# SYNTHESIS REPORT FOR THE PACKWOOD LAKE HYDROELECTRIC PROJECT FERC NO. 2244

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**PACKWOOD LAKE HYDROELECTRIC PROJECT**
**SYNTHESIS REPORT**

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# PACKWOOD LAKE HYDROELECTRIC PROJECT
# FERC NO. 2244

# SYNTHESIS REPORT

## 1.0 INTRODUCTION

To answer key questions that have arisen in the context of the Packwood Lake Hydroelectric Project (Project) relicensing, Energy Northwest (EN) is employing a synthesis process suggested by watershed planning[1] to integrate the results from several individual relicensing studies. This process is intended to assess how the study results demonstrate interrelationships among the different resources and the extent to which the Project appears to be affecting them. The results may also include non-project influences acting on the resources.

## 2.0 PURPOSE

The purpose of this Synthesis Report is to address concerns raised by agency and tribal representatives where individual studies performed for relicensing overlap different resources. It became clear as the studies progressed that the investigations of individual resource issues were not capable of addressing the complexity of biological processes in the vicinity of the Project. In the Synthesis process, interrelationships among resources in and around the Project were identified and conclusions drawn regarding the Project's effects on them. The effects of concern are primarily to biological resources, but effects on historic and cultural resources and recreation were also reviewed.

## 3.0 APPROACH

Each of the study plans and resulting reports for relicensing included a section discussing the nexus between project operations and effects on resources. Key questions regarding project effects were collected from the agency consultation on the individual relicensing studies. Using the study plans, reports and the key questions, a team of the scientists who performed resource studies for relicensing formulated several hypotheses regarding the interrelationships among certain of the resources in the Project area and how the Project may be influencing them. These hypotheses were discussed in interdisciplinary science team meetings, and the conclusions drawn by the team are captured in this Synthesis Report.

### 3.1 <u>Elements of the Analysis</u>

As a first step in the synthesis process, the lead investigator for each resource study prepared a list of possible hypotheses that addressed linkages between resources. Hypotheses were intended to consider the inputs, Project effects, non-Project effects (where applicable) and vulnerable resources. At the initial team meeting the preliminary hypotheses for each issue were reviewed.

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[1] http://www.epa.gov/owow/watershed/wacademy/wam/step3.html

Competing hypotheses were discussed and the most viable one was selected. A series of critical questions helped guide initial discussion.

1. What and where are the potential Project impacts altering watershed input variables?

2. What are the inputs delivered to the pertinent response areas (stream segment or other area of concern) and in what quantity?

3. What is the habitat or resource sensitivity to the inputs?

4. The current condition of a resource is the baseline for environmental analysis in the relicensing of the Project. It may be helpful to understand (to the extent it is known) how the resource has changed from pre-project conditions during the current license term and to what extent this has been due to the Project. Is the Project impact a change from historical pre-project conditions due to the original construction of the Project, or is it an incremental additional effect that will occur during the new license term?

5. Routing considers how an input, and a potentially Project-related change for that input, moves to the location of a vulnerable resource. For example, in order for sediment generated on a Project-related road to affect anadromous fish that occupy only the lower portion of Lake Creek, it must be *routed* to lower Lake Creek. The linkage between the location(s) where a Project effect may occur and an affected resource was a critical component of each hypothesis. The following elements were included in the discussion for each Issue.

The issues were grouped according to the following geographic locations:

- Packwood Lake and Tributaries
- Lower Lake Creek
- Project Tailrace
- Cowlitz River/Tailrace Slough
- Snyder and Hall Creeks
- Roads and Trails

The interdisciplinary EN team discussed the hypotheses for each issue in the geographic areas, chose the most viable of the hypotheses, and developed summary statements, or conclusions, for each one. Summary statements were intended to specifically describe:

1) How the Project affects input(s),
2) How changes in inputs are routed to the sensitive response area, and
3) The resulting impacts to resources, if any.

The interdisciplinary team also qualified summary statements with the level of certainty based on study results. A hypothesis that is only supported by indirect or weak evidence has lower certainty than a condition where a Project influence can be quantitatively highly correlated to an effect on a resource.

**Inputs**
Inputs included:

- Hydrology
- Sediment
- Large woody debris (LWD), and
- Energy (nutrients/ temperature).

**Project Effects**
Project effects were categorized as a change in any of the following:

- Peak flows: timing and magnitude
- Average monthly base flow: timing and magnitude
- Lake level: timing, rate of decrease
- Sediment inputs/transport
- Large woody debris input/transport
- Ground disturbance
- Noise

**Non-Project Effects**
Other human caused influences, as well as natural processes, may be acting on certain resources. The scope of the Synthesis analysis did not include the effects of all natural processes acting on the resources, but rather focused on the Project and non-Project human caused effects.

**Affected Resources**
The primary resources affected by the Project considered in the synthesis process included:

- Fisheries
- Other aquatic biota (amphibians, macroinvertebrates, aquatic plants)
- Water quality
- Riparian vegetation
- Other terrestrial vegetation
- Terrestrial wildlife
- Recreation
- Cultural resources

**Summary Statement and Documentation**
Each hypothesis was discussed, and supporting documentation was provided for the most viable hypothesis. The summary statements, together with the supporting evidence and documentation of the synthesis process, and the overall conclusions that bring together the relationships among the main issues, comprise the Synthesis Report. The Synthesis Report is being issued for agency, tribal, and stakeholder review and comment. Comments will be addressed, incorporated where appropriate, and a final report will be published.

# 4.0 SYNTHESIS STATEMENTS BY GEOGRAPHIC AREA

The synthesis statements have been developed and grouped by the appropriate geographic area of the Project, which include Packwood Lake and tributaries, lower Lake Creek, tailrace, Cowlitz River and tailrace slough, Snyder and Hall Creeks, and roads and trails.

## 4.1 Packwood Lake and Tributaries

The source of water for the Packwood Lake Hydroelectric Project, Packwood Lake, is a lake situated at an elevation of approximately 2,857 feet (ft) above mean sea level (MSL), about 1,800 feet above the powerhouse. Extensive investigations related to the natural resources within the Project area (resident fish, water quality, wildlife and cultural) have been ongoing since 2004 on the lake and the seven of its nine tributaries that are fish bearing.

The Packwood Lake Hydroelectric Project did not create Packwood Lake or induce recreation use of Packwood Lake. Packwood Lake was formed approximately 1100 years ago when a landslide from Snyder Mountain blocked the Lake Creek valley. Historically Packwood Lake was extremely popular for fishing, boating and camping. Archaeological evidence demonstrates Native American use of the Packwood Lake area in the late prehistoric period (HRA 2005). Local Native American visits to Packwood Lake recorded in the early 19$^{th}$ and 20$^{th}$ centuries included temporary camps, fishing, and huckleberry picking. By 1900, local settlers in the upper Cowlitz River were attracted to Packwood Lake "for recreation pleasure as well as to catch large amounts of fish" (Combs et al. 1954). Trail #78 to Packwood Lake was built in 1909 by the Valley Development Company and Trail #81, which runs along the east side of Packwood Lake, was first noted on a 1931 map. In 1917, the Forest Service established a public campground at Packwood Lake. The popularity of the Lake led to the development of a tent camp resort under permit to the Forest Service near the Lake outlet in 1921, where meals and rented boats were provided. A two-story cedar lodge complete with store, kitchen and dining area, and floating dock, boathouse and new rowboats and eleven small wood cabins were provided in the mid 1930s. In 1972, the main lodge, utility room, and the boiler building were damaged by fire and most of the cabins were removed in 1974. The boat concession, with boathouse and dock, continued until 1991. The remaining structures were removed by the Forest Service in the 1990s (Bedell 2004).

Prior to closing down the Forest Service-permitted resort in 1992, visitor use at Packwood Lake was estimated to be an average of about 60 people per day during the summer months with up to 300 people per day on weekends (Bedell 2004). Based on the average number of visitors per day, prior to 1992, it is estimated that 6,060 people visited Packwood Lake during the summer months. After the Forest Service-permitted resort and facilities were removed, visitor use decreased significantly. Current visitor use at Packwood Lake, based on surveys conducted in 2006, is estimated to be an average of less than 30 people per day during the peak-season, with an estimated 50 people per day on weekends (Howe 2007). Based on the 2006 surveys, an estimated 2,535 people visit Packwood Lake during the summer months (peak-season).

Operation of the Project results in fluctuations of the lake level. During the summer months, the lake level is held at 2,857 ft MSL plus or minus 6 inches, as required by Article 37 of the Project license (Federal Energy Regulatory Commission 1982). From May 1 to September 15, the Project operates with generation flow adjusted to match lake inflow in order to hold the lake elevation relatively constant. After mid-September, the lake level may be drawn down 8 feet, to a level no lower than 2,849 ft MSL (License Art. 37) to accommodate a Project shutdown in October for annual maintenance. The lake then refills with natural inflow during October while the Project is shut down. The 8 feet of vertical storage allows the Project to store and utilize winter runoff for power generation. The influence on lake level exerted by the Project is approximately one-half inch per hour at maximum capacity (260 cfs), assuming no inflow. This effect can be easily reduced or offset by large inflows. When seasonal high runoff exceeds the Project capacity and the ability of the lake to absorb peak discharges, the drop structure is overtopped (at elevation 2,858.5 ft MSL) and excess runoff is directed down Lake Creek. The Project's influence on fluctuations in lake level raises concerns regarding effects on:

- The migratory efforts of adfluvial rainbow trout
- Alteration of wetland hydrology and the biological effects of potential dewatering of habitat
- Bank erosion and related turbidity
- Erosion and exposure issues related to prehistoric artifacts along the shoreline of Packwood Lake

The EN team developed a set of hypotheses for each of the issues related to lake level fluctuations. For each issue, the most scientifically viable hypothesis was selected and discussion and references to supporting data from relevant studies are provided.

Synthesis issues for Packwood Lake and its tributaries included:

1. Drawdown Issue 1 – Drawdown Effects on Rearing Trout in Packwood Lake
2. Drawdown Issue 2 – Effects on Aquatic Vegetation in Packwood Lake
3. Drawdown Issue 3 – Effects on Archaeological/Cultural Resources around Packwood Lake
4. Drawdown Issue 4 – Effects on Amphibians Associated with Wetlands Adjacent to Packwood Lake
5. Drawdown Issue 5 – Effects on Wetland Vegetation
6. Fish Distribution and Species Composition Issue 1 – Effects on Migration of Spawning Rainbow Trout
7. Fish Distribution and Species Composition Issue 2 – Effects on Migration of Juvenile Rainbow Trout
8. Recreation Resources

### 4.1.1 Drawdown Issue 1 - Drawdown Effects on Rearing Trout in Packwood Lake

**Inputs**

Hydrology

**Project Effects**

The magnitude and timing of lake drawdown in late September, with refill in October, as well as Project induced lake level fluctuation below 2857 ft MSL during November - April

**Non-Project Effects**

None

**Affected Resources**

Rainbow trout rearing within Packwood Lake

**Hypotheses**

(1) Drawdown of the lake below 2857 ft MSL reduces littoral habitat within the lake that is utilized by juvenile and adult rainbow trout for feeding.
(2) Rainbow trout shift feeding locations within the lake during drawdown so there is no net effect.
(3) Rainbow trout within Packwood Lake are not dependent upon feeding habitat within the drawdown zone.

**Most Scientifically Viable Hypothesis**

Rainbow trout shift feeding locations from nearshore littoral habitats to deeper water pelagic sites as water temperatures increase and remain there throughout the drawdown period. Therefore, a drawdown of the lake beginning in mid-September does not reduce functional habitat for rearing rainbow trout. High turbidity levels in Packwood Lake, which could adversely affect trout, are due to tributary inflow associated with storm events, not drawdown.

**Summary Statement and Documentation**

There are 34 acres (7.6% total lake area) of littoral habitat between elevations 2857 ft MSL (summer lake elevation) and 2849 ft MSL (maximum drawdown level) (EES Consulting 2007a). The fall drawdown typically approaches but does not quite reach 2849 ft MSL. Storm events in October and November result in the lake elevation increasing. The 50% exceedence elevation for winter months (November through March) is in the range of 2854 ft to 2855 ft, which corresponds to an area below 2857 ft of 11 to 15 acres.

Adult and juvenile rainbow trout utilize littoral habitat for rearing in the spring and early summer. As near surface water temperatures increase during the summer, resident trout move to deeper water based on observations. Very few trout are utilizing littoral habitats in mid-September when the drawdown is initiated. In mid-July and August 2006, no fish were caught in horizontal Oneida traps deployed for two days in littoral habitat near the mouths of Osprey Creek and in littoral habitat at the upper end of Packwood Lake (Fish Distribution and Species Composition report to be issued in July 2007). In comparison, a total of 107 fish were caught for a similar netting effort in May 2006.

Because conditions do not allow collection, data are not available for fish distribution within Packwood Lake during the winter months when the Project influences lake elevation. Vertical distribution of fish in lakes is influenced by water temperature and oxygen. While fish are confined to a narrower band of suitable conditions during the summer months when temperatures increase, those constraints are not present during the winter months. Fish would be expected to have a larger vertical distribution (Rowe and Chisnall 1995).

High turbidity in Packwood Lake coincides with periods of high runoff from Upper Lake Creek (EES Consulting 2006a, 2007b). Turbidity levels measured in Packwood Lake during the 2004 and 2005 drawdown periods were relatively low (range from 1.3 NTU to 8.87 NTU). Runoff and high turbidity in upper Lake Creek were noted during a storm event that preceded the date when turbidity levels of 8.87 NTU were measured in Packwood Lake. Whereas upper Lake Creek, which is glacial in origin, carries a high suspended sediment load, there are only relatively minor sources of erodible material along the shores of Packwood Lake. The majority (69%) of the drawdown zone has a low or moderate erosion potential (EES Consulting 2007a).

In conclusion, drawdown of Packwood Lake due to Project operations to a minimum elevation of 2849 ft during the fall does not substantially affect rainbow trout rearing in the lake. Drawdowns between mid-July through April would not affect rearing trout since the fish are located at greater depths in the lake.

**Level of Certainty**

The level of certainty for fish distribution in the lake is moderate as it is supported by casual observations and gill netting data. Studies are ongoing.

### 4.1.2 Drawdown Issue 2 - Effects on Aquatic Vegetation in Packwood Lake

**Inputs**

Hydrology

**Project Effects**

The magnitude and timing of lake drawdown in late September, with refill in October, as well as project induced lake level fluctuation below 2857 ft MSL during November - April

**Non-Project Effects**

None

**Affected Resources**

- Aquatic vegetation in Packwood Lake

**Hypotheses**

(1) Winter drawdowns freeze out aquatic vegetation within the drawdown zone.

(2) The isolated location of Packwood Lake and lack of boat access minimizes the potential for introduction of non-native aquatic plants.

**Most Scientifically Viable Hypothesis**

The relatively sparse distribution of aquatic plants in Packwood Lake between elevation 2857 ft MSL and approximately 2852 ft MSL is partially a result of plant desiccation during winter drawdown of Packwood Lake by Project operations. The isolated location of Packwood Lake and lack of boat access minimizes the potential for introduction of non-native aquatic plants.

**Summary Statement and Documentation**

The species distribution and relative abundance of aquatic plants in Packwood Lake were visually inventoried during August 2004 and 2005. Turbidity is lowest at this time and plant growth is at its annual peak. Visual observations were made from a boat with all near shore habitats reviewed. Limited grab samples were collected by dropping a rake on a tow line into plant beds. Elodea canadensis (a native species) was the only aquatic plant species observed in Packwood Lake. Aquatic plants only occupy limited areas of littoral habitat; their distribution is patchy with the largest plant beds growing at the upper end of the lake. The lack of non-native invasive aquatic species is likely due to the remoteness of the site and lack of mechanisms for transporting invasive plant species from other water bodies.

The winter drawdown of the lake during freezing conditions is more likely influencing the scarcity of aquatic plant growth in shallow water than the fall drawdown, since plant growth is dense in some areas above 2849 ft MSL. The 90% exceedence elevation of Packwood Lake in December through February is approximately 2852 ft MSL. Density of aquatic plants is sparse above approximately 2852 ft MSL. A distinctive band in vegetation density can be observed at approximately this elevation. In other locations, drawdown is commonly used as a method of aquatic plant control (Smith et al 1967; TVA 1990, 1993). The effectiveness of drawdown in reducing aquatic plant density is dependent upon sub-freezing temperatures that desiccate the plants (personal communication, Kathy Hamel, WDOE, February 20 1998). Drawdown without freezing temperatures has been shown to be less effective at reducing aquatic plant density (Geiger 1983).

While aquatic vegetation can provide cover for rainbow trout; predation in Packwood Lake is low, making cover less important. Therefore, there are no detrimental effects to trout populations because of reduced aquatic vegetation in shallow waters.

**Level of Certainty**

The level of certainty is high. Lake elevation data are well documented.

### 4.1.3 Drawdown Issue 3 – Effects on Archaeological/Cultural Resources around Packwood Lake

**Inputs**

- Hydrology
- Raindrop and Wave Energy (wind)
- Recreational Use (trampling shoreline)

**Project Effects**

Control of lake level results in wave erosion at different elevations than without the Project in place.

**Non-Project Effects**

- Erosion related to recreational use (trampling, climbing on banks) is occurring.
- Wave erosion along the lake shoreline would occur without Project in place.

**Affected Resources**

Archaeological site 45LE285 contains deposits related to prehistoric use of the Packwood Lake area for camping, tool making, and subsistence activities that may have included fishing and berry picking between about 500 and 1,000 years ago. The site has been determined eligible for listing in the National Register of Historic Places because it contains information important to prehistory of the area. The site's deposits are located along the shoreline and extend to at least 1.7 m in soil depth. Artifacts have been found in lag deposits along the shoreline and the banks above it.

**Hypotheses**

(1) Waves breaking along the Packwood Lake shoreline erode the shoreline in the vicinity of the listed resources. Wave erosion between 2849 ft MSL and 2858.5 ft MSL is partially Project-related. Wave erosion between 2854 ft MSL and 2860 ft MSL would occur on the lake shorelines without the Project. The Project holds the lake elevation at 2857 ft MSL plus/minus 6 inches for a longer period of time than the lake would be at that elevation naturally.

(2) Recreational use of the shoreline in the vicinity of the listed resource causes trampling and shoreline erosion.

(3) Shoreline erosion is affecting archaeological site 45LE285. This erosion is a combination of Project and non-Project effects. These effects are interrelated and cannot be distinguished.

**Most Scientifically Viable Hypothesis**

Waves breaking along the Packwood Lake shoreline erode the shoreline in the vicinity of the listed resources. Wave erosion between 2849 ft MSL and 2858.5 ft MSL is partially Project related. Wave erosion between 2854 ft MSL and 2860 ft MSL would occur on the lake shorelines without the Project. The Project holds the lake elevation at 2857 ft MSL plus/minus 6 inches for a longer period of time than the lake would be at that elevation naturally.

Recreational use of the shoreline in the vicinity of the listed resource causes trampling and shoreline erosion.

**Summary Statement and Documentation**

Shoreline erosion is affecting archaeological site 45LE285 (Dampf and Thompson 2006). This erosion is a combination of Project and non-Project effects. These effects are interrelated and cannot be distinguished.

No other cultural resources were identified to be at risk due to this effect (Dampf and Thompson 2006). Other archaeological sites may exist along the shoreline. However, no other archaeological sites have been found or verified.

**Level of Certainty**

This discussion is based on measurements made during archaeological excavations in the late 1980s and early 1990s. There is insufficient information to calculate the rate of shoreline change in the vicinity of Site 45LE285.

#### 4.1.4 Drawdown Issue 4 – Effects on Amphibians Associated with Wetlands Adjacent to Packwood Lake

**Inputs**

Hydrology

**Project Effects**

The magnitude and timing of lake drawdown in late September with refill in October, as well as project-induced lake level fluctuation below 2857 ft MSL during November – April

**Non-Project Effects**

None

**Affected Resources**

Amphibians associated with wetlands adjacent to Packwood Lake

**Hypotheses**

(1) The rate and/or magnitude of drawdown during the fall results in dewatering of surface flooded areas within adjacent wetlands that adversely impacts aquatic amphibians within these wetlands.

(2) In April, project induced lake level fluctuations below 2857 ft MSL, which are greater in magnitude than natural lake fluctuation, reduce available habitat for breeding amphibians and may strand egg masses.

