of the tailrace was slowly migrating toward the tailrace and airstrip. Water exiting the tailrace flowed into an old, dry side channel. Tailrace water flowed south several thousand feet before joining the main Cowlitz River flow.

During the 1977 high flow, the main Cowlitz channel migrated rapidly toward the airstrip and across the end of the tailrace. During this high flow, the lower approximately 900 feet of the lined tailrace was eroded and removed by the river. A rip-rap lined levee was constructed to protect the tailrace and airstrip along the river bank in the late 1970’s. This halted the southern migration of the high flow channel. In the vicinity of the tailrace, the main low flow channel migrated progressively southward across the broad high flow channel, toward the rip rap, tailrace and the airstrip through the mid 1990’s. During this same period, the river upstream of the tailrace migrated toward Skate Creek, eventually breaking through and forming a side channel that connected with Skate Creek, effectively shortening Skate Creek several thousand feet. Between the 1993 and 1999 aerial photos, the main flow shifted to this northern channel near Skate Creek, widening the northern channel. At present, the main flow is in the northern channel, with a smaller amount of flow in the southern channel near the tailrace. A high flow event occurred in November 2006 with a provisional peak flow of 37,100 cfs. This estimated peak flow is the highest on record for the Packwood gage. During this high flow, water overtopped the road just downstream of the current end of the lined tailrace, between cross sections 11 and 12 on Figure 4.3, and eroded a channel between the road and Teal Lake (the road prism was not washed out). The southeastern channel downstream of the end of the original tailrace also experienced erosion and deposition, resulting in a different configuration than in 2006. It is very likely that the channel will shift again in the future, with minor annual shifts to be expected, and major shifts during peak flows (at least eight high peak flows have occurred and several major channel shifts since 1959).
Figure 4.1 – Cowlitz River Channel Changes near Tailrace Terminus
(1959-1999; base photo shows 2003 river position)
4.2 Cross Section Survey and Floodplain Features

Twenty four cross sections were surveyed in April and May 2006 between the wooden bridge over the tailrace and the downstream end of the study area (Figure 4.3). Cross sections in the tailrace and slough (Transects 1-18) extended from the re-graded area or berm around Teal Lake on the south through the tailrace, and north across the former floodplain to the Cowlitz River. Cross sections were spaced approximately 50 feet apart along the tailrace from the small wooden bridge over the tailrace to the end of the tailrace slough, approximately 250 feet downstream from the end of the lined tailrace. Cross sections downstream of the slough were spaced approximately 100 feet apart and extended from the base of the rip rap in the Cowlitz River up over the levee and road and into the floodplain far enough to cover old channel features in the vicinity.

There has been extensive timber harvest, road and skid trail construction, re-grading, and borrow pit excavation in the Cowlitz River floodplain in the vicinity of the tailrace. These activities have obscured evidence of past channel locations in many areas of the floodplain. However, evidence of a few historic channels, or portions of channels were seen on the ground and in the air photographs. These features, along with cultural features (roads, rip rap levees) are shown on Figure 4.3 and marked on the cross sections. Note that the historic channel locations are difficult to determine due to past disturbance; these locations were determined as best as possible.
Figure 4.3 – Cross Section Locations and Channel Features
4.2.1 Cross Sections

Cross sections were plotted at a common x-y scale and marked with natural and cultural features observed in the field (Figure 4.4). Items to note:

- There is no Transect 17 due to a numbering error in the field (transects are spaced correctly, number 17 was skipped in sequence).

- The primary natural and cultural features noted on the transects include:
  - Main gravel road on South side of tailrace
  - Levee/vegetated road on North side of tailrace
  - Old dug channel on North side of tailrace; this appears to have been totally excavated by machinery and is not a natural channel
  - Old river channel that meanders through transects 1, 2, and 3 on North side of dug channel
  - Levee along Cowlitz River on North side of tailrace
  - Levee along Cowlitz River on South side of tailrace/slough/river
  - Sand bar that currently separates the tailrace slough from the Cowlitz River on Transects 13-15.
  - New road that splits from old road/levee and heads into adjacent properties
  - Possible old natural river channel on south side of slough in vicinity of Transect 10 – very short, can only be seen in this transect – mostly obscured by re-grading for Teal Lake and road
  - Old natural river channel on south side of slough/river (seen in Transects 18-19; much of this has been obscured by regrading)
  - Teal Lake and associated berm
  - Parking lot in Transects 24/25 – likely old construction staging area.

- There is a low point in the levee along the Cowlitz River channel north of the tailrace, as seen in the cross section marked T9. The lowest point on the levee in this vicinity was at elevation 1042 ft msl. This was approximately 5 feet above the water surface of the Cowlitz River on the day of the survey. If the main flow shifts back to this southern channel it is likely that this low point in the levee would be overtopped during high flows and water from the Cowlitz River would enter the area behind the levee. It is not known why the low point was constructed; possibly to let water trapped on the south side of the levee to drain.