(3) Amphibian larvae rearing by most species is unaffected because larvae have metamorphosed prior to the drawdown. Spring reproductive timing and larval rearing largely coincides with periods when lake levels do not fluctuate markedly. Effects are concentrated on northwestern salamander, a species whose larvae require a second year to reach metamorphosis

(4) The response rate/magnitude for soil saturation within adjacent wetlands to drawdown of the lake is largely a function of upslope hydrology, not lake hydrology; therefore, wetland associated biota is unaffected.

**Most Scientifically Viable Hypothesis**

Project-induced lake level fluctuation in early spring has a limited potential to affect amphibians breeding in depressional wetlands on the edge of the lake (larval amphibians were not found in the more extensive wetlands upslope of these depressions). The onset of amphibian breeding is probably normally delayed until May because of low temperatures and snow cover. Beginning in May effects on developing eggs and larvae are unlikely to occur because lake water surface elevation is held relatively constant (2857 ft MSL ± 0.5ft). The Packwood Lake drawdown (mid to late September) occurs after two of the three amphibian species that are present have metamorphosed and exited the adjacent wetlands; the third species is presumably adversely affected because larvae require additional months before metamorphosing, unless larvae can escape from the pools into the lake, or can survive in moist substrates.

**Summary Statement and Documentation**

Three species of amphibians (northwestern salamander [*Ambystoma gracile*], Pacific treefrog [*Pseudacris regilla*], and Cascades frog [*Rana cascadae*]) breed within a few relatively shallow depressions on the southeastern edge of Packwood Lake. Pacific treefrog and Cascades frog are adapted for breeding in wetlands which dry seasonally, whereas northwestern salamander has a prolonged larval period and is usually associated with permanent or semi-permanently flooded sites. Table 1 summarizes published information concerning the life stages of each species that may be pertinent to the consideration of possible effects of water level fluctuations.

Observations during the amphibian survey on July 18, 2006 were consistent with the expected chronology: larval Cascades frogs and Pacific treefrogs were in advanced stages of development (some individuals of both species had hind limbs) and would likely have completed metamorphosis within a month, in contrast to the northwestern salamanders which were small and would not have reached metamorphosis until the following year.

Potential effects on amphibians are considered within three periods: November-April (lake water surface elevation fluctuates as needed), May to mid-September (lake water surface elevation held at 2857 ft MSL ± 0.5 ft), and mid-September-October (annual drawdown and refill). Amphibian breeding at the Packwood Lake wetlands is likely initiated by periods of warm rain, snow melt, and nights when temperatures are above freezing. These conditions probably do not occur on a predictable schedule each year, but observations by Energy Northwest personnel (Dan Ross personal communication) suggest that the snow melt often does not occur until May. Eggs deposited prior to May could be subject to water level fluctuations sufficient to cause stranding, which can expose embryos to desiccation, freezing, or predation. Cascade frog egg masses are most at risk of stranding because this species oviposits in very shallow water. However, Cascade frog egg masses are also somewhat tolerant of temporary or partial stranding (Corkran and Thoms 1996).

**Table 1. Summary of published accounts of life stage timing of three species known to breed at wetlands adjacent to Packwood Lake.[1]**

| Species | Life Stage Timing |
|---|---|
| **Northwestern salamander** | Eggs: Breeds early (snow melt); eggs usually attached to stems of emergent vegetation or submerged twigs. Eggs are surrounded by a dense, firm gelatinous envelope that provides some protection from desiccation if mass is temporarily stranded out of water. Hatching in 2-4 weeks.<br>Larvae: Typically metamorphose 12-14 months after hatching.<br>Adults: Completely terrestrial except when breeding or may retain gills and remain aquatic in some sites. |
| **Pacific treefrog** | Eggs: Probably breeds slightly later than Cascades frog, and egg laying may be prolonged over several weeks. Eggs are attached to vegetation, and each female deposits numerous small egg masses. Hatching in 2-3 weeks.<br>Larvae: Metamorphose after 2-3 months.<br>Adults: Terrestrial and may disperse far from breeding sites. |
| **Cascades frog** | Eggs: Breeds early (snow melt); eggs are laid in shallow water (often less than 8 inches deep), not attached to vegetation, and egg masses of many females often placed in large aggregations. Egg masses are sometimes partly exposed out of water during embryonic development, but eggs are known to survive these conditions. Hatching within 2 weeks.<br>Larvae: Hatchlings may emerge out of stranded egg masses and survive until they can swim away. Metamorphose after 1-3 months.<br>Adults: Often disperse from breeding sites, but usually remain near water. |

[1]Sources: Corkran and Thoms 1996, Jones et al. 2005.

From May to mid-September Packwood Lake surface elevation is held relatively constant, suggesting little risk that unhatched eggs or larvae would be affected by Project operations. Cascades frogs and Pacific treefrog larvae grow and develop during this period, and should have completed metamorphosis well in advance of mid-September. Northwestern salamander larvae develop more slowly and rarely metamorphose in their first year. Larvae of this species that are trapped in dewatered pools presumably do not survive the drawdown. Possibly, larvae move out into the main body of the lake (large logs appear to pose a barrier to fish movement into the breeding area, but may allow larvae to escape into the lake) or may survive under debris if substrates remain moist.

The significance of any drawdown-related mortality to northwestern salamander at the population level is not known. However, it is clear that this species would not be present if a sustainable population did not exist here or somewhere in the vicinity. Larvae either survive in drawdown zone wetlands at least occasionally, or the salamanders breed and survive elsewhere within dispersal distance of the Packwood Lake wetlands. On this basis, the loss of some larvae from drawdown is not distinctly different from mortality that might have occurred in pre-project conditions when lake levels reportedly dropped seasonally to 2854 ft MSL, which may also have been sufficient to dewater depressions on the edge of the lake.

**Level of Certainty**

Conclusions are based on an amphibian survey mostly conducted in one year, bolstered by general life history information for the species found to occur. The presumed fate of northwestern salamander larvae that are present in wetland pools prior to and during drawdown is not known with certainty.

### 4.1.5 Drawdown Issue #5 – Effects on Wetland Vegetation

**Inputs**

- Hydrology
- Nutrients

**Project Effects**

The magnitude and timing of lake drawdown in late September through October as well as project-induced lake level fluctuation below 2857 ft MSL during November – April

**Non-Project Effects**

None

**Affected Resources**

Vegetation in wetlands adjacent to Packwood Lake

**Hypotheses**

(1) Project induced reduction of water level in Packwood Lake during the fall drawdown (starting in mid-September with refill in October) and drawdowns during November through April cause a lowering of the groundwater level within wetlands adjacent to Packwood Lake

(2) Habitat disturbance due to drawdowns promotes the proliferation of certain weedy plant species, which have a competitive advantage over native plant species.

(3) The response rate/magnitude for soil saturation within adjacent wetlands to drawdown of the lake is minimal and therefore biota within the wetlands is unaffected.

(4) Soil saturation within adjacent wetlands is primarily a function of upslope hydrology during periods when the Project reduces lake level below 2857 ft MSL.

(5) Habitats exhibit high quality (vegetation patterns do not show apparent signs vegetation limited by drawdowns or water level fluctuations).

**Most Scientifically Viable Hypothesis**

The hydrology for wetlands adjacent to Packwood Lake exhibits complex patterns that vary spatially and seasonally. Upslope hydrology that is a function of precipitation and runoff dominates wetland hydrology for all wetlands during winter and spring (November – June). During drier periods (July – October), lake level has a greater effect on wetland soil saturation for some, but not all, of the adjacent wetlands. The relative influence of lake level varies spatially dependent upon soil conditions, topography and drainage patterns. Since vegetation is beginning to go seasonally dormant at the time of the fall drawdown, the effects on wetland vegetation are minimal.

**Summary Statement and Documentation**

Hydrology is critical to the structure and function of wetlands. Hydrology and timing can influence species composition and richness, primary productivity, accumulation of organic matter, and nutrient cycling in wetlands (Mitsch and Gosselink 1986). Therefore, understanding wetland hydrology is central to characterizing any potential effects of Project operations on wetlands and associated fish and wildlife.

A study of lake level effects on wetlands adjacent to Packwood Lake was conducted (EES Consulting 2007a). A total of seven piezometers were installed within two wetland complexes adjacent to Packwood Lake. Water levels in the piezometers, as well as lake water surface elevation were monitored, and records compared to establish the response of groundwater level within the wetlands to fluctuations in lake level. The monitoring period extended from September 14, 2005 through November 1, 2006. Piezometers 1 and 2 were installed at the head of Packwood Lake adjacent to Muller Creek. Piezometers 3, 4 and 7 were installed at the head of the lake adjacent to Upper Lake Creek (Figure 1).

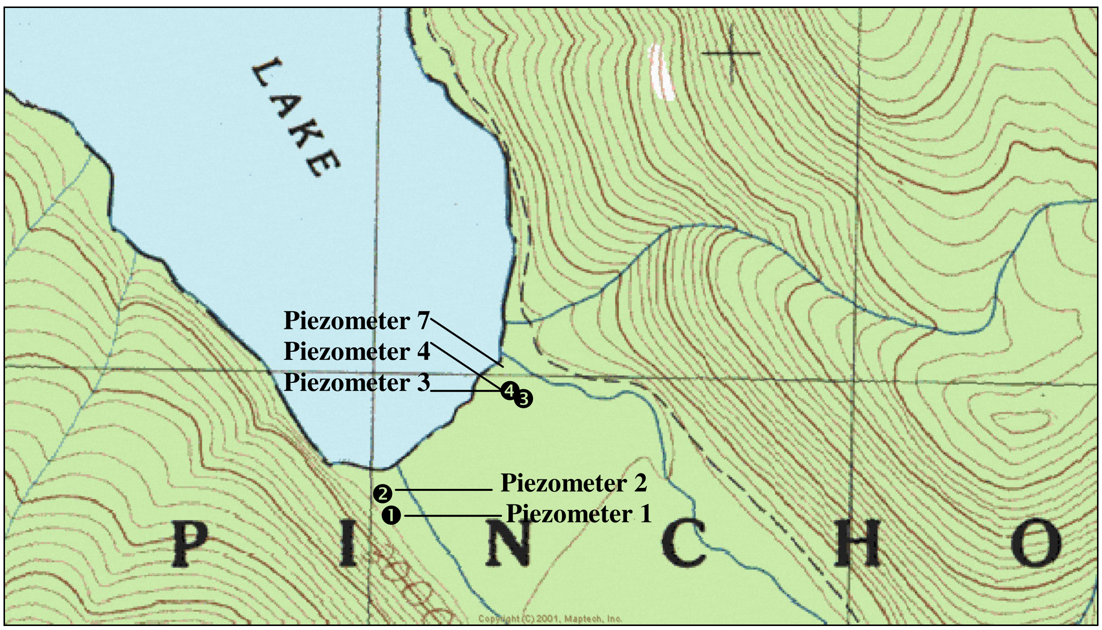


**Figure 1. Piezometers 1, 2, 3, 4, and 7.**

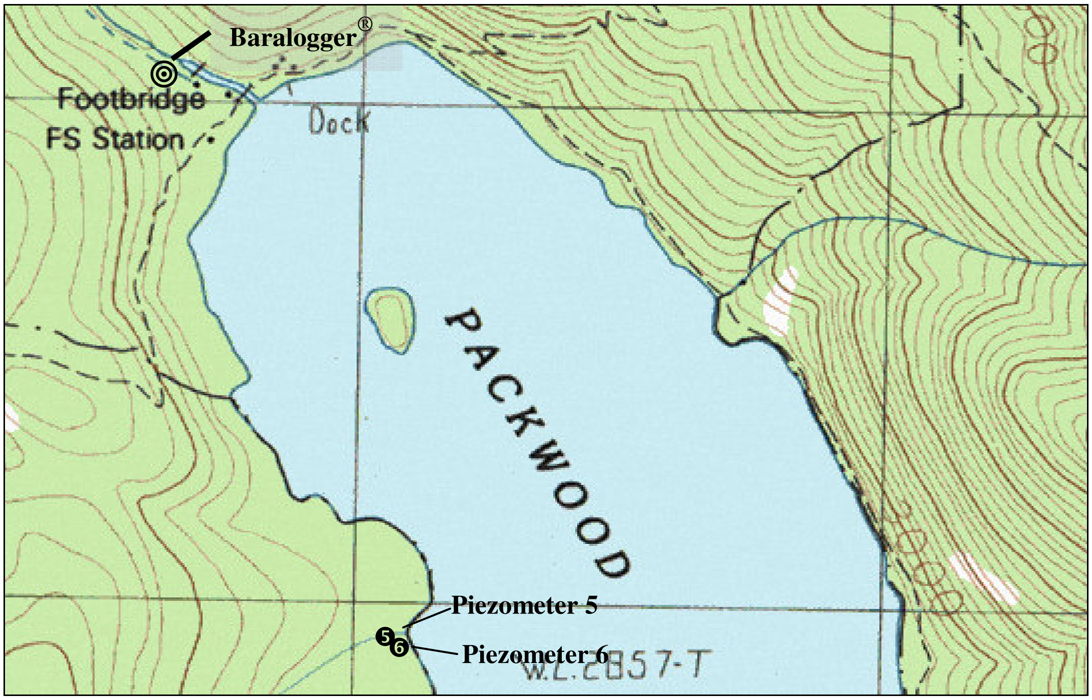


**Figure 2. Piezometers 5 and 6**

Piezometers 5 and 6 were installed in the Osprey Creek wetland complex on the southwest side of Packwood Lake (Figure 2). A Baralogger® was deployed at the existing weather station situated near the intake structure at the outlet of Packwood Lake. The two large wetland complexes adjacent to Packwood Lake showed very different responses to drawdown. The wetland complex adjacent to Osprey Creek includes both palustrine emergent seasonally flooded and palustrine forested wetlands dominated by red alder. Other tree species in this wetland include mountain hemlock and red cedar. There is abundant downed large woody debris. The soils in this wetland are saturated near the surface nearly year round. The upslope hydrology was the primary determinant of groundwater hydrology for this wetland complex. Water level within the piezometers was unresponsive to lake level drawdowns. Shallow groundwater hydrology supporting wetlands adjacent to Osprey Creek was very stable throughout the monitoring period. Water levels in P-5 remained stable, in spite of significant changes in lake level and inflow. Water levels in P-6 also were stable throughout a majority of the monitoring period.

The wetland complex at the upper end of the lake was mapped as a palustrine forested wetland with areas dominated by red alder as well as mixed tree stands (DTA 2006). Red alders were dominant with typical trunk diameter being 10 – 14 in dbh. Downed large woody debris was abundant. Upper Lake Creek and Muller Creek flow through this wetland complex. The near-shore area of this wetland complex exhibited complex hydrologic functions. Low lying areas, as best represented by P-2 are seasonally flooded much of the year. The water table at slightly higher ground elevations that occur on hummocks (similar to P-3) was within the upper 18 inches of soil but only sporadically saturated to the surface.

The portion of this wetland near Muller Creek was mapped as a mixed stand palustrine forested wetland. Piezometers P-1 and P-2 were located in this part of the wetland. The groundwater level at both of these piezometers was primarily a function of lake level during the drier portion of the year (July through October). Precipitation and upslope hydrology (inflow) were the primarily determinants of groundwater level during the rest of the year. The transition was abrupt in both 2005 and 2006 with the onset of the first large fall storm events in October – November.

The fall drawdown had the effect of lowering the groundwater level 1.0 ft to 1.3 ft, which resulted in the groundwater level being lower than 18 inches below the ground surface; the latter is considered the vegetation rooting zone (Brinson 1993). This magnitude of change was muted relative to a lake level change of approximately 7.5 ft. The water table and ground level was at a higher elevation at P-1 than P-2 with the slope towards the lake; however the relative magnitude of the effects of lake drawdown on wetland water elevation were very similar.

The groundwater level at P-3, which is closer to Lake Creek, was not closely associated with lake level. The gradual decline in water level at P-3 during the summer months suggests that the hydrology for the wetland in the vicinity of this piezometer was primarily a function of upslope hydrology or inflow. The water level at P-3 dropped about 0.6 ft during the fall 2006 drawdown; however, this rate of decline was similar to rates observed earlier in the summer (Figure 3). The minimum elevation for the water table at P-2 was very similar to the level at P-3 for the fall 2006 drawdown, which suggests that the lake level may define the minimum water table elevation throughout the near shore area of this wetland. The lake level likely had some influence on wetland hydrology during the drawdown but the effect was partially masked by the greater influence of upslope hydrology.

Piezometer P-3 was located approximately 200 ft from the lake shoreline. Piezometers P-4 and P-7 were located approximately 60 ft from the shoreline. While the summer/fall groundwater table at P-3 was primarily a function of upslope hydrology, the groundwater hydrology was strongly controlled by lake level for the nearshore environment adjacent to Lake Creek, as represented by P-4 and P-7. There was no obvious transition in vegetation between the locations of these piezometers. This portion of the wetland was mapped as a red-alder dominated palustrine forested wetland. The canopy matrix was red alder with 70% - 90% canopy coverage (DTA 2006). Abundant downed wood was present. According to DTA (2006), shrub cover was dominated by red elderberry (*Sambucus racemosa*) and vine maple (*Acer circinatum*). Herbaceous species found were diverse and included lady fern (*Athyrium filix-femina*), skunk cabbage (*Lysichitum americanum*), cow-parsnip (*Heracleum lanatum*), Cooley's hedge-nettle (*Stachys cooleyae*), mitrewort (*Mitella* sp.), piggy-back plant (*Tolmiea menziesii*), forget-me-not (*Myosotis laxa*), and monkey-flower (*Mimulus* sp.).

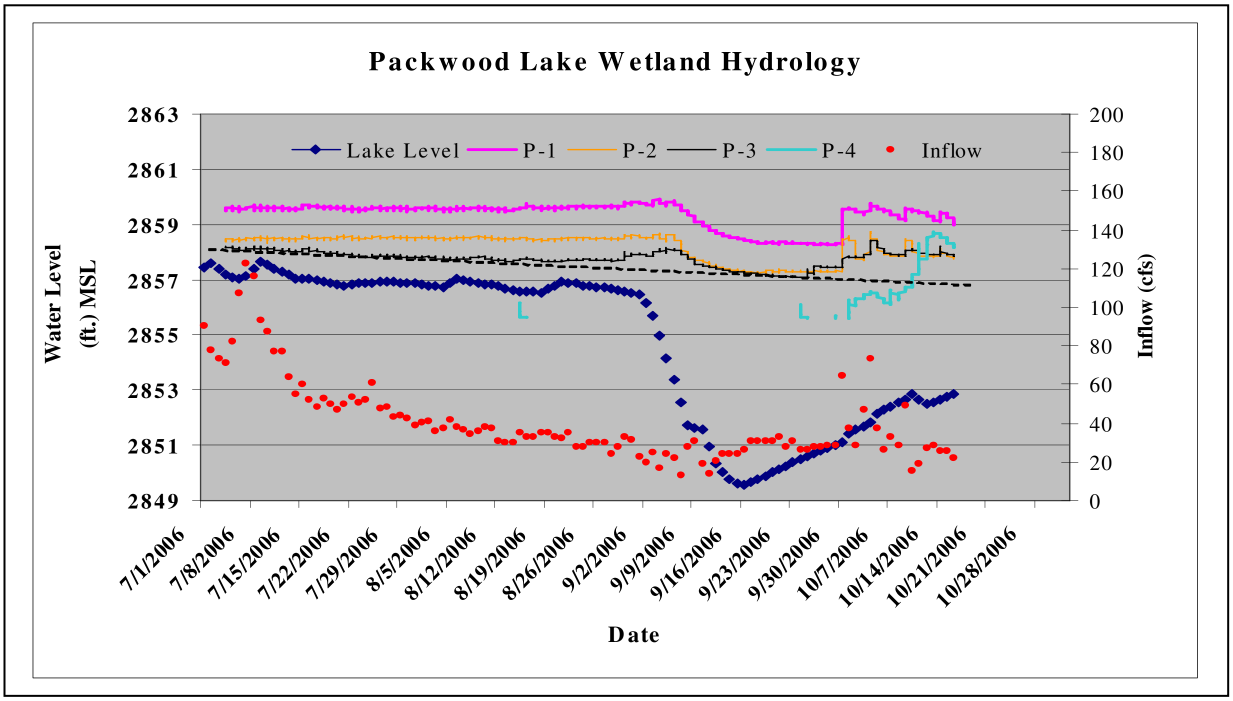


**Figure 3. Water level for Piezometers at the upper end of Packwood Lake Level for summer/fall 2006**

The soil near P-4 and P-7 was characterized as clay overlaying sandy clay. The soil profile was heavily gleyed, which is indicative of seasonal saturation for extended periods. A clay lens was perforated when P-4 was installed. A second piezometer (P-7) installed nearby at a slightly shallower position in the soil did not perforate the clay lens. Both piezometers reported nearly identical trends for water level, which indicated that the installation of P-4 did not bias results. Although the water table at this location dropped to a level several feet below the ground surface at this location, the surface soils remained saturated due to their high clay content.

The effect of lake drawdown on the hydrology of the wetland complex at the upper end of the lake was most pronounced in the vicinity of P-4. The lake level had very little effect on wetland hydrology at a point approximately 200 ft from the shoreline for the eastern portion (closer to Lake Creek P-3). The soil hydrology of the portion of this wetland closer to Muller Creek was a function of lake level during the drier months (July - October) and a function of upslope hydrology during wetter months. Even in areas where the water table dropped below the typical vegetation root zone of 18 inches, the high clay content of the soil kept it at or near saturation.

There is only very limited information on seasonal lake level fluctuations prior to construction of the project. Maintaining the lake level at 2857 ±0.5 ft may have the effect of maintaining a slightly higher groundwater table within the nearshore portion of the wetland complex at the head of Packwood Lake during late summer. The linear trend for summer groundwater elevation at P-3 is shown in Figure 3. The groundwater level reached an equilibrium elevation relative to lake level by mid-August and remained at that elevation until drawdown. The level then dropped to a level comparable to an elevation likely, had the seasonal trend continued.

For the wetlands at the upper end of Packwood Lake, non-native plant species are localized in areas closest to the lake shoreline. While soil moisture in this area is a function of lake level, the soil dries out in the summer despite elevated lake level. At other areas of this wetland, non-native plants appear to be not as prevalent due to canopy shading.

**Level of Certainty**

The level of certainty is high. Quantitative data on groundwater hydrology covering two drawdown seasons is available. Correlation analyses were completed to establish the relationship between lake level and wetland hydrology.

**Additional Comments** -

Habitat for birds and mammals may be negatively affected by the presence of weedy species.

### 4.1.6 Fish Distribution and Species Composition Issue 1 – Effects on Migration of Spawning Rainbow Trout

**Inputs**

Hydrology

**Project Effects**

Potential blockages to upstream migration of spawning rainbow

**Non-Project Effects**

None

**Affected Resources**

Adult adfluvial rainbow trout attempting to migrate to the tributaries to spawn

**Hypotheses**

(1) Adult rainbow trout attempting to emigrate from Packwood Lake to upstream tributaries to spawn may be precluded from doing so as a result of lake drawdown due to shallow stream depths/no water connectivity across the deltas.
(2) Rainbow trout migration does not coincide with periods of lake drawdown, so there is no effect.
(3) A continuous channel is maintained during drawdown that allows fish passage.
(4) Increased predation on juvenile/adult fish migrating across the drawdown zone occurs.

**Most Scientifically Viable Hypothesis**

Rainbow trout spawning migration does not coincide with periods of lake drawdown. Potential project related blockages are not an issue during this time of year (May 15 – July 15).

**Summary Statement and Documentation**

An adfluvial population of rainbow trout resides in Packwood Lake and utilizes its primary tributaries for spawning and rearing purposes. A typical year would see rainbow trout migrating from Packwood Lake in May and June to spawn in the tributaries shown in Figure 4. The spawners typically return to the lake immediately after spawning occurs, leaving the tributaries by early July at the latest.(Energy Northwest Fish Distribution and Species Composition Report, in preparation, July 2007). The rainbow trout spawning migration coincides with spring runoff when stream flows and the corresponding lake level are typically at the highest stage of the year (Figure 5).

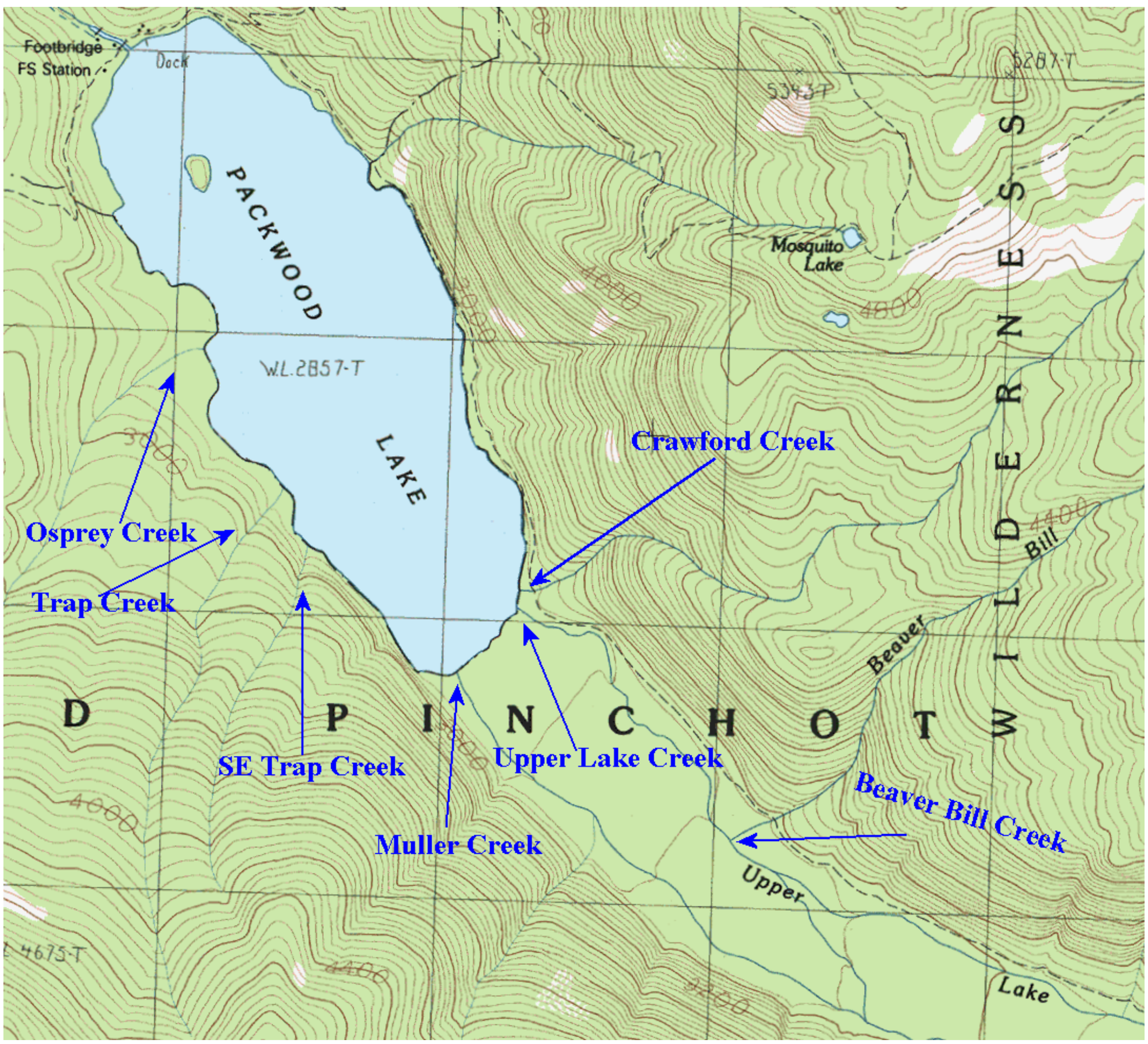


**Figure 4. Primary rainbow trout spawning tributaries**

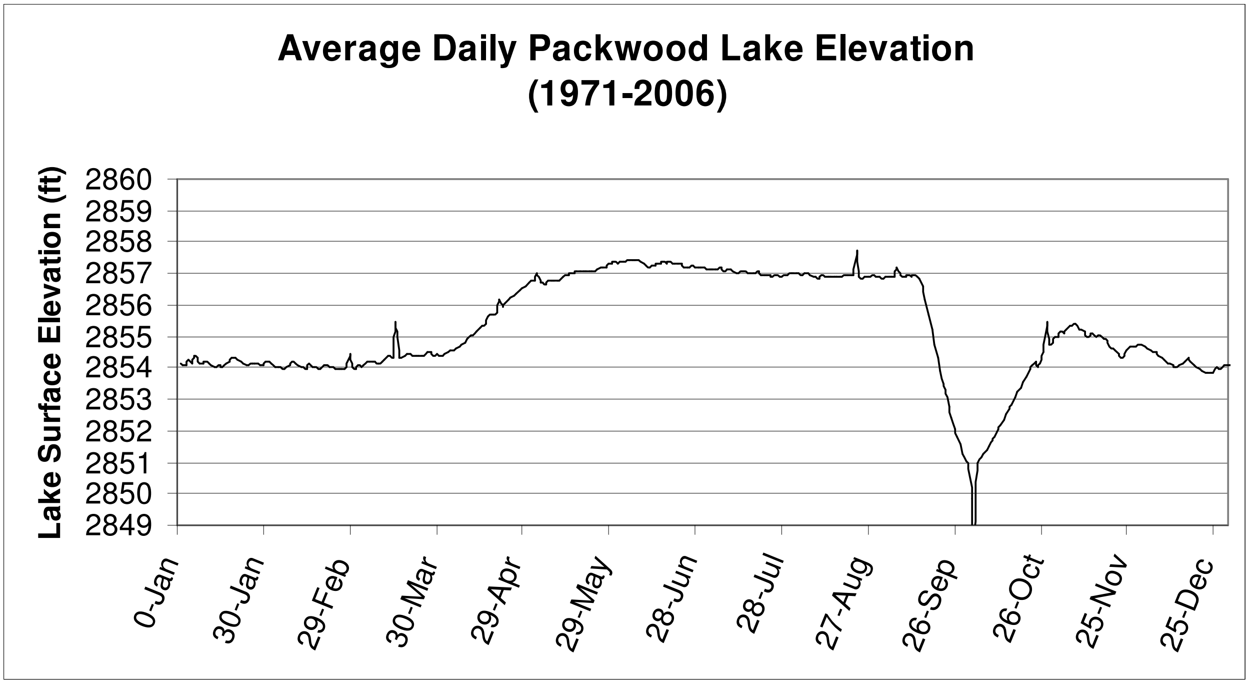


**Figure 5. Average Packwood Lake elevation (1971-2006).**

Both historical spawning data and surveys conducted in conjunction with Energy Northwest's relicensing effort demonstrate that spawning rainbow migrating from Packwood Lake to the tributaries do not encounter any Project-related blockages due to an overall lack of passage obstructions and further supplemented by high water conditions during the spawning period. Specifics related to connectivity issues at each tributary are located in the Revised Draft Stream Connectivity in Packwood Lake Tributaries Study Report (Watershed GeoDynamics and EES Consulting 2006). The numbers of spawning fish counted on an annual basis indicate access to quality spawning habitat in the tributaries is not impeded by any Project effects (See Table 2).

**Table 2. Adult rainbow trout count from annual spawning surveys in major tributaries to Packwood Lake.**

| | Packwood Lake Tributaries | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Year** | **Osprey Creek** | **Trap Creek** | **Muller Creek** | **Upper Lake Creek*** | **Beaver Bill Creek** | **Crawford Creek** | **Trib SE of Trap Creek** | **Total** |
| 1980 | | | 194 | | | | | **194** |
| 1981 | 16 | 18 | 67 | 5 | | | | **106** |
| 1982 | | 0 | 0 | 0 | | | | **0** |
| 1983 | 0 | | 0 | | | | | **0** |
| 1984 | | | 55 | 317 | | | 40 | **412** |
| 1985 | 3 | 0 | 14 | 200 | | | 0 | **217** |
| 1986 | | | 13 | 112 | | | | **125** |
| 1987 | | | 78 | 332 | | | | **410** |
| 1988 | | 180 | 61 | 721 | | | 4 | **966** |
| 1989 | 490 | 160 | 180 | 405 | 82 | | 5 | **1322** |
| 1990 | 24 | 5 | 149 | 60 | | | | **238** |
| 1991 | 314 | 94 | 399 | 363 | | | 0 | **1170** |
| 1995 | 1 | 0 | 86 | 166 | | | | **253** |
| 1996 | 0 | 3 | 299 | 238 | | | | **540** |
| 1997 | 29 | 13 | 590 | 214 | | | | **846** |
| 1998 | 28 | 9 | 374 | 220 | | | | **631** |
| 1999 | 19 | 30 | 155 | 107 | | | | **311** |
| 2000 | 355 | 27 | 249 | 153 | | | | **784** |
| 2002 | 138 | 60 | 414 | 265 | | | 8 | **885** |
| 2003 | 181 | 6 | 201 | 305 | | | 0 | **693** |
| 2006 | 0 | 10 | 500 | 0 | 3 | 166 | 0 | **679** |
| **Avg** | **107** | **38** | **172** | **220** | **43** | **11** | **7** | **597** |

WDFW Survey**

WDFW and EESC Surveys Combined

Blank cells indicate years when surveying did not occur on a specific tributary
*It is likely Crawford Creek data was incorporated into Upper Lake Creek numbers during WDFW surveys
**WDFW survey data was taken from Wieman 2004

## Level of Certainty

The level of certainty is high. It is supported by multiple years of quantified data.

### 4.1.7 Fish Species Distribution and Composition Issue 2 - Effects on Migration of Juvenile Rainbow Trout

**Inputs**

Hydrology

**Project Effects**

The magnitude and timing of Packwood Lake drawdown annually in late September with refill during October.

**Non-Project Effects**

None

**Affected Resources**

Juvenile adfluvial rainbow trout attempting to out-migrate from their natal streams to Packwood Lake.

**Hypotheses**

(1) Juvenile rainbow trout migration does not coincide with periods of lake drawdown, so there is no effect.
(2) A continuous channel is maintained during drawdown that allows fish passage.
(3) Increased predation on juvenile/adult fish migrating across the drawdown zone occurs.

**Most Scientifically Viable Hypothesis**

Juvenile rainbow trout migration from tributaries into Packwood Lake does not coincide with periods of drawdown, so there is no Project effect.

**Summary Statement and Documentation**

Connectivity between Packwood Lake and the pertinent tributaries (Figure 4) as it relates to out migrant juvenile rainbow remains intact all year. If out-migration were to occur during lake drawdown, juvenile rainbow trout may be more prone to predation due to channel extension into the delta area of Packwood Lake. The lack of instream and overhead cover in this area could potentially contribute to higher predation levels during drawdown.

However, juvenile rainbow trout migrate from their native streams prior to the drawdown of Packwood Lake. Low water in the tributaries in August and September typically cues out migration behavior. A low water survey was conducted on August 8, 2006 during which over 1000 juvenile rainbow trout were seen in Crawford Creek. Prior to Crawford Creek going completely dry, as it naturally does, in late August or early September, a supplemental survey was done. Very few juvenile rainbow trout remained in Crawford Creek. The fish had out-migrated to Packwood Lake. It is important to note that the occasional dewatering of the tributaries is a natural occurrence and would occur sporadically without the existence of the Project.

**Level of Certainty**

The level of certainty is moderate. Supplemental data collected later this year related to out migrant timing will assist in finalizing the conclusion.

## 4.2 Lower Lake Creek

Prior to installation of the drop structure and intake building for the Packwood Lake Hydroelectric Project in 1960, lower Lake Creek naturally drained all runoff that entered Packwood Lake from the upper tributaries. Water is now diverted from lower Lake Creek immediately below the drop structure at River Mile (RM) 5.3; water discharged from the Project is released to the Cowlitz River via a tailrace channel. The Project can divert up to 260 cfs and modifies the hydrology of lower Lake Creek. The two significant effects of a hydroelectric project on stream habitat are its ability to change the quantity of streamflow and the rate of change of flow.

Energy Northwest releases a minimum of 3 cfs of Packwood Lake water into lower Lake Creek to protect resident stream fish and other aquatic species. Additional inflow into lower Lake Creek is the result of snowmelt from tributaries, ground water accretion in locations throughout the 5.4-mile reach, and by high flows that exceed the Project's capacity and overtop the intake structure.

Lower Lake Creek supports populations of resident rainbow trout, sculpin and westslope cutthroat, (although none were observed during EES Consulting surveys) as well as several species of amphibians. The resident fish exist in segmented populations due to a series of natural falls and chutes along the 5.4-mile stretch of lower Lake Creek. The lower reaches of Lake Creek are accessible to anadromous salmonids, including Chinook salmon, coho salmon, steelhead, and sea-run cutthroat trout. All of the anadromous species with the exception of steelhead are restricted to the lower 1.03 miles of lower Lake Creek by a natural bedrock chute. Steelhead are restricted to the lower 1.95 miles due to a large natural falls which prevents passage. (See Draft Fish Passage Barriers Study Report, EES Consulting 2006d, for information on barriers to fish passage.) All of these fish and amphibians depend on aquatic habitat that is affected by Project-influenced flows. The Project's alteration of natural flows and the associated water quality and connectivity issues raise concerns regarding:

- Migratory efforts of resident rainbow trout
- Habitat availability for juvenile and spawning anadromous salmonids
- Overall reduction in wetted habitat for fish and macroinvertebrate species
- Gravel transport into anadromous zones of lower Lake Creek
- Effects of elevated water temperature due to low flows in the summer months
- Dewatering of amphibian habitat

In-depth collaborative discussions with the resource specialists involved in the Energy Northwest relicensing have resulted in a set of hypotheses for each of the issues in this section. For each issue the most scientifically viable hypothesis has been selected. Supporting data from relevant studies has been synthesized in support of each hypothesis.

Issues for the lower Lake Creek area include:

1. Fish Population Characterization Near the Drop Structure Issue 1
2. Instream Flows Issue 1
3. Instream Flows Issue 2
4. Water Quality Issue 1 – Water Temperature in Lake Creek
5. Flow Effects on Lake Creek Amphibians

### 4.2.1 Fish Population Characterization Near the Drop Structure Issue 1

**Inputs**

Hydrology

**Project Effects**

Lack of connectivity between Packwood Lake and lower Lake Creek

**Non-Project Effects**

None

**Affected Resources**

Rainbow trout isolated in the 1,464-foot stretch of lower Lake Creek immediately below the Project drop structure

**Hypotheses**

(1) Some of the resident population of rainbow trout in Packwood Lake is infrequently routed to lower Lake Creek as a result of overtopping of the drop structure. Given the healthy rainbow trout population in Packwood Lake, the relocation of a small number of fish will not impact Packwood Lake populations but may benefit lower Lake Creek by supplementing existing populations.

(2) Overtopping events that result in fish being removed from Packwood Lake potentially depletes the population to detrimental levels.

(3) Packwood Lake rainbow trout and lower Lake Creek rainbow are two distinct populations. Integration of the two species due to overtopping events may result in detrimental genetic implications.

**Most Scientifically Viable Hypothesis**

Some of the resident population of rainbow trout in Packwood Lake is infrequently routed to lower Lake Creek as a result of overtopping of the drop structure. Given the healthy rainbow trout population in Packwood Lake, the relocation of a small number of fish will not impact Packwood Lake populations but may benefit lower Lake Creek by supplementing existing populations.

**Summary Statement and Documentation**

As spawning surveys from the lake tributaries demonstrate, the adfluvial population of rainbow trout that utilize Packwood Lake is at a very healthy level (see Table 2). Currently the 2007 spawning surveys are taking place in tributaries to Packwood Lake and are showing high numbers of spawners in their characteristic tributaries relative to historical documentation. The Fish Distribution and Species Composition Report will detail these numbers when completed in August, 2007. The density of fish in Packwood Lake is much higher than in the isolated 1464 ft. of lower Lake Creek immediately below the drop structure, as documented by the population size of fish observed in both areas (Figure 6).

During one overnight gill netting effort in Packwood Lake in early May 2006, 105 rainbow trout were captured. Conversely, during an electroshocking effort in August 2006 that spanned the entire 1464 ft reach below the drop structure, a total of only 12 rainbow trout were captured. The average size of rainbow trout captured in the lake was 242 mm versus 124 mm in the isolated reach of lower Lake Creek below the drop structure (Figure 6).