- The elevation of Teal Lake on May 5, 2006 was 1033.74 ft msl. Elevation of the Cowlitz River was approximately 1036 ft msl. The lake is likely hydrologically connected through groundwater to the Cowlitz River, but connectivity is unknown.

Photos of the tailrace and slough are included in Appendix 2.
Figure 4.4 – Tailrace, Slough, and River Cross Sections
Figure 4.4 – Tailrace, Slough, and River Cross Sections (cont’d.)
Figure 4.4 – Tailrace, Slough, and River Cross Sections (cont’d.)
Figure 4.4 – Tailrace, Slough, and River Cross Sections (cont’d.)
Figure 4.4 – Tailrace, Slough, and River Cross Sections (cont’d.)
Figure 4.4 – Tailrace, Slough, and River Cross Sections (cont’d.)
Figure 4.4 – Tailrace, Slough, and River Cross Sections (cont’d.)
Figure 4.4 – Tailrace, Slough, and River Cross Sections (cont’d.)
4.2.2 Pebble Counts and Grain Size in Tailrace and Tailrace Slough

A visual estimate of grain size was made at each transect location where possible (Table 4.1). Water conditions were too deep and fast to see the substrate at the Cowlitz River transects. Pebble counts were made at five locations in the tailrace slough during low water conditions (Figure 4.6, Appendix 3). The tailrace channel is constructed of asphalt with some concrete sections. As a result, the substrate is asphalt, with some minor gravel pockets. Grain size in the tailrace slough was boulder rip rap on the southern shore with cobble and gravel in the main channel. A sand bar was present in the high water channel near the end of the slough.
Table 4.1. Grain Size at Transect Locations

<table>
<thead>
<tr>
<th>Transect</th>
<th>Grain Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100% Asphalt</td>
</tr>
<tr>
<td>2</td>
<td>90% Asphalt; 10% Gravel</td>
</tr>
<tr>
<td>3</td>
<td>100% Asphalt</td>
</tr>
<tr>
<td>4</td>
<td>100% Asphalt</td>
</tr>
<tr>
<td>5</td>
<td>80% Asphalt; 20% Gravel</td>
</tr>
<tr>
<td>6</td>
<td>100% Asphalt</td>
</tr>
<tr>
<td>7</td>
<td>90% Asphalt; 10% Gravel</td>
</tr>
<tr>
<td>8</td>
<td>90% Asphalt; 10% Gravel</td>
</tr>
<tr>
<td>9</td>
<td>90% Asphalt; 10% Gravel</td>
</tr>
<tr>
<td>10</td>
<td>100% Asphalt</td>
</tr>
<tr>
<td>11</td>
<td>100% Asphalt</td>
</tr>
<tr>
<td>12</td>
<td>100% Boulder (rip rap at tailrace outlet)</td>
</tr>
<tr>
<td>13</td>
<td>40% Boulder, 30% Cobble, 30% Gravel</td>
</tr>
<tr>
<td>14</td>
<td>10% Boulder, 50% Cobble, 40% Gravel</td>
</tr>
<tr>
<td>15</td>
<td>20% Boulder, 60% Cobble, 20% Gravel</td>
</tr>
<tr>
<td>16</td>
<td>20% Boulder, 50% Cobble, 10% Gravel; 20% Sand</td>
</tr>
<tr>
<td>18-25</td>
<td>Water too deep and fast to see (boulder rip rap on levee/channel side; likely cobble and gravel in channel)</td>
</tr>
</tbody>
</table>

![Figure 4.6 – Grain Size Distribution of Pebble Count Data.](image-url)
4.2.3 Levees and Man-made Features

Levees are present on the north and south side of the tailrace (Figure 4.3). All levees and bank protection were installed following the December 1977 flood that washed away the end of the tailrace and caused extensive channel movement toward the airstrip north of the tailrace. The purpose of the levees are to prevent the Cowlitz River from migrating toward the airstrip/tailrace/private property and roads on the south and east side of the river.

The levee along the Cowlitz River on the north side of the tailrace extends from the end of the lined tailrace at least 3,000-4,000 feet upstream along the Cowlitz River channel. This levee was constructed by the Soil Conservation Service (SCS – now National Resource Conservation Service – NRCS) in 1978. The levee is approximately 20-25 feet across at the top, approximately 50 feet across at the bottom (far upstream from the tailrace the levee was constructed as bank protection so it does not have a bottom width), and approximately 10-14 feet high depending on location. The river side of the levee is faced with rip rap ranging in size from 4-6 feet diameter at the base of the levee to 1-2 feet diameter near the top of the levee. Alder, willow, and Douglas fir trees are growing out of the river side of the levee (4-6 inch diameter trees) as well as scotch broom.