The highest number of fish ever observed in the isolated reach of lower Lake Creek occurred in late May 2006 when 30 to 40 rainbow trout were observed immediately below the drop structure. These fish were oriented directly into the release flow coming from the lake and were larger by approximately 50 mm than the other fish observed in the reach on subsequent surveys. It is very likely that these fish were routed over the drop structure during overtopping events occurring in conjunction with gravel studies in lower Lake Creek.

Spawner surveys are ongoing in the isolated reach and will be described in detail the Fish Distribution and Species Composition Report. To date, no spawners or redds have been observed in the isolated stretch of lower Lake Creek. The occasional introduction of a limited number of rainbow trout from Packwood Lake could potentially assist in increasing the population numbers and overall health of the naturally isolated populations in lower Lake Creek.

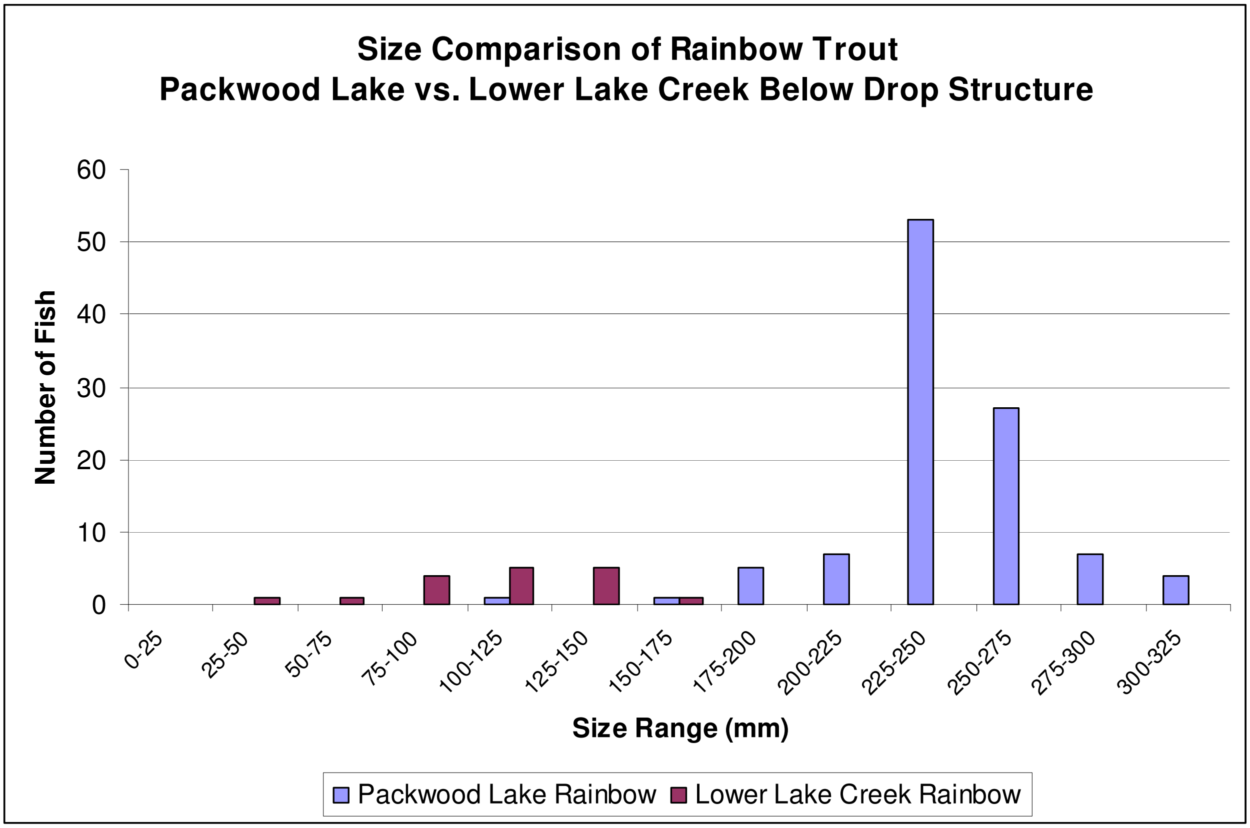


**Figure 6. Lower Lake Creek vs. Packwood Lake Rainbow Trout Size Observations**

**Level of Certainty**

The level of certainty is moderate. Supplemental data collected later this year related to fish populations in the lake and lower Lake Creek will assist in finalizing the conclusion.

### 4.2.2 Instream Flows Issue #1 – Influence of Peak Flows on Gravel and Large Wood in Lower Lake Creek

**Inputs**

- Hydrology
- Sediment
- Large wood

**Project Effects**

- The drop structure stops large wood coming from Packwood Lake and upstream sources from traveling into lower Lake Creek.
- Peak flows have been reduced, which reduces the frequency and magnitude of bedload (gravel/cobble) and large woody debris transport.

**Non-Project Effects**

- Packwood Lake is a natural gravel sink
- Past timber harvest in riparian areas along lower Lake Creek

- Residential development in the lower 0.3 miles of Lake Creek

**Affected Resources**

- Spawning and rearing fish habitat (anadromous and resident)
- Amphibian habitat
- Macroinvertebrate habitat
- Gravel transport
- Large wood recruitment and transport

**Hypotheses**

(1) Continued operation of the Project reduces Peak flows in Lake Creek below the drop structure. As a result, there is less gravel transport so gravel is "stuck" in Reaches 2, 3, and 4, and large woody debris is not moving through the stream. This lack of gravel and structure has reduced the amount of spawning and rearing habitat available for both resident and anadromous fish and benthic macroinvertebrates.

(2) The relatively low amounts of gravel in the lower 0.8 miles of Lake Creek are the result of a lack of structure to hold gravel (not Project-related).

(3) Packwood Lake is not a major source of large wood to Lake Creek downstream of the drop structure. Few pieces of large wood arrive at the drop structure. There are nearly 70 pieces of countable large wood/mile within the wetted channel in Reach 5.

(4) The majority of large wood in lower Lake Creek (even very old wood) is not fluvially transported, indicating most large wood is derived from local sources rather than wood transport.

(5) Higher and more frequent peak flows in Lake Creek downstream of the drop structure would transport gravel through the anadromous zone in Lake Creek and deposit it in the Cowlitz River resulting in low amounts of spawning gravel in Lake Creek.

(6) If more spawning gravel were present in the anadromous zone of Lake Creek, more spawning would occur.

(7) Habitat conditions for stream-dwelling amphibians are influenced by the distribution of gravel, but the prevalence of coarser substrates that are not embedded is the primary determinant of habitat suitability (See Section 4.2.5).

**Most Scientifically Viable Hypothesis**

Peak flows have been reduced in Lake Creek below the drop structure. Sediment input from upstream of Packwood Lake is limited since the lake is a gravel trap. There are limited gravel sources in Lake Creek downstream of the drop structure. Lower Lake Creek is a high gradient, course substrate (boulder/cobble) system with limited instream gravel storage. The majority of large wood in lower Lake Creek (even very old wood) is not fluvially transported, indicating most large wood is derived from local sources rather than wood transport. The magnitude and frequency of gravel transport in lower Lake Creek is changed by Project operations due to the altered peak flow regime. There is relatively little gravel in the lower 0.8 miles of Lake Creek despite the lower gradient in this section. There are few pieces of large wood or other large roughness elements in this lower section of Lake Creek that would provide gravel retention areas. The lack of large wood is likely the result of past forest practices and human disturbance that is not Project-related. The low amount of spawning-sized gravel in the lower 0.8 miles of Lake

Creek is likely the combined result of a lack of structure to hold gravel (not Project-related), few sediment sources downstream of the drop structure, and reduced transport from upstream reaches. All gravel associated with spawning habitat is currently being utilized in the anadromous zone of lower Lake Creek.

**Summary Statement and Documentation**

Peak Flows: Peak flows are altered by operation of the Project. Figure 7 shows a comparison of highest annual mean daily flow near the mouth of Lake Creek from the pre- and post-Project periods (Watershed GeoDynamics 2007a). The majority (65%) of highest annual flows before the Project were between 200-500 cfs. During the post-Project period, 24% of the high flows were between 200-500 cfs. Sixty percent of flows during the post-Project period were between 0-200 cfs. Flows over about 600 cfs appear to have a similar frequency during the without- and with-Project periods.

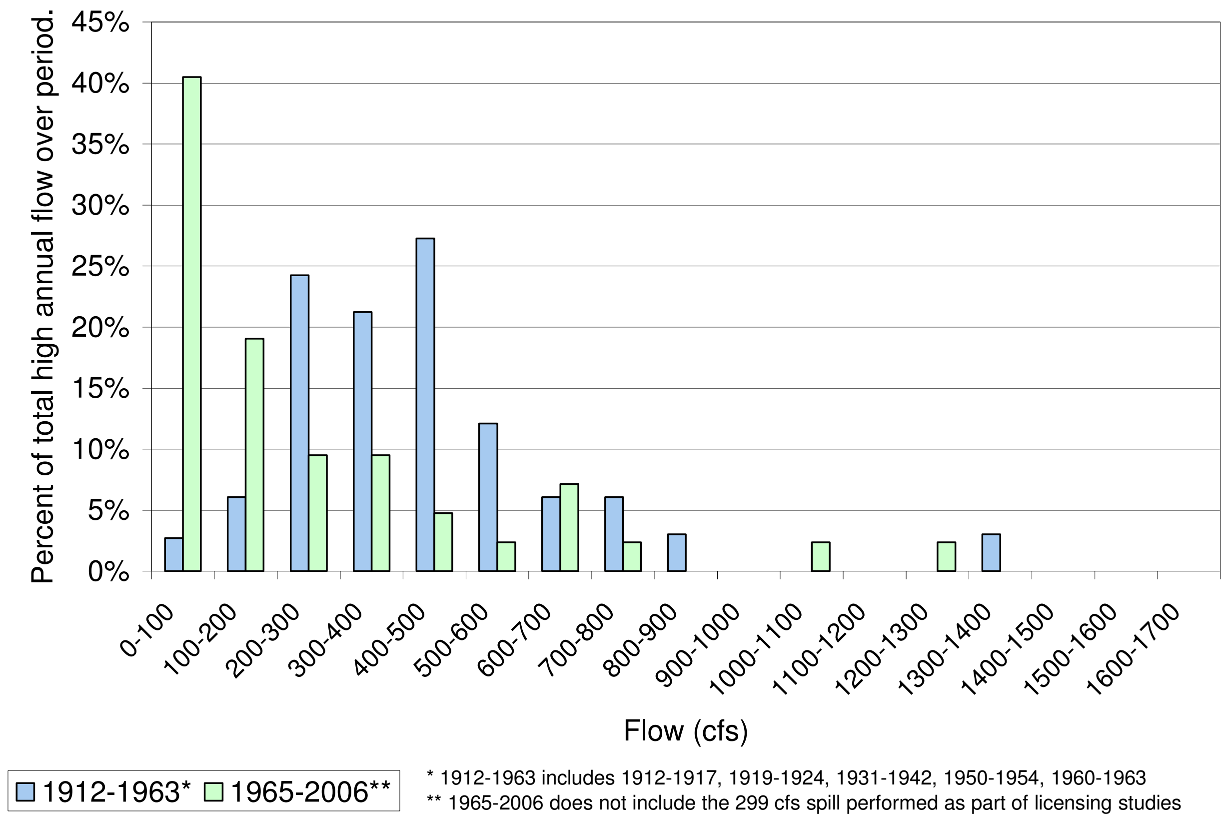


**Figure 7. Comparison of Pre and Post Project annual highest mean daily flow, Lake Creek near Packwood Gage (near mouth of Lake Creek).**

Large Wood: The primary source of instream wood in lower Lake Creek is local trees falling into the creek by windthrow, tree mortality, and mass wasting (Watershed GeoDynamics 2006). Wood and log jams are abundant upstream of approximately River Mile 2.1, with 90-130 pieces of countable wood/mile (over 12 inches in diameter and 25 feet long) in the combined wetted and bankfull channel in Reaches 3, 4, and 5 (Figures 8 and 9). The undisturbed riparian forest in these reaches and riparian protections under the USFS Forest Plan should result in a continued wood supply in these reaches in the future.

There is less wood in the lower 2.1 miles of the creek. A total of 35 countable pieces of wood/mile were inventoried in Reach 2, and 15 pieces of wood/mile in Reach 1. There are few local sources of future large wood in Reaches 1 or 2. These reaches are less confined than upstream reaches, and appear to have been affected by past harvest of mature trees from the riparian zone in at least some locations. It is likely that mature conifer stands will not be available to provide local sources of instream wood in these reaches over the term of the new license. The Project has no control over, and continued operation of the Project has no effect on, the past or future harvest of riparian areas along Lake Creek.

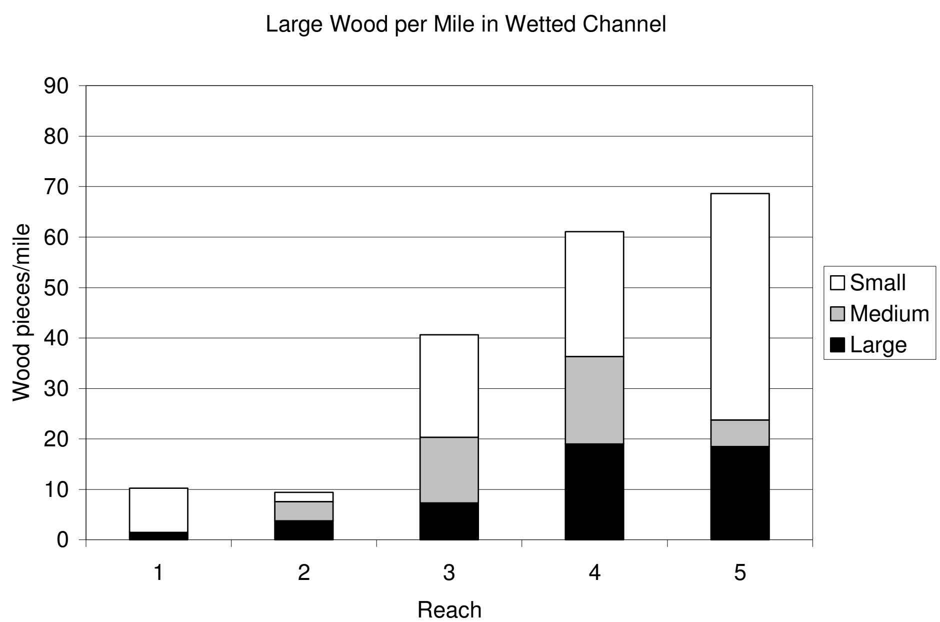


**Figure 8. Large wood in wetted channel.**

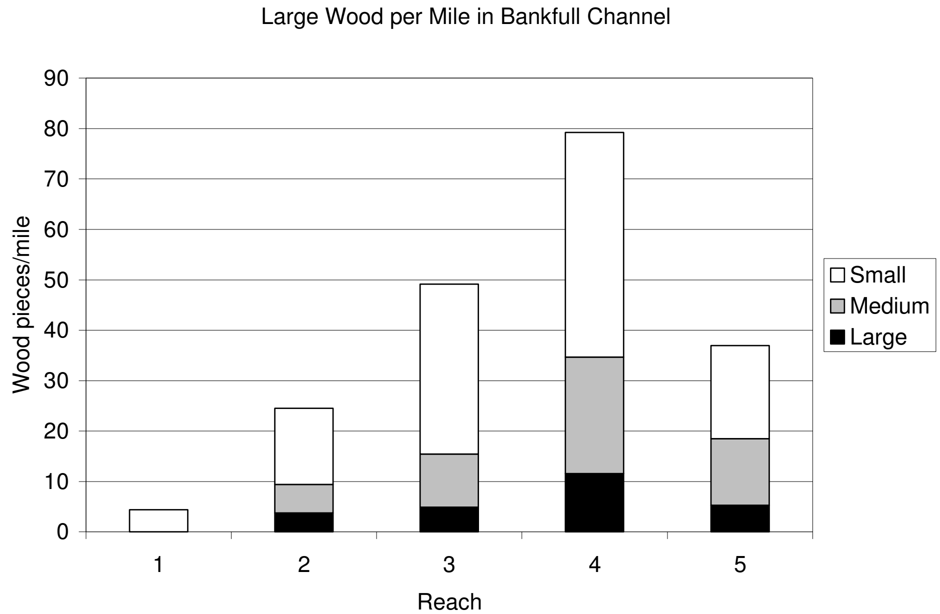


**Figure 9. Large wood in bankfull channel.**

Packwood Lake is not a major source of wood for Lake Creek. Information collected as part of the large wood study suggests that the majority of instream wood in Lake Creek comes from local sources. The numerous channel constrictions and large boulders make it nearly impossible for wood to be transported very far in the stream. No wood in the large size class, 6% of medium wood, and 12% of small wood showed signs of fluvial transport during the 2005 inventory. Fluvially transported wood was either old or very old, further reinforcing the hypothesis that large woody debris is transported very infrequently in lower Lake Creek. The lower 2 miles of Lake Creek were re-visited in 2007, following the November 2006 peak flow event. The magnitude of flows near the mouth of Lake Creek during that event were not recorded, but an estimated 1,000 cfs passed over the drop structure. It is likely that several hundred cfs of inflow occurred between the drop structure and the mouth based on historic USGS flood records (the November 2006 flow in the Cowlitz River at Packwood had the highest peak recorded since recording began in 1911). There was movement of large woody debris in the lower 2 miles of Lake Creek during the peak flow event. All pieces of tagged large wood had moved in Reach 1 and 2, and it was evident that other, non-tagged wood had also moved.

There is adequate wood in Lake Creek upstream of RM 2.1. There are few pieces of wood downstream of RM 2.1, but this is likely the result of past management activities in the riparian zone which removed large trees. Future operation of the Packwood Lake Hydroelectric Project will not have an effect on the supply of local large woody debris in any of the stream reaches.

<u>Spawning-sized Gravel</u>: Gravel is an important component of aquatic habitats because it provides spawning substrate for fish, and habitat for other aquatic organisms. The size of gravel used by fish varies by species, but the majority of anadromous fish (Chinook,

coho, chum, steelhead) prefer gravel in the range of 0.5-4 inches; sea-run cutthroat trout prefer gravel between 0.2 and 2 inches in diameter.

Packwood Lake was formed by a large landslide that blocked Lake Creek approximately 1100 years ago (Swanson 1996). Packwood Lake is large and deep enough (452 acres and over 100 feet deep) that it traps all sand, gravel, and larger material that are transported into it from upstream sources. The only source of sand, gravel, cobble, and boulder to Lake Creek downstream of Packwood Lake is from tributaries, landslides, and erosion in the lower stream watershed. Operation of the Project does not change the trap efficiency of sand and larger particles in the lake.

Lake Creek downstream from Packwood Lake is a cobble/boulder bedded stream with a dominantly step-pool structure. An inventory of spawning-sized gravel between the drop structure and the confluence with the Cowlitz River found a total of 42,660 sq ft of gravel, with the highest concentrations in Reaches 2, 3, and 4 between RM 0.8-RM 4.9 (Table 3, Figure 10, Watershed GeoDynamics 2007a). Based on visual observations during the inventory, the majority of gravel in Lake Creek was stored along the margins of the channel, behind large scale roughness elements such as boulders or logs, or upstream of log jams.