The SCS also constructed a bank protection/levee on the south side of the tailrace in 1978. This levee extends from the outlet of the lined portion of the tailrace approximately 1,000 feet downstream to the end of the former tailrace. The levee has the same dimensions and rip rap size as the levee on the north side of the tailrace and also has 4-6 inch alders and other vegetation growing on the river side.

The levee immediately adjacent to the lined tailrace on the north and south side of the tailrace was constructed as part of the tailrace canal. Energy Northwest (Washington Public Power Supply System at the time) constructed several short sections of new levee as part of the rebuilding of the end of the tailrace that was damaged during the 1977 flood. These levees were constructed in 1979 and tied into the then newly constructed SCS levees on both sides of the tailrace (Appendix 4). These levees are similar in dimension and construction details to the SCS levees and required an estimated 1,300 cubic yards of fill and 650 cubic yards of rip rap. Vegetation, including Douglas fir, scotch broom, alder, and willows are also growing along the sides of this portion of the levee.

Other man-made features on the floodplain include the roads, old skid trails, and Teal Lake. A road runs immediately adjacent to the south side of the tailrace from Highway 12 to a point approximately 250 feet downstream from the end of the lined tailrace (Transect 18). At this point the road angles slightly away from the channel toward the new home lots south of the river. The floodplain south of Teal Lake was harvested sometime in the early 1950’s. Many logging roads and skid trails were constructed (evident on the 1959 aerial photograph) which obscure the more subtle natural floodplain features such as old channel positions. Teal Lake is a borrow pit that moved across the floodplain as it was mined and material was re-worked. The pit first appeared in the 1966 aerial photographs. The pit continued to be mined through the late 1990’s and migrated approximately 1,000 feet southwest across the floodplain through time (Figure 4.1). There is a high berm on the tailrace side of the lake, presumably unused material removed from the pit. The land around Teal Lake is zoned as mineral extraction; future plans for gravel
removal are unknown, but it is likely that the lake will be used for recreation rather than sand and gravel extraction under the new ownership (Teal Lake Homeowner’s Association).

4.3 Land Ownership, Zoning, and Development Plans

The land on both sides of the lower tailrace, tailrace slough, and Cowlitz River side channel has been subdivided into lots and sold to private parties as part of the Teal Lake Homeowner’s Association (Figure 4.7). The tailrace is located in parcels 35179-3 and 35176-1. Parcels 35180-11, 12, 13, and 14 surround the tailrace. These parcels are privately owned and are planned for residential development (personal communication, Jodi Ausbun, Teal Lake Homeowners Association President, e-mail of 9/29/06). It is likely that additional re-grading, road/driveway and building construction and river bank protection will take place in the future as part of development of the area. This will affect the floodplain, but not the existing river channel.

Figure 4.7 – Land Ownership along the Tailrace, Slough, and River.
Land in the Northwest and Southwest quarter of the Southwest quarter of Section 21 (North and South of the tailrace) are zoned for Mineral Extraction (Lewis County March 31 2006 Zoning Map). Other lands around the tailrace and slough are zoned RDD-20; Rural Development District 20 which allows a density of one dwelling unit per 20 acres for subdivision purposes (Lewis County 2006). The entire area is included in the Lewis County Critical Areas FEMA 100 Year Flood Plain designation (Lewis County 2002).

Energy Northwest plans to construct a permanent fish barrier at the end of the tailrace. Plans have not been finalized; however, the preliminary drawing shows the structure starting approximately 10 feet from the existing concrete headwall. At this time, Energy Northwest does not plan to modify the tailrace as it enters the slough, nor do we anticipate the need to modify the tailrace as it enters the slough over the course of the new license.

5.0 DISCUSSION

Water in the tailrace of the Packwood Lake Hydroelectric Project flows from the powerhouse through the tailrace to the Cowlitz River. The Cowlitz River is an active, braided, glacially-influenced channel that has changed position significantly in the vicinity of the tailrace outflow several times since the Project was constructed in the 1960’s, including eroding 900 feet of tailrace during the 1977 flood. These major shifts have resulted in large changes in the distance water flows from the outlet of the tailrace until it meets a flowing channel of the Cowlitz River, ranging from approximately 1,500 feet when the Project was constructed to 0 feet following the 1977 flood to approximately 250-3,000 feet (depending on river flow) under current conditions. This study provides information on the potential for changes in the tailrace, tailrace slough, and Cowlitz River channel over the course of the new license. This information will help to understand Project effects on salmonids that use the habitat in the vicinity of the tailrace outlet.

The following critical questions were identified:

Critical Question 1. What is the existing physical habitat present in the tailrace slough and vicinity?