**Table 3. Area of spawning-sized gravel inventoried in Lake Creek (2005 Inventory)**

| Reach | River Mile | Average Gradient | Gravel in wetted channel | | Gravel in bankfull channel* | |
|---|---|---|---|---|---|---|
| | | | Area (sq ft) | Sq ft/mile | Area (sq ft) | Sq ft/mile |
| 1 | 0-0.7 | 2.9% | 2,775 | 4,070 | 2,700 | 3,960 |
| 2 | 0.7-1.3 | 7.3% | 6,175 | 11,644 | 2,375 | 4,479 |
| 3 | 1.3-3.5 | 8.0% | 22,025 | 8,946 | 7,550 | 3,066 |
| 4 | 3.5-4.9 | 4.3% | 11,635 | 9,599 | 7,925 | 6,538 |
| 5 | 4.9-5.3 | 8.4% | 50 | 132 | 0 | 0 |
| Total | 0-5.3 | 6.3% | 42,660 | 8,102 | 20,550 | 3,903 |

*Not including wetted channel

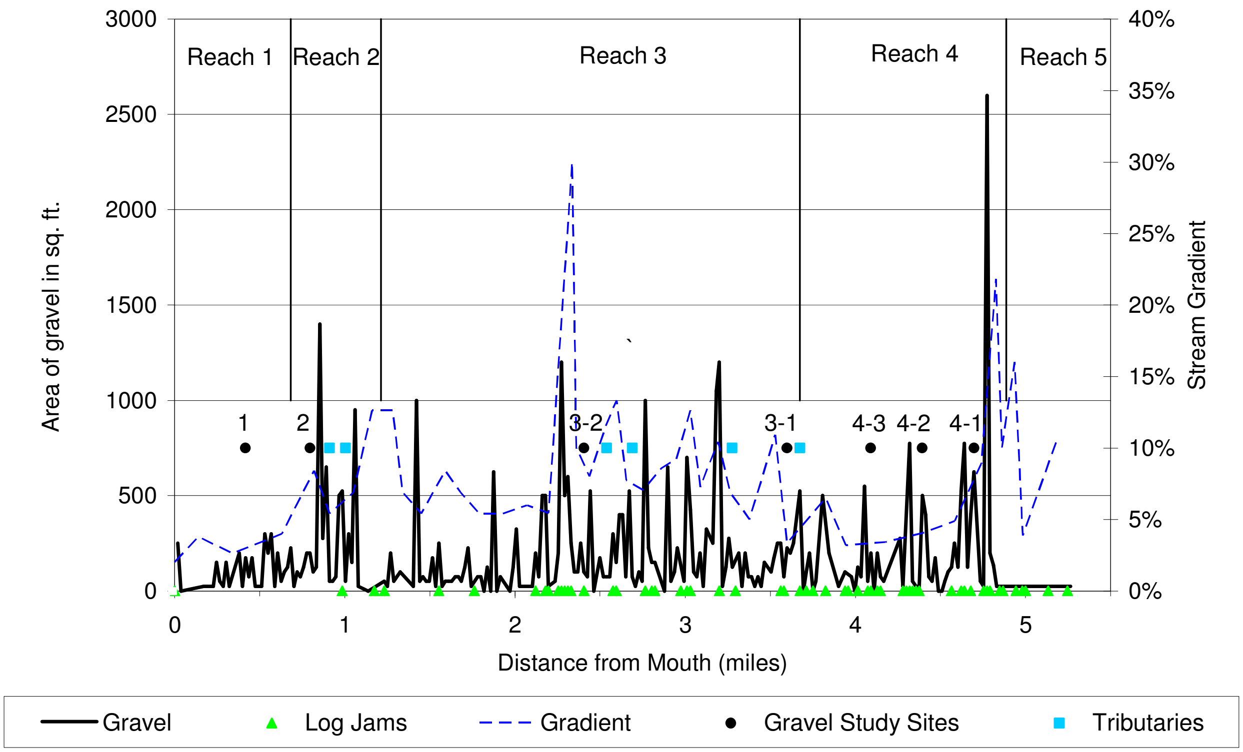


**Figure 10. Spawning-sized gravel in wetted channel / stream gradient in lower Lake Creek (2005 inventory)**

Movement of painted rocks placed at gravel study sites throughout the stream suggest that high flows (on the order of 250-300+ cfs) are needed to mobilize the largest sized spawning gravels (3-4 in. diameter) across the entire channel width. Lower flows would likely mobilize smaller gravels if they occurred in the middle of the channel, but the majority of gravel is stored on the channel margins or behind boulders/logs, requiring the higher flows to be mobilized. However, fewer rocks (5-9%) were retained at the transects in Reaches 1 and 2 than at the transect in Reaches 3 and 4. These test results are consistent with the gravel inventory results; there is less gravel downstream of RM 0.8 than in Reaches 3 and 4. One hypothesis for the lower amounts of gravel downstream of RM 0.8 is that the Project has reduced the frequency of flows capable of transporting gravel, so gravel is being retained in upstream reaches. Another hypothesis is that channel conditions that favor gravel retention (log jams, large woody debris, large boulders) are not as frequent downstream of RM 0.8 so that much of the gravel transported from upstream reaches during high flows is not retained downstream of RM 0.8. The low amount of spawning-sized gravel in the lower 0.8 miles of Lake Creek is likely the combined result of a lack of structure to hold gravel, few sediment sources downstream of the drop structure, and reduced transport from upstream reaches. Additional painted rock sites were deployed in the lower mile of Lake Creek during the Spring of 2007 (Figure 11). An overtopping event is scheduled for 2007, provided inflows are high enough to provide flows needed. These sites will provide additional information regarding the potential to retain gravel in the lower mile of Lake Creek.

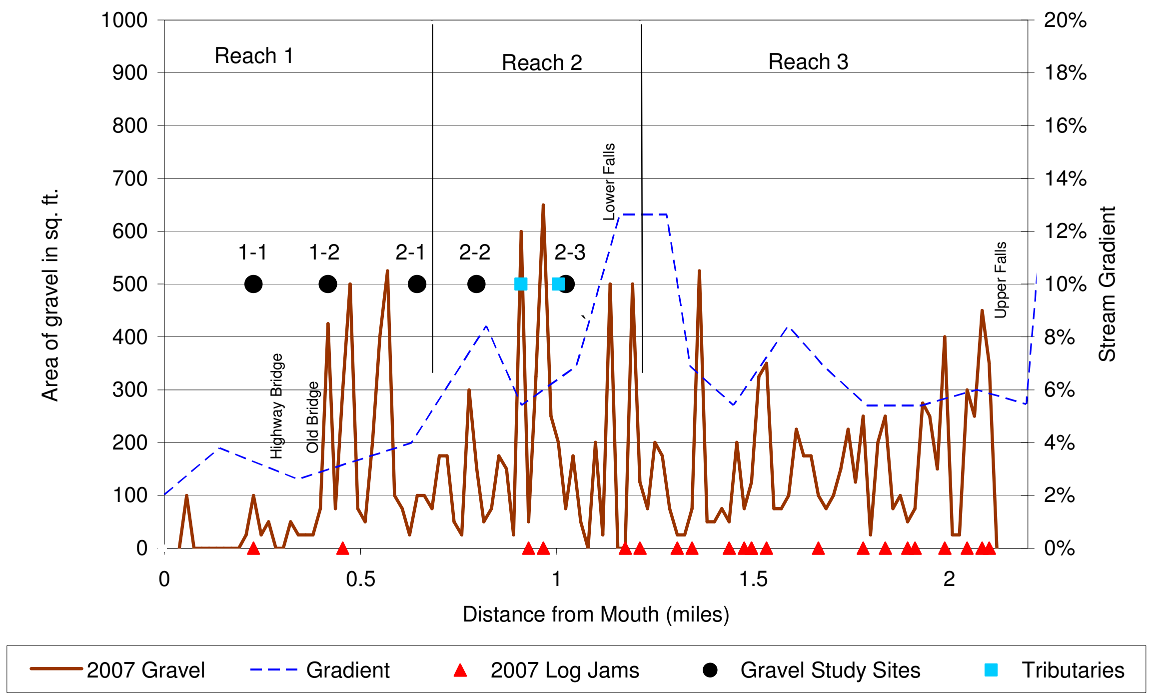


**Figure 11. Spawning-sized gravel in wetted channel and stream gradient in the lower two miles of Lake Creek (2007 inventory)**

Fish Spawning and Rearing: With the current amount of gravel and structures in lower Lake Creek, the spawning grounds below RM 1.03 (site of the lower anadromous barrier) are very limited. Habitat is also limited below RM 1.95 (location of the anadromous barrier for steelhead trout); however, no steelhead have been observed in either this reach or Lake Creek itself (Please see Instream Flow Issue No. 2 and EES Consulting 2007d). Anadromous spawner surveys conducted by EES Consulting for Energy Northwest over a two-year period indicated that suitable spawning gravels were full seeded (EES Consulting 2007c). Snorkeling and electrofishing surveys conducted by EES Consulting for the Fish Distribution and Species Composition Study (EES Consulting 2005b) indicate stable populations and low density levels, indicating limited rearing habitat that may also be fully seeded (Fish Distribution and Species Composition Study report is in preparation).

## Level of Certainty

The changes to peak flows in lower Lake Creek were based on analysis of flow records from the USGS and Project operations. The level of certainty in changes to peak flows is high. Based on the full inventory of large wood in lower Lake Creek during 2005, the level of certainty in the statement that the majority of wood is from local sources is high. The level of certainty that additional structure would help retain gravel in the lower mile of Lake Creek is high based on new deposits of gravel behind newly downed wood below the highway bridge (with a fresh redd) in the 2007 inventory. The level of certainty that flows high enough to transport gravel through Reaches 2, 3, and 4 would also move gravel through Reach 1 with the current low amount of structure is moderate. The USDA Forest Service has requested additional testing of painted gravel sites in Reach 1; this study is underway.

**Additional Comments**

Spawner surveys conducted by EES Consulting for Energy Northwest indicated that the spawning habitat for anadromous salmonids below the barrier at RM 1.03 is fully seeded. Coho salmon were observed many times over the 2004 - 2006 period. Spawning in the same locations, without expanding the utilized areas' superimposition of redds appeared to be occurring. This indicates that the spawning habitat that currently exists in the lower reach of Lake Creek is fully seeded.

Effects of Lake Creek flows on instream amphibians are discussed in Section 4.2.5.

### 4.2.3 Instream Flows Issue #2 – Adequacy of Flows for Stream Dwelling Fish

**Inputs**

Hydrology

**Project Effects**

Reduced flow in lower Lake Creek

**Non-Project Effects**

None.

**Affected Resources**

- Spawning and rearing habitat (anadromous and resident)
- Spawning and rearing fish populations (anadromous and resident)
- Macroinvertebrates
- Water quantity

**Hypotheses**

Mean annual flow in Lake Creek, as measured below the lake outlet (USGS Gage No. 14225500) was approximately 100 cfs, ranging from a low of 56.5 cfs in WY 1941 to a high of 135.6 cfs in WY 1921. September and October tend to be the driest months, averaging 55.9 and 62.8 cfs respectively. The lowest mean monthly flow during this period was 21.5 cfs in November 1936, while the wettest month during this period was 364.5 cfs in December 1933. The lowest daily flows recorded were 18 cfs, measured from Octber 27 – December 2, 1952. Since the Project has been constructed and operated, the release flows have been approximately 3 cfs (excluding special releases and spill events). This reduction in natural flows has reduced the depths and velocities of habitats available to resident and anadromous fish and benthic macroinvertebrates, thereby reducing the amount of available habitat.

**Most Scientifically Viable Hypotheses**

The reduction in flows has reduced the wetted area and altered depths and velocities of habitats available to resident and anadromous fish, benthic macroinvertebrates, and stream-dwelling amphibians. Different reaches possess different physical characteristics, which favor some species and life stages over others. Decreased flows in lower Lake Creek alter the physical habitat available for amphibians and both resident and anadromous fish.

**Summary Statement and Documentation**

Base flows at the drop structure have been reduced to approximately 3 cfs since the Project has been constructed and operated. Accretion downstream of the drop structure can increase the flow in lower Lake Creek appreciably, depending upon the season. The Cowlitz River projects, located on the mainstem Cowlitz River downstream of the Packwood Lake Project, prevented anadromous fish from gaining access to the upper Cowlitz River, including Lake Creek. Prior to reintroduction, only resident fish could utilize the upper watershed. Now runs of Chinook and coho salmon and steelhead trout, all listed under the Endangered Species Act, are being reintroduced. Flow requirements for spawning and rearing vary species by species, with anadromous fish generally requiring higher depths and velocities than resident fish.

A physical habitat survey of Lake Creek from the drop structure downstream to its confluence with the Cowlitz River was conducted in 2004 (EES Consulting 2005a). An instream flow study was also conducted for anadromous and resident fish surveys to document the distribution and timing of species and life stages within Lake Creek (EES Consulting 2007d). Anadromous barriers were identified and additional inflow from the drop structure down to Lake Creek was also calculated.

Through the studies conducted and agency consultation, it was determined that Chinook and coho salmon and sea-run cutthroat trout could migrate up Lake Creek as far as RM 1.03, where a chute/falls complex blocks access. Steelhead trout adults could migrate as far as RM 1.95 where a 25 ft falls complex prevents their continuing upstream (EES Consulting 2006d). Resident rainbow trout are found throughout lower Lake Creek. Anadromous fish are represented by IFIM study sites 1 and 2, while resident rainbow trout were modeled at all 4 study sites. Adequacy of flows for fish and amphibians, is addressed in Section 4.2.5.

<u>Fish Spawning Habitat</u>: Spawning habitat for both anadromous and resident fish in Lake Creek is scarce; it is defined as the area (in square feet) where the combination of suitable spawning-sized substrates, and water depths and velocities that anadromous and resident fish prefer for spawning and depositing eggs in redds is present. Figure 12 shows that for the month of June steelhead trout spawning Weighted Usable Area (WUA) is maximized at a release flow of 25 cfs, while rainbow trout spawning is maximized at a release flow of 35 cfs. Spawning habitat in Lake Creek, however, is extremely limited, and comprises on average less than 1% of the total habitat available (Figure 13; Table 4). WUA is calculated as the number of square feet of habitat per 1000 linear feet of stream. For

example, rainbow trout spawning is maximized at a value of 263 $ft^2$/1000 ft of stream at a flow of 35 cfs. One way to evaluate this is to imagine a strip of good habitat 0.263 ft wide (or about 3 inches) that extends up and down entire length of Lake Creek from the drop structure to its confluence with the Cowlitz River. The average wetted width of Lake Creek under the scenarios modeled for June is 23.93 feet; therefore, spawning habitat for rainbow trout comprises 1.1% of the total habitat. It is extremely important, however, to note that WUA is an INDEX of habitat suitability; a maximum WUA value could comprise a small amount of very suitable habitat, a larger amount of very marginal habitat, or sometimes a combination of both.

The IFIM is a tool to evaluate different scenarios and evaluates changes in habitat quantity and quality under different flow regimes. It is not intended to be a model to evaluate how fish populations respond to these changes in habitat.

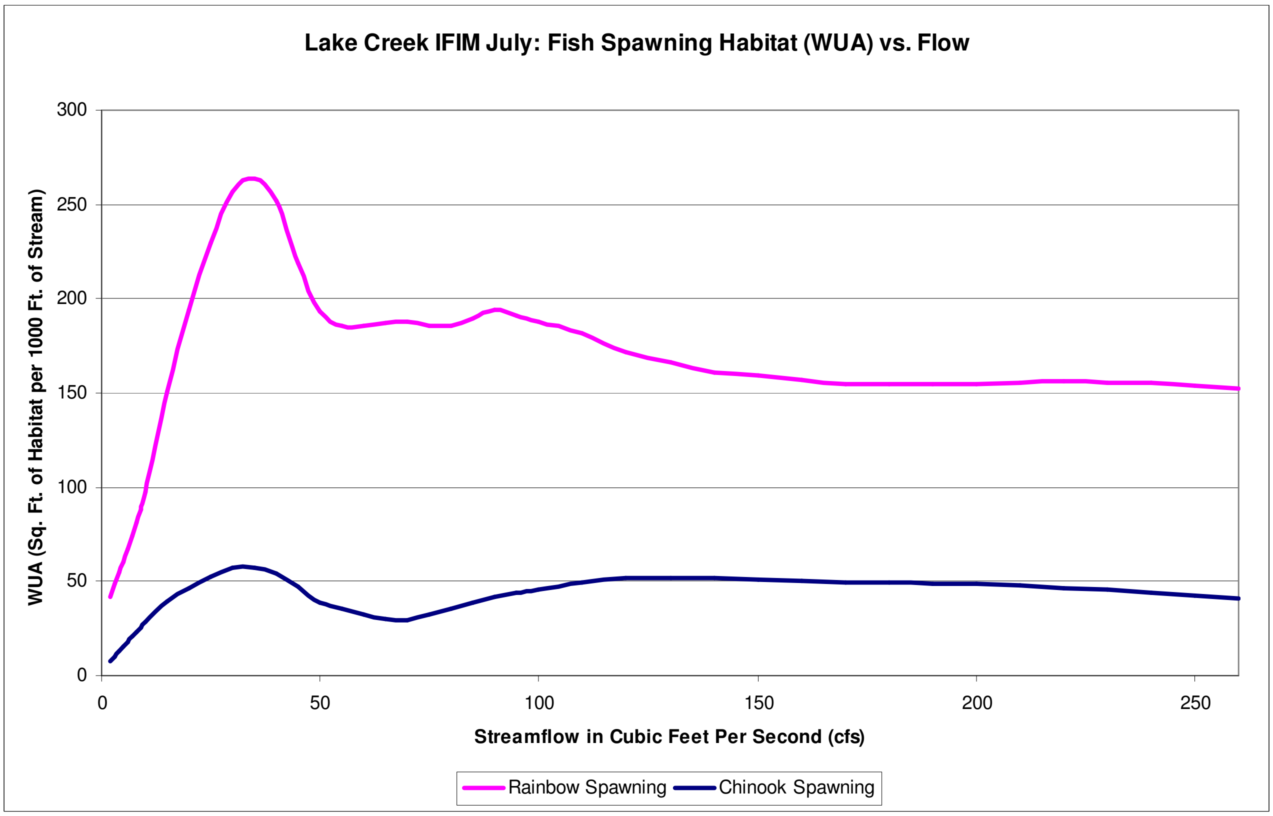


**Figure 12. Lake Creek Spawning WUA spawning for July, with flows as released from the drop structure.**

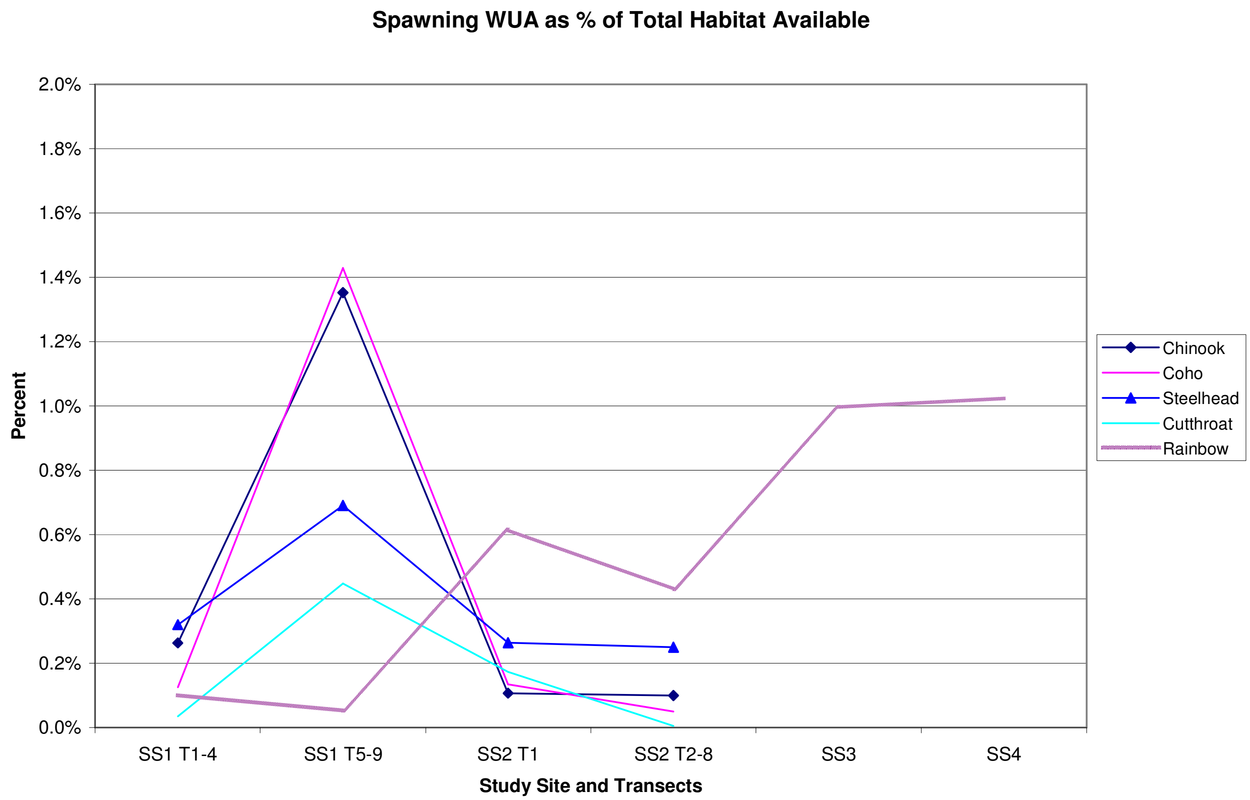


**Figure 13. Spawning habitat for salmon and trout in Lake Creek study reaches as a percentage of total habitat.**

**Table 4. Salmon and trout spawning WUA as a percentage of total available habitat per study site and transects.**

| Study Site | Transects | Statistic | Chinook | Coho | Steelhead | Cutthroat | Rainbow |
|---|---|---|---|---|---|---|---|
| 1 | 1-4 | Mean | 0.3% | 0.1% | 0.3% | 0.0% | 0.1% |
| | | Maximum | 2.0% | 1.2% | 1.9% | 1.0% | 1.1% |
| 1 | 5-9 | Mean | 1.4% | 1.4% | 0.7% | 0.4% | 0.1% |
| | | Maximum | 1.9% | 4.0% | 0.9% | 0.7% | 0.2% |
| 2 | 1 | Mean | 0.1% | 0.1% | 0.3% | 0.2% | 0.6% |
| | | Maximum | 0.3% | 0.3% | 0.7% | 0.3% | 1.2% |
| 2 | 2-8 | Mean | 0.1% | 0.0% | 0.2% | 0.0% | 0.4% |
| | | Maximum | 0.1% | 0.2% | 0.2% | 0.0% | 0.6% |
| 3 | 1-6 | Mean | N/A | N/A | N/A | N/A | 1.0% |
| | | Maximum | N/A | N/A | N/A | N/A | 2.9% |
| 4 | 1-11 | Mean | N/A | N/A | N/A | N/A | 1.0% |
| | | Maximum | N/A | N/A | N/A | N/A | 2.1% |

Salmon and Trout Rearing Habitat: Figure 14 (from Figure 5.2-13 of the Lake Creek Instream Flow report) shows rearing habitat for salmon and steelhead in Lake Creek during July. Different species and life stages prefer various depths and velocities; as a result, maximum WUA rarely coincides at the same flow for all species. Rainbow trout prefer greater depths and velocities, and its habitat units are maximized at a flow of 200 cfs; coho juveniles, however, prefer less depths and velocities, and its habitat is maximized at 2 cfs. Other species have life history requirements where depths and velocities are met over a wider range of flows (e.g., Chinook salmon, where WUA is maximized at 160 cfs, but habitat is fairly steady from 25 cfs to 260 cfs).

Rearing habitat is also limited in Lake Creek for anadromous and resident salmonids. Table 5 summarizes rearing WUA as a percentage of total available habitat. Transects 5 – 9 of Study Site 1 has the most habitat per unit, while lower Study Site 2 had the lowest amount of habitat per unit. Figure 15 depicts rearing habitat as a percentage of total habitat available.

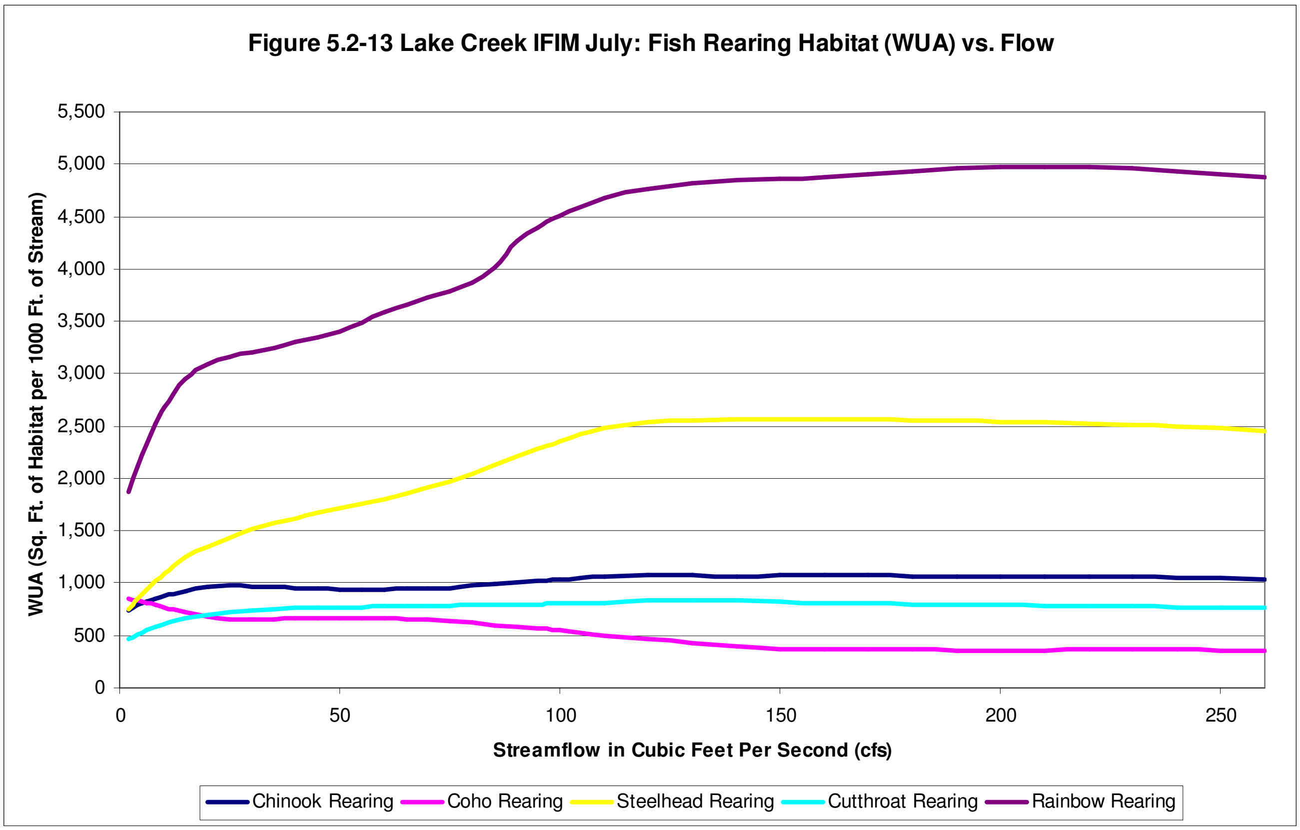


**Figure 14. Lake Creek salmon and trout rearing WUA for July with flows as released from the drop structure.**

**Table 5. Salmon and trout rearing WUA as a percentage of total available habitat per study site and transects.**

| Study Site | Transects | Statistic | Chinook | Coho | Steelhead | Cutthroat | Rainbow | W Rearing |
|---|---|---|---|---|---|---|---|---|
| 1 | 1-4 | Mean | 12.0% | 7.4% | 15.3% | 9.4% | 10.1% | 15.1% |
| | | Maximum | 18.0% | 20.7% | 19.7% | 12.5% | 13.3% | 52.5% |
| 1 | 5-9 | Mean | 27.7% | 12.5% | 26.1% | 20.5% | 21.0% | 21.5% |
| | | Maximum | 33.1% | 31.6% | 33.1% | 22.9% | 26.2% | 62.8% |
| 2 | 1 | Mean | 1.0% | 1.1% | 3.4% | 0.7% | 5.8% | 18.4% |
| | | Maximum | 2.7% | 3.6% | 6.7% | 1.8% | 14.7% | 79.8% |
| 2 | 2-8 | Mean | 2.4% | 1.1% | 11.3% | 1.8% | 18.3% | 13.8% |
| | | Maximum | 3.0% | 3.6% | 13.6% | 2.4% | 21.8% | 57.2% |
| 3 | 1-6 | Mean | N/A | N/A | N/A | N/A | 12.5% | 14.8% |
| | | Maximum | N/A | N/A | N/A | N/A | 13.7% | 51.5% |
| 4 | 1-11 | Mean | N/A | N/A | N/A | N/A | 16.5% | 23.5% |
| | | Maximum | N/A | N/A | N/A | N/A | 19.3% | 55.7% |


**Figure 15. Lake Creek rearing WUA as a percentage of total habitat available in Lake Creek at the various study sites and transects.**

**Level of Certainty**

The level of certainty is high. It is supported by multiple years of quantified data.

**Additional Comments**

We anticipate further analysis of the data that was collected will integrate spawning and rearing needs of salmon and trout with amphibians and other considerations. Analysis of WUA is often complex, and needs to consider:

- Location of habitat along transects and within reaches
- Target species and life history stage needs
- Methods to integrate competing needs of various life stages
- Examination of limiting factors for fish habitat.

Figure 16 shows species and life history periodicity for anadromous and resident fish found in Lake Creek. Figure 17 shows species and life history periodicity for amphibians. Table 5 shows agreed upon distribution of fish and amphibians in lower Lake Creek.

Various anadromous and resident species at certain life stages may favor reduced flows. It is important to note that there can be a difference between maximum and optimum WUA values. WUA is calculated as the sum of all the values for each cell over the study at a given flow, for a particular life stage. WUA values can be misleading; for example, a large amount of WUA can be the result of a small amount of high quality habitat, or a large amount of marginal, poor quality habitat. Often, habitat, particularly for rearing fish, increases with flow, since it “moves” to the outer margin of the stream as the thalweg often becomes too deep and fast for certain species. These flows can often be higher than the natural hydrograph. Another common occurrence is to have habitat, particularly spawning habitat, located on the margins of the stream, where the risks of impacts from any reductions in flow are greater.

**Lake Creek Fish Periodicity**

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

Based on:

John Serl, WDFW Fish Biologist, Cowlitz Falls (May 10, 2007)

**Key:**

Black indicates periods of heaviest use

Grey indicates periods of moderate use

Blank areas indicate periods of little or no use

**Figure 16. Lake Creek Fish Periodicity**

| Lake Creek Amphibian Periodicity | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species** | **Lifestage** | **Oct** | **Nov** | **Dec** | **Jan** | **Feb** | **Mar** | **April** | **May** | **June** | **July** | **Aug** | **Sept** |
| **Giant Salamander** | Eggs | ■ | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| | Larvae | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| **Coastal Tailed Frog** | Eggs | | | | | | | | ■ | ■ | ■ | ■ | ■ |
| | Larvae | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| **Cascade Torrent Salamander** | Eggs | ■ | ■ | ■ | | | | ■ | ■ | ■ | ■ | ■ | ■ |

<u>Based on:</u> S. Nyman, DTA (05/24/07); M. Hayes, WDFW (05/25/07)
Black indicates periods of heaviest use
Blank areas indicate periods of little or no use

**Figure 17. Lake Creek Amphibian Periodicity**

### 4.2.4 Water Quality Issue 1 - Water Temperature in Lake Creek

**Inputs**

Hydrology

**Project Effects**

Reduced stream flow in Lake Creek downstream of Packwood Lake

**Non-Project Effects**

Localized reduction in riparian canopy along Lake Creek near its mouth due to residential development

**Affected Resources**

- Resident and anadromous fish
- Macroinvertebrates
- Amphibians
- Water quality

**Hypotheses**

Reduced stream flows in lower Lake Creek results in summer water temperatures within lower Lake Creek that are lower than would occur naturally without the Project.

**Most Scientifically Viable Hypothesis**

Reduced stream flows in lower Lake Creek result in summer water temperatures within lower Lake Creek that are lower than would occur naturally without the Project due to the high proportion of groundwater. As a result, the longitudinal extent of warmwater-tolerant macroinvertebrate taxa is shortened. The resulting cooler water temperatures are preferential for fish species (resident and anadromous) pertinent to lower Lake Creek.

**Summary Statement and Documentation**

Streamflow in lower Lake Creek is derived from the 3 cfs release flow at the drop structure plus accretion within the lower Lake Creek drainage. Water temperature was monitored at three locations in lower Lake Creek (EES Consulting 2006a and EES Consulting 2007e). Table 6 and Table 7 provide a summary of monthly temperatures for lower Lake Creek for 2004 and 2005, respectively. Water quality standards for temperature focus on summer maximum temperatures. Summer water temperatures decline in a downstream direction within Lake Creek. While the water temperature immediately downstream of the lake commonly exceeds the State water temperature criteria, the water temperature near the mouth never exceeded the criteria. The number of days in 2005 that the water temperature criterion of 16°C was exceeded is 77, 62 and 0 days for LCDS, LCDS1500 and LCMH, respectively. A similar pattern was observed in 2004.

**Table 6 Monthly temperatures for lower Lake Creek 2004**

| | May | | | June | | | July | | | August | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Site Code** | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min |
| **LCDS** | 11.19 | 10.29 | 9.27 | 13.08 | 11.85 | 10.66 | 18.08 | 17.27 | 16.21 | 19.50 | 18.63 | 17.92 |
| **LCDS 1500** | | | | 15.19[1] | 13.9[1] | 12.87[1] | 17.46 | 16.44 | 15.60 | 18.50 | 17.74 | 17.11 |
| **LCMH** | 9.12 | 8.41 | 7.79 | 10.76 | 9.81 | 8.97 | 13.19 | 12.24 | 11.36 | 13.44 | 12.74 | 12.09 |
| **CRULC** | 7.25 | 6.21 | 5.34 | 9.83 | 8.39 | 7.14 | 13.46 | 11.42 | 10.07 | 14.00 | 11.70 | 10.39 |
| | **September** | | | **October** | | | **November** | | | | | |
| | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | | | |
| **LCDS** | 14.84 | 14.18 | 13.58 | 12.03 | 11.72 | 11.41 | | | | | | |
| **LCDS 1500** | 14.08 | 13.56 | 13.04 | 11.62 | 11.31 | 10.99 | | | | | | |
| **LCMH** | 10.78 | 10.38 | 10.15 | 8.78 | 8.42 | 8.04 | 6.48 | 6.08 | 5.70 | | | |
| **CRULC** | | | | | | | | | | | | |

[1]Partial month 6/25/04 – 6/30/04

**Table 7. Monthly Temperatures for Lower Lake Creek, 2005**

| | April | | | May | | | June | | | July | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Site Code** | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min |
| **LCDS** | 6.91 | 6.15 | 5.48 | 11.19 | 10.29 | 9.27 | 13.08 | 11.85 | 10.66 | 18.08 | 17.27 | 16.21 |
| **LCDS 1500** | 8.71* | 7.85* | 7.07* | | | | 15.19 | 13.90 | 12.87 | 17.46 | 16.44 | 15.60 |
| **LCMH** | 7.32 | 6.68 | 6.08 | 9.12 | 8.41 | 7.79 | 10.76 | 9.81 | 8.97 | 13.19 | 12.24 | 11.36 |
| **CRULC** | 6.33 | 5.48 | 4.74 | 7.25 | 6.21 | 5.34 | 9.83 | 8.39 | 7.14 | 13.46 | 11.42 | 10.07 |
| | **August** | | | **September** | | | **October** | | | **November** | | |
| | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | | | |
| **LCDS** | 19.50 | 18.63 | 17.92 | 14.84 | 14.18 | 13.58 | 12.03 | 11.72 | 11.41 | | | |
| **LCDS 1500** | 18.50 | 17.74 | 17.11 | 14.08 | 13.56 | 13.04 | 11.62 | 11.31 | 10.99 | | | |
| **LCMH** | 13.44 | 12.74 | 12.09 | 10.78 | 10.38 | 10.15 | 8.78 | 8.42 | 8.04 | 6.48 | 6.08 | 5.70 |
| **CRULC** | 14.00 | 11.70 | 10.39 | | | | | | | | | |

*Partial month

Immediately downstream of the drop structure (LCDS), the water temperature is a function of the lake temperatures at the intake. Whereas, water temperatures near the mouth of Lake Creek are primarily a function of groundwater accretion. For the period July through October, the average maximum daily water temperature declines 1°C within approximately 1,500 ft downstream of the drop structure. This decline is attributed to the water temperature responding to ambient conditions within the channel; riparian shade is high relative to the lake and some cold groundwater inflow is assumed. Figure 18 shows the trend for the 7-day average of the maximum daily temperature (7-DADMax) for Lake Creek downstream of the drop structure.

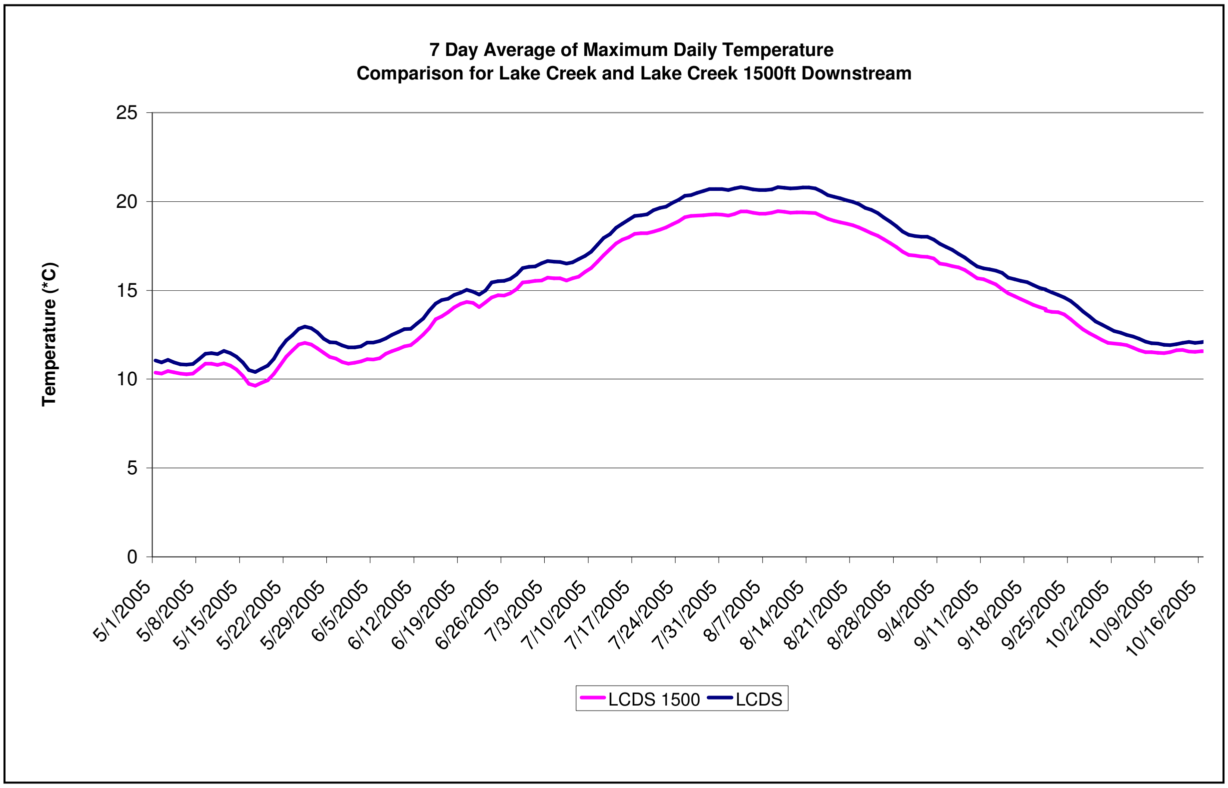


**Figure 18. 7-Day average of maximum daily temperature (7-DADMax) for Lake Creek below the drop structure**

The natural pre-Project streamflow from Packwood Lake in August is approximately 77 cfs (period of record 1912 – 1962). The 7Q2 and 7Q10 August low flow is 56.4 cfs and 39.9 cfs, respectively. The downstream water temperature in Lake Creek associated with this flow volume out of the lake is considerably warmer than temperatures occurring with Project flow diversion.

Lower temperatures in Lake Creek associated with Project operation may affect amphibians living within the stream, coastal giant salamander and coastal tailed frog. Growth and development rates of amphibian embryonic and larval stages are directly and positively related to temperature, provided that temperatures are within tolerances. Recorded temperatures within Lake Creek are well within tolerance and are comparable to temperatures normally experienced by these species at other locations in their ranges, which extend to high elevation sites (coastal giant salamander to 6,000 ft and coastal tailed frog to 7,000 ft). Under experimental conditions deVlaming and Bury (1970) determined that tailed frog larvae selected temperatures below 22$^{o}$ C, with first-year larvae actually selecting temperatures below 10$^{o}$ C.

Table 8 shows effects of temperature on fish in the rearing and spawning life history stages (from Bell 1990).