As of October 2006, the tailrace slough was approximately 250 feet long with mixed cobble/gravel substrate on the bottom of the channel, boulder sized rip rap on the southern side, and a sand bar on the northern bank at the downstream end. Alder and willow were growing in the rip rap and on the sand bar. A description and analysis of aquatic habitat will be included in the Tailrace Slough Instream Flow report; use of the slough by anadromous salmonids will be described in the Tailrace Slough Use by Anadromous Salmonids report.

The tailrace slough configuration following the November 2006 peak flow event is similar to that prior to the flood, but substrate is likely somewhat different. Turbid water prevented visual assessment of substrate in the tailrace slough during field visits that were made following the flood.
Critical Question 2. What are the likely physical changes to the tailrace slough area over the course of the new license as a result of natural processes?

The Cowlitz River is heavily influenced by glacial runoff and sediment loads. It is braided in character in the vicinity of the tailrace slough, shifting frequently and migrating across a broad zone. It eroded and removed approximately the lower 900 feet of the lined tailrace during high flows in 1977. Placement of rip rap levees has restricted the southeastern migration of the river channel near the end of the tailrace, but major channel shifts in other parts of the floodplain are expected to occur on decadal time scales in the future with minor channel shifts nearly every year. It is very likely that the tailrace slough will change between a main channel of the Cowlitz River, a side channel of the Cowlitz River with flow at some times of the year, and a channel with flow only during flood events during periods when the main channel shifts northwest.

Critical Question 3. What is the potential for development (residential/industrial) in the area surrounding the tailrace slough?

The area surrounding the tailrace has been used in the past for logging and sand and gravel extraction. Ownership has changed to private lots that are expected to be developed for home or cabin sites (density of one home/20 acres) over the next few years.

Critical Question 4. What is the potential for Energy Northwest to stabilize or modify the tailrace outlet over the course of the new license?

Energy Northwest is required to install a permanent fish barrier at the end of the tailrace. Plans have not been finalized; however, the preliminary drawing shows the structure starting approximately 10 feet from the existing concrete headwall. At this time, Energy Northwest does not plan to modify the tailrace as it enters the slough, nor do we anticipate the need to modify the tailrace as it enters the slough over the course of the new license.

6.0 LITERATURE CITED

Jodi Ausbun, 2006. Personal communication. Teal Lake Homeowners Association President, e-mail of 9/29/06.

Lewis County. 2002. Lewis County, Washington Comprehensive Plan, Figure 4.16a (3). Map dated 3/29/02 from Lewis County GIS Services.

Lewis County. 2006. Lewis county Assessor’s Mapping, Section 21, Township 13N Range 09E. Map dated 6/30/06 from Lewis County GIS Services.


Appendix 1. Historic Cowlitz River Aerial Photographs and Channel Locations
Note: all channel position plots are overlain on 2003 orthophoto base map for comparison.

1959 Aerial Photograph (source: University of Washington Map Library)
1959 Channel Position Plot
1966 Aerial Photograph (source: WashDOT Geographic Services Photo Lab)
1966 Channel Position Plot
1973 Aerial Photograph (source: WashDOT Geographic Services Photo Lab)
1973 Channel Position Plot
1981 Aerial Photograph (source: WashDOT Geographic Services Photo Lab)
1993 Aerial Photograph (source: WashDOT Geographic Services Photo Lab)
1993 Channel Position Plot
1999 Aerial Photograph (source: WashDOT Geographic Services Photo Lab, photo from WDNR Engineering Division, Resource Mapping Section)
1999 Channel Position Plot
Appendix 2. Photographs of the Tailrace Slough Area

Wooden bridge over tailrace (top of study area)  Tailrace canal

Tailrace Slough  Sandbar at end of slough

Cowlitz River Channel and downstream bank protection  Upstream bank protection
### Appendix 3. Pebble Count Data

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Appendix 4. Original Tailrace Levee Drawings

**PLAN VIEW (scale: 1"=200')**

**SECTION A**

**PURPOSE:** Repair of Canal Outlet Structure

**DATE:** USGS BM

**ADJACENT PROPERTY OWNERS:**
1. Menasha Woodenware Co.
2. F. Huntington

**LOCATION:** In Cowlitz River

**AT:** Packwood, Washington

**COUNTY OF:** Lewis

**STATE:** Wash

**APPLICATION BY:** W.P.P.S.S.

**SHEET:** 1 of 1

**DATE:** 8/2/79
Geomorphology and Habitat of Tailrace Slough Study Report
Energy Northwest Packwood Lake Hydroelectric Project
May 2007
FERC No. 2244

Proposed Fill in Cowlitz River
at River Mile 125.5
County of Lewis, State of Washington
Application by Supply Systems
Date 22 August 1979

Scale in Feet
100 50 0
200
400

SCALE IN FEET

Proposed Fill in Cowlitz River