**Table 8. Effects of Temperature on Fish (Bell 1990)**

| Life History Stage | Species | | Preferred | | |
|---|---|---|---|---|---|
| | | Lower Lethal | Lower | Upper | Upper Lethal |
| Rearing | Chinook | 0.0 | 1.1 | 14.4 | 25.0 |
| | Coho | 0.0 | 3.3 | 20.6 | 25.6 |
| | Steelhead/Rainbow | 7.2 | 7.2 | 14.4 | 23.9 |
| | Cutthroat | 0.6 | 9.4 | 12.8 | 22.8 |
| Spawning | Chinook | 0.0 | 5.6 | 10.6[1/] | |
| | Coho | | 4.4 | 9.4 | |
| | Steelhead/Rainbow | | 3.9 | 9.4 | |
| | Cutthroat | | 6.1 | 17.2 | |

[1/] Upper Threshold

Temperatures at the drop structure exceed the preferred temperatures of most of the resident fish and anadromous salmonids found in Lake Creek; however, these temperatures are below the upper lethal temperatures for these species. Cooler temperatures downstream of the drop structure are beneficial to those species found in Lake Creek.

The macroinvertebrate population in lower Lake Creek was sampled at multiple points along the stream. Methods and results for the macroinvertebrate study are reported in EES Consulting (2006c). Reduced flow out of Packwood Lake has the effect of shortening the stream length populated by tolerant macroinvertebrate taxa. The reduced streamflow does favor feeding groups that are dependent upon fine particulate organic matter and negatively effected by filamentous algae. These effects only extend a short distance downstream of the drop structure. Natural mean monthly inflow from Packwood Lake for August through October ranges from 71 cfs to 56 cfs. The Project releases 3 cfs just downstream of Packwood Lake. The natural flow would have the effect of extending the length of channel with warm water temperatures. Total taxa richness in downstream reaches, particularly Plecoptera and Ephemeroptera, would likely be lower without the Project. The proportion of warmwater Trichoptera taxa would be greater than the mix of cold and warm water taxa that now occur in reach 4 and further downstream. The aquatic invertebrate community characteristic of Reach 5 that had higher tolerant taxa richness would extend further downstream.

### Level of Certainty

The level of certainty is high. Two years of temperature data as well as temperature modeling support the conclusion. Macroinvertebrates were inventoried and biotic indices quantified.

### 4.2.5 Flow Effects on Lake Creek Amphibians

**Inputs**
- Hydrology
- Sediment
- LWD

**Project Effects**

The magnitude and timing of average monthly base flows, and the magnitude and timing of peak flows.

**Non-Project Effects**

None

**Affected Resources**

Amphibians residing in lower Lake Creek or reliant on streamside habitats that could be affected by stream flows (e.g., splash zones).

**Hypotheses**

(1) Amphibian habitat quality and availability may be altered by Project-related flows in Lake Creek. Effects are manifested through one or more of the following (effects may be inter-related): average monthly base flows, peak flows, or rate of change associated with peak flow events.

(2) Instream amphibians utilize microhabitats at flows that are appropriate to the species and life stage (e.g., flows that safely permit foraging activities); that support or deliver food organisms (primarily macroinvertebrates and diatoms, organisms that may be smothered by excessive siltation); and maintain interstitial spaces in substrates (necessary to hide from predators and retreat during unfavorable flow periods).

(3) Instream amphibians are supported by current Project operational conditions: minimum flows are sufficient; periodic high flow events occur that move silt and other fine sediments that might otherwise clog substrate interstices and smother food organisms.

(4) Streamside-specialist amphibian species probably do not occur along lower Lake Creek, but regardless, the diminishment of splash zones does not affect areas that are otherwise highly suitable for streamside amphibians.

(5) The rate of change of flows associated with peak events may affect amphibians; however, the magnitude, rate of change in flows, or frequency of peak events is not increased by the Project under normal operating conditions.

**Most Scientifically Viable Hypothesis**

Instream amphibians are supported by current Project operational conditions: minimum flows are sufficient; and reduction in periodic high flow events that move silt and other fine sediments that might otherwise clog the interstices of coarse substrates and smother food organisms. Rate of stage change may affect instream amphibians; however, the magnitude, rate and frequency of events where the rate of change is rapid are not increased by the Project under normal operating conditions. Streamside-specialist amphibians probably do not occur along lower Lake Creek; however, if these species are present, the suitability of their preferred splash zone habitats is not governed by flow characteristics because other requisite habitat features are lacking.

**Summary Statement and Documentation**

Two species of amphibians were documented in and are reliant on flowing water habitats of lower Lake Creek, coastal giant salamander[2] (*Dicamptodon tenebrosus*) and coastal tailed frog (*Ascaphus truei*). Coastal giant salamanders were found in a variety of habitats, including pools, runs, and riffles, in Reach 2, 3, 4, and 5. Observations were most numerous in areas where side channels or stepping creates small pools. Habitat limitation due to sand-embedded substrates was apparent at some sites, but was limited in extent (e.g., occurring in areas at low gradient or downstream of sediment sources). A preponderance of coarse substrates was documented in the Lake Creek Physical Habitat Assessment Survey (EESC 2005a), and the Lake Creek Gravel Transport Study (Watershed GeoDynamics 2007a).

Coastal tailed frogs were also observed in Reach 2, 3, 4, and 5. Because most of the observations were of adults or sub-adults, it is not known whether larvae have a similar or more localized pattern of distribution (evidence for a patchy distribution of larvae within streams is presented by Diller and Wallace 1999, and Hayes et al. 2006)[3]. Larval coastal tailed frogs tend to favor higher stream gradients and areas of faster flow velocity than those used by coastal giant salamanders (Parker 1991, Diller and Wallace 1999). In streams smaller than Lake Creek, Wahbe and Bunnell (2003) found the majority (66 percent) of larvae in runs, with the rest in pools and riffles. Surveys by Diller and Wallace (1999) showed that larvae occupied high gradient riffles more than other microhabitats, and were most frequently associated with cobble or gravel substrates, a low degree of substrate embeddedness, and low percentage of fine sediments. Coastal tailed frog larvae in Lake Creek might be affected if flows were insufficient to move fine sediments, resulting in embedded substrates or preventing diatoms (primary food for tailed frog larvae) from growing on substrates. As discussed for coastal giant salamander, areas with embedded substrates were noted, but are not prevalent.

Existing habitats of lower Lake Creek appear to be highly suitable for both instream amphibian species. Current flow regimes are evidently maintaining these habitats, and an adverse Project effect is not supported.

Instream amphibians are periodically exposed to higher than average flows resulting from precipitation events and snowmelt. During periods of high flow, aquatic amphibians move under sheltering substrates, but are liable to be swept downstream when flows are sufficient to move coarse substrates. Flood-induced reduction of a larval tailed frog

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[2] A related species, Cope's giant salamander was not documented on the basis of morphological characteristics, but could nevertheless be present. If this species does occur in lower Lake Creek, habitat use patterns should be similar to those expected for coastal giant salamander.

[3] Adult coastal tailed frogs in amplexus were found at locations near the mouths of small tributaries in Reach 3. Possibly the females would later lay eggs in the vicinity of these sites. However, because female tailed frogs reportedly store sperm for a year before laying fertilized eggs, these females might have subsequently moved to another part of the stream to oviposit.

population in an unregulated stream has been reported (Metter 1968). High flow events occur periodically on lower Lake Creek and are important in maintaining fluvial processes, such as sediment transport. High flow events are overwhelmingly controlled by inflow coming from precipitation and/or snow melt. The Project does not increase the incidence of high flow events, which occur when inflow exceeds the storage and bypass capacity of the system. The magnitude and rate of stage increase during high flow events is beyond the control of the Project. If the Project is not operating at full capacity, the Project could increase power production to reduce flows going over the drop structure; however, the controlling factor for stage change and overtopping events remains inflow.

Two species of streamside specialist amphibians potentially occur along lower Lake Creek: Van Dyke's salamander and Cascade torrent salamander. Neither species was found during the amphibian survey, which targeted perennial tributaries, seeps, waterfall splash zones, talus slopes, and cliffs with seeps. These survey results, together with habitat patterns that do not closely match reported habitat requirements of either species (e.g., Jones 1999, McIntyre 2003, Jones et al. 2005) suggest that the species do not occur. However, if either species occurs, there is the potential for flow effects from Project operations (e.g., diminishment of splash zones).

Potential habitats for streamside amphibians along Lake Creek are concentrated within splash zones associated with several waterfalls, chutes, and cascades; rocky tributaries; and seeps. The waterfalls, chutes, and cascades mostly occur in areas of bedrock or steep-gradient boulder-dominated sections; accumulations of loose rocks that could be used as cover by streamside amphibians are infrequent within associated splash zones and adjacent areas that might be enveloped by splash at higher flows, and the bedrock did not exhibit deep fracturing that could provide hiding areas and retreats when surface conditions are unfavorable. Flow within tributaries and seeps are not affected by the Project. Based on these observations, a Project effect is unlikely.

**Level of Certainty**

The amphibian survey study was not designed to directly assess flow effects on amphibians. Conclusions concerning the adequacy of habitat conditions are not directly testable from available information.

## 4.3 Tailrace

The Project stilling basin collects the generation outflow from the Project and dissipates the flow. Depths fluctuate depending on the level of generation. The stilling basin can reach a depth of approximately 11 ft along the trench that is directly in line with the outflow during high generation events.

The stilling basin empties into the tailrace about 200 ft downstream of the powerhouse. The tailrace channel is trapezoidal in shape, with a width at the top of the asphalt lining of approximately 29 ft and 9 ft at the base. The average depth of the lined part of the tailrace is approximately 5.75 ft. The length of the flume over Hall Creek is 356 ft, and the length of the culvert under U.S. Highway 12 is 200 ft. Outflow discharges can range from a low of 17 cfs to a high of 222 cfs if the plant is at a maximum operating level of 27 megawatts. Figure 19 displays the average daily plant outflow from 2000-2004.

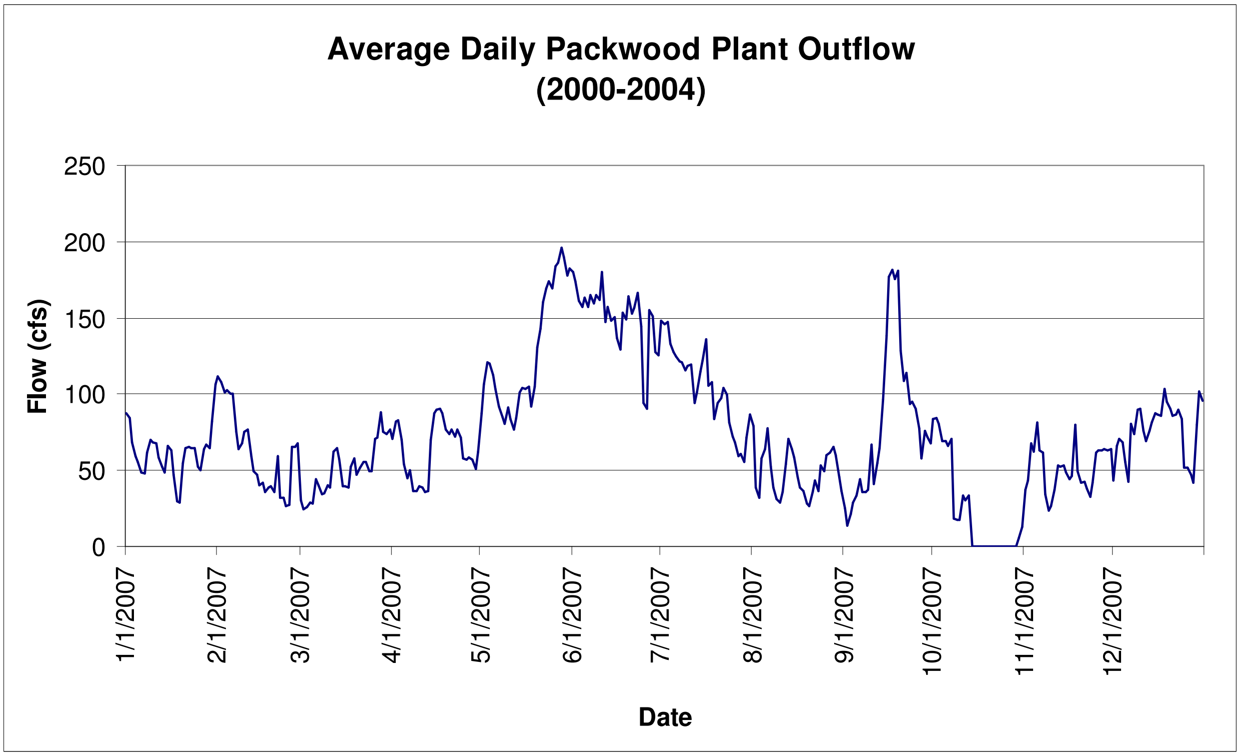


**Figure 19. Average daily plant outflow (2000-2004)**

The original tailrace channel was approximately 8,100 ft in length. A large flood event on the Cowlitz River in 1977 washed out approximately 1,400 ft of the lower end of the tailrace, including the fish screens that prevented fish from entering the tailrace. The tailrace is now approximately 6,690 ft in length and discharges water to a side channel of the Cowlitz River (Butler Surveying 2004). Currently, there is no barrier that prevents upstream migration into the tailrace or stilling basin by either juvenile or adult anadromous fish (both life history stages have been captured in the stilling basin). A permanent barrier will be installed at the end of the tailrace in October 2007. A monitoring plan has been designed to ensure the effectiveness of the barrier after it installed. Prior to installation of the barrier, concerns exist regarding temporary shutdowns in the summer and fall as a result of low-lake levels and maintenance. These shutdowns raise questions regarding: depleted oxygen levels in the tailrace and stilling basin and their detrimental effects on spawning and rearing anadromous salmonids.

Issues for the tailrace area include:

1. Fish Use of Lined Tailrace and Stilling Basin

### 4.3.1 Fish Use of Lined Tailrace and Stilling Basin

**Inputs**

Hydrology

**Project Effects**

Reduced dissolved oxygen within the tailrace stilling basin during temporary Project shutdowns in late summer.

**Non-Project Effects**

None

**Affected Resources**

Spawning, incubating and rearing fish

**Hypotheses**

During summer months when the Project temporarily shuts down and during fall Project shutdown, biological oxygen demand depletes dissolved oxygen levels in the stilling basin. This can stress anadromous fish rearing in the stilling basin and adversely affect survival of incubating spring Chinook eggs.

**Most Scientifically Viable Hypothesis**

During summer months when the Project temporarily shuts down and during fall Project shutdown, biological oxygen demand depletes dissolved oxygen levels in the stilling basin. This can stress anadromous fish rearing in the stilling basin and adversely affect survival of incubating spring Chinook eggs.

**Summary Statement and Documentation**

Water quality in the tailrace stilling basin (upper end of the tailrace; POWT1) was continuously monitored seasonally to assess diurnal trends. A Hydrolab was deployed in the stilling basin for the periods March 17-25, July 14-27, September 29-October 12, October 27 – November 1, 2004. The latter two periods encompassed Project shutdown and startup (EES Consulting 2006a).

When the Project is operating (flow through the tailrace), dissolved oxygen levels showed about 0.5 mg/L or less diurnal variation (Figure 20). The Project was shutdown with no flow through the tailrace stilling basin from October 1, 2005 at 19:15 through October 29 (Figure 21). The diurnal range in dissolved oxygen increased to about 1 mg/L during the first days of shutdown (D.O. range 8.17 – 9.17 mg/L). The diurnal variation in dissolved oxygen within the stilling basin was less towards the end of Project shutdown due to colder temperatures and D.O. levels were above 9 mg/L. After the Project resumed operations in November, there was essentially no diurnal variability in dissolved oxygen.

Both anadromous and resident fish have access up the tailrace to the stilling basin (pool) below the powerhouse. The Project experiences both planned and unplanned shutdowns and outages. During these outages, depending upon initial flow and the length of the outage, there is the potential for fish to be stranded in the stilling basin or the tailrace. Energy Northwest has agreed to install a permanent barrier to fish migration in the tailrace. Until the permanent barrier is installed, Energy Northwest has agreed to implement a Fish Rescue Plan (EES Consulting 2006b). The Fish Rescue Plan provides protocol for seining and transport of fish stranded in the stilling basin and tailrace as well as measures for providing a temporary supplemental flow into the stilling basin. The schedule identified in the Fish Rescue Plan ensures that fish are safely removed before dissolved oxygen levels reach critically low levels. The construction of the permanent barrier will preclude any adverse effect to fish due to low D.O. levels in the stilling basin caused by Project shutdowns. Plans for the permanent barrier include monitoring its effectiveness (EES Consulting 2007f).

**Level of Certainty**

The level of certainty is high. Two years of data support the conclusions.

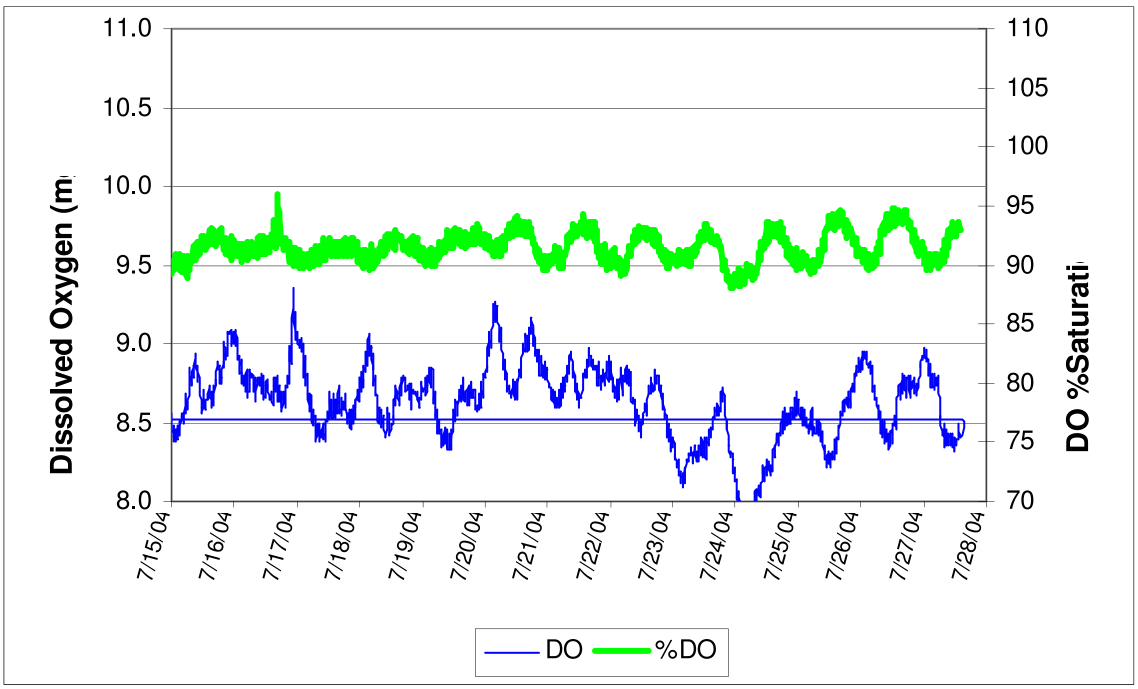


**Figure 20. Dissolved oxygen monitoring for July 2004 in powerhouse stilling basin**

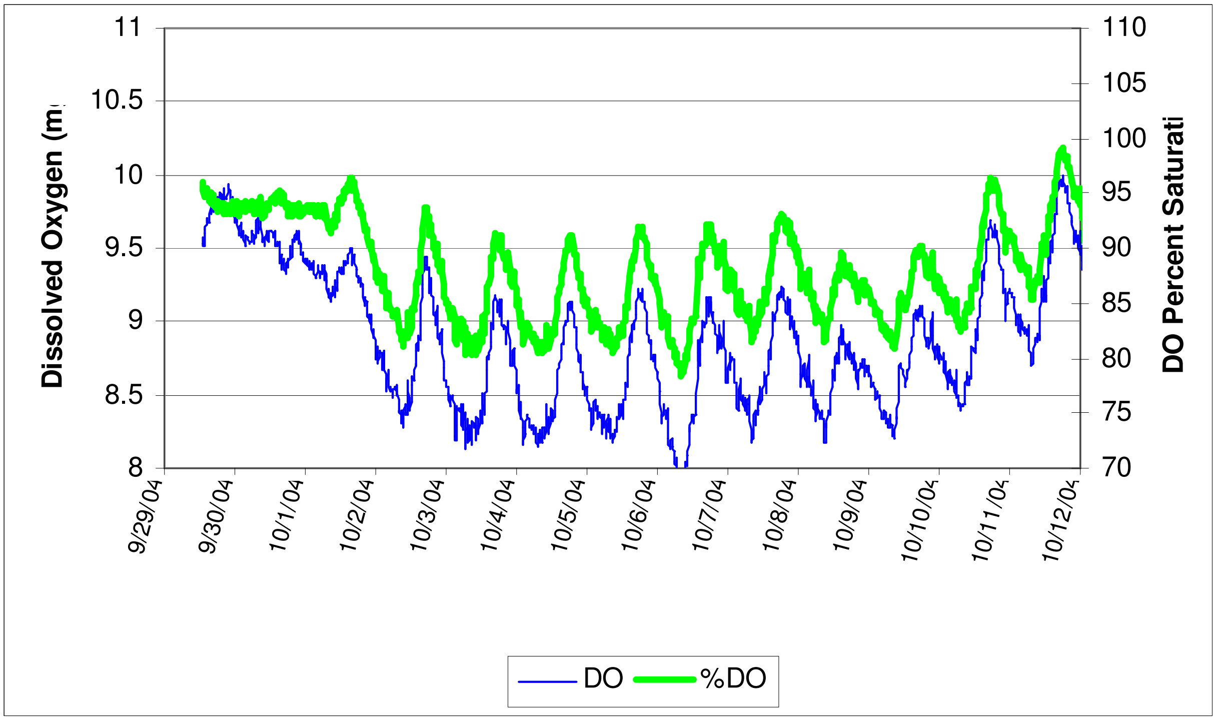


**Figure 21. Dissolved oxygen monitoring for September–October 2004 in powerhouse stilling basin**

## 4.4 Cowlitz River/Tailrace Slough

The water released from the Packwood Lake Hydroelectric Project eventually reaches the Cowlitz River in one of two ways: via Lake Creek or via the Project tailrace. A minimum 3 cfs release flow is continually released into lower Lake Creek at all times. During high flow events, water spills over the drop structure into lower Lake Creek when flows are beyond the capacity of the Project (220 cfs at the intake structure). Water that is used for Project generation is released to the stilling basin and tailrace, and at the terminus of the manmade tailrace, enters a side channel of the Cowlitz River (the tailrace slough).

Extensive water temperature investigations and modeling have been ongoing since 2004 on lower Lake Creek, the tailrace, and the Cowlitz River. The amount of water traveling down the concrete-lined tailrace relative to the natural channel in lower Lake Creek primarily in the summer months raises potential questions regarding:

- Lack of thermal cooling in the tailrace
- Groundwater influence on water temperatures in lower Lake Creek
- Potential increases in water temperatures in the Cowlitz River from tailrace water

The Packwood Lake Hydroelectric Project lined tailrace empties into a side channel and combines with the Cowlitz River. This side channel is dynamic and high-flow events in the Cowlitz River cause it to fluctuate frequently. Flows and water levels in the tailrace slough are also affected by water releases from Project operations. Adult spawners and redds have been observed in the tailrace slough. Thus, it is likely that fish utilizing habitat in the slough are directly impacted by Project operations.

Currently, the waters in the Tailrace Slough area are derived both from the Project and the Cowlitz River, which has re-occupied a side channel that flowed around an island near the mouth of the slough. In 2006, approximately 13% of the Cowlitz River flows were diverted to the Tailrace Slough. Since November 2006, the Tailrace Slough has been reconfigured twice, the percentage of the flows is currently being determined. The fluctuation in project flow and the dynamic nature of the side channel raise potential concerns regarding:

- The effect of Project shutdown on spawning and rearing anadromous salmonids
- The effect of Project shutdown on resident fish species
- Potential alteration of Project shutdown timing and alteration
- Effects of Project operations at the tailrace terminus

Issues for the Tailrace Slough Area include:

1. Tailrace Slough Use by Anadromous Salmonids
2. Water Quality Issue 2 – Temperature
3. Rare plants

### 4.4.1 Tailrace Slough Use by Anadromous Salmonids

**Inputs**

Hydrology

**Project Effects**

The timing of Project shutdown and Project fluctuation of flow in the tailrace.

**Non-Project Effects**

Natural configuration of the tailrace slough as it relates to the Cowlitz River contribution of water.

**Affected Resources**

Spawning, incubating and rearing fish and their habitat.

**Hypotheses**

(1) The tailrace slough is a dynamic complex of various aquatic habitat types that frequently changes during Cowlitz River high flow events. These high flow events typically occur from October thru March and are the main variable affecting spawning and rearing fish and macroinvertebrates.

(2) Flows from the Cowlitz River in the tailrace slough are a result of natural events and fluctuations. Without the Project, fish production in this reach would be subject to the same variation as the rest of the unregulated upper Cowlitz River.

(3) In years when the tailrace slough has been configured in such a way as to be dependent upon Project operations, reduction or cessation in Project flows can impact the following:

(a) the availability of spawning habitats for federally listed species (anadromous stocks) found in the Project area;
(b) eggs deposited in the gravel may be subject to dewatering or desiccation; or
(c) anadromous fish present in the tailrace slough (fry, juvenile, or adult) may be subject to stranding.

**Most Scientifically Viable Hypothesis**

In years when the tailrace slough has been configured in such a way as to be dependent upon Project operations, reduction or cessation in Project flows can impact the following:

1) the availability of spawning habitats for federally listed species (anadromous stocks) found in the Project area;
2) eggs deposited in the gravel may be subject to dewatering or desiccation; or
3) anadromous fish present in the tailrace slough (fry, juvenile, or adult) may be subject to stranding.

**Summary Statement and Documentation**

Water in the tailrace slough is a function of water from the Cowlitz River and tailrace flows. The contribution from the Cowlitz River side channel is highly variable due to the dynamic nature of the river. The contribution from the Project is also variable, based upon Packwood Lake levels and subsequent generation; the Project is also subject to shutdowns. Depending upon high flow activity in the upper Cowlitz River, the tailrace slough flow may either be largely dependent upon the Cowlitz River, Project operations, or both. The potential reduction in habitat through reduced flows during spawning and rearing timing may result in a reduced production potential for resident and anadromous fish.

The entire tailrace slough downstream of the mouth of the Packwood tailrace to its confluence with the mainstem Cowlitz River was surveyed for anadromous spawners twice monthly from July 26, 2004 to July 26, 2006 (EES Consulting 2007c). A total of 34 coho salmon and 57 redds were observed over the two-year period. All but one of the 34 coho and all 57 definite redds were observed during the 2004/2005 season. No Chinook salmon or steelhead trout were observed over the course of the surveys. All spawning fish were observed in the left side channel of the slough (Figure 22). The left side channel possesses the necessary velocities and substrate types for spawning of Chinook, coho and steelhead. For a majority of the 2005/2006 coho salmon spawning period, the water was abnormally high and turbid, making observations of fish and redds difficult. During some of the surveys conducted during the Chinook and coho spawning periods, the left side channel that possesses a majority of the accessible spawning habitat was dry.

The peak number of observations occurred on December 9, 2004 when 14 fish and 45 redds were observed. No carcasses were observed during any of the surveys. It is important to note that a major component of entrance and spawn timing is related to the timing of the trap and haul program. Fish are transported from Barrier Dam to the Skate Creek Road Bridge (Franklin Bridge) and the dates of transport vary depending on return timing of fish downstream of the dam. Table 9 documents all dates when coho and/or their redds were observed.

**Table 9. Packwood Tailrace Slough Spawning Data and Associated Water Temperature Information (2004)**

| Date | Fish Observed | Redds Observed | Mean Daily Water Temperature (°C) |
|---|---|---|---|
| 11/11/04 | 3 | 3 | 7.73 |
| 11/23/04 | 14 | 9 | 7.00 |
| 12/9/04 | 14 | 45 | 5.38 |
| 12/21/04 | 2 | 0 | 4.63 |

Figure 23 documents the cumulative effect of the Cowlitz River and tailrace at a variety of natural and generated flows during the coho spawning and incubation period in the tailrace slough. When a low-flow period for the Cowlitz River and low generation levels for the Project coincide (Figure 24), the resulting lack of water down the side channel has the potential to eliminate quality spawning habitat and dewater incubating eggs. Figure 22 displays the areas of concentrated spawning that have the highest potential for dewatering during low flow scenarios.

On average, the highest likelihood for reduction in spawning habitat and dewatering of incubating eggs occurs between October and February annually. This directly coincides with Chinook and coho spawning and incubation. Depending upon how the tailrace slough has been configured by the Cowlitz River, low flows down the tailrace as a result of low lake levels and a lack of generation capability, may contribute to the overall lack of water in the tailrace slough. The result is a lack of production potential for the anadromous species utilizing the slough for spawning and rearing purposes.

Project flows generally follow Cowlitz River flows, with one notable exception. Project flows in September are higher than would be expected. After September 15, the Project is not required to hold lake elevation to 2857.0 +/- 0.5 ft, and the Project can reduce lake elevations to as low as El 2849.0 ft. The Project typically runs to full capacity after September 15 in order to lower Packwood Lake as much as possible to reduce the likelihood of spills during the annual shutdown. As a result, mean Project flows are much higher in September than would occur if the Project followed normal inflow.

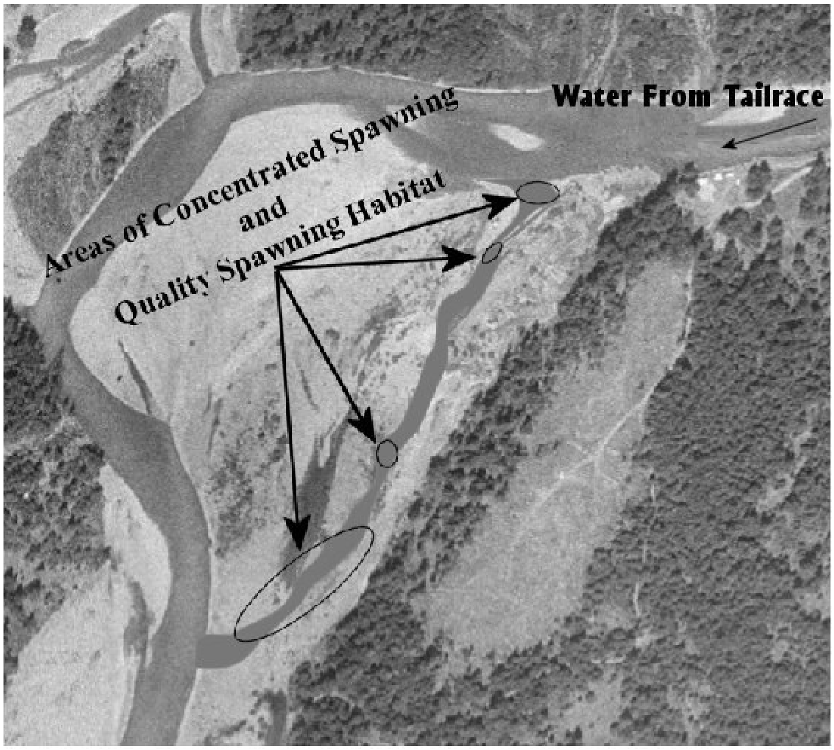


**Figure 22. Areas of Quality Habitat and Documented Spawning in the Packwood Tailrace Side Channel**

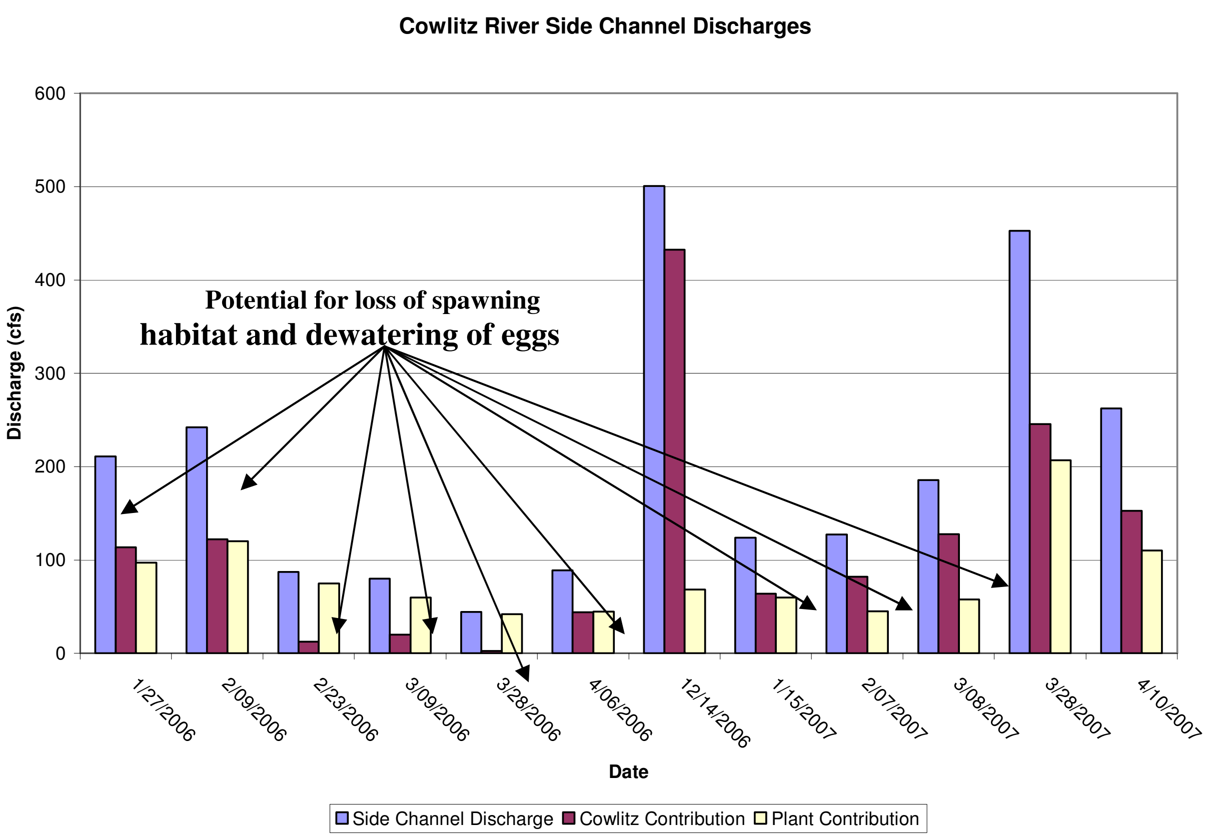


**Figure 23. Cowlitz River side channel discharges (2006-2007)**

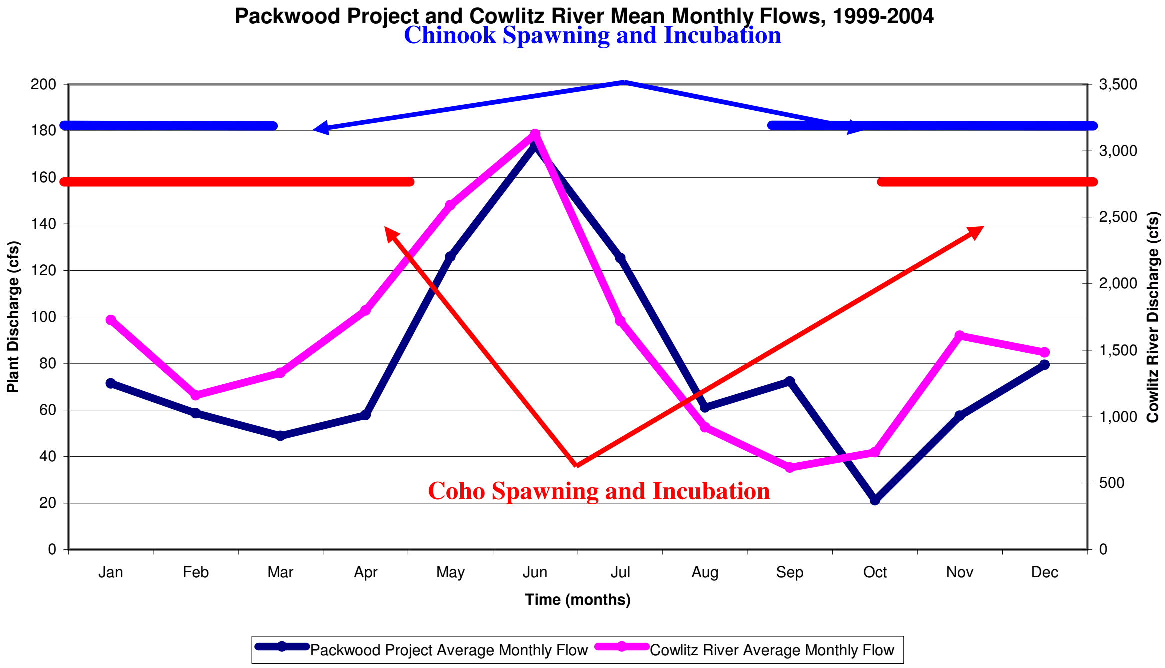


**Figure 24. Mean monthly flows for the Cowlitz River and tailrace (1999-2004)**

Figure 25 depicts the amount of spawnable gravels available in the left channel of the tailrace slough in the vicinity of the Tailrace IFIM (Transects 1 – 4 and 6) for salmon and steelhead. The linear length of habitat represented by this figure is 910 feet.

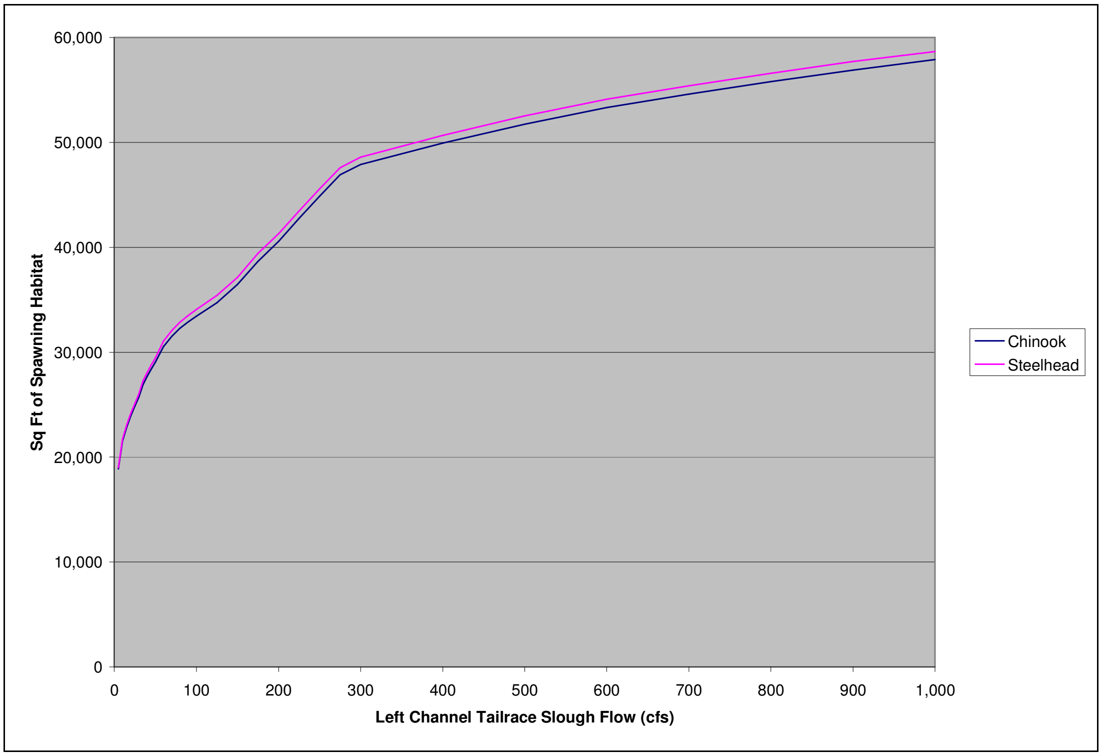


**Figure 25. Amount of salmon and steelhead spawning gravels in left channel of Tailrace Slough (transects 1 – 4 and 6).**

Figure 26 shows the amount of salmon and steelhead spawning gravels at Transect 8, immediately below the tailrace. The length of habitat represented by this figure is 28 feet.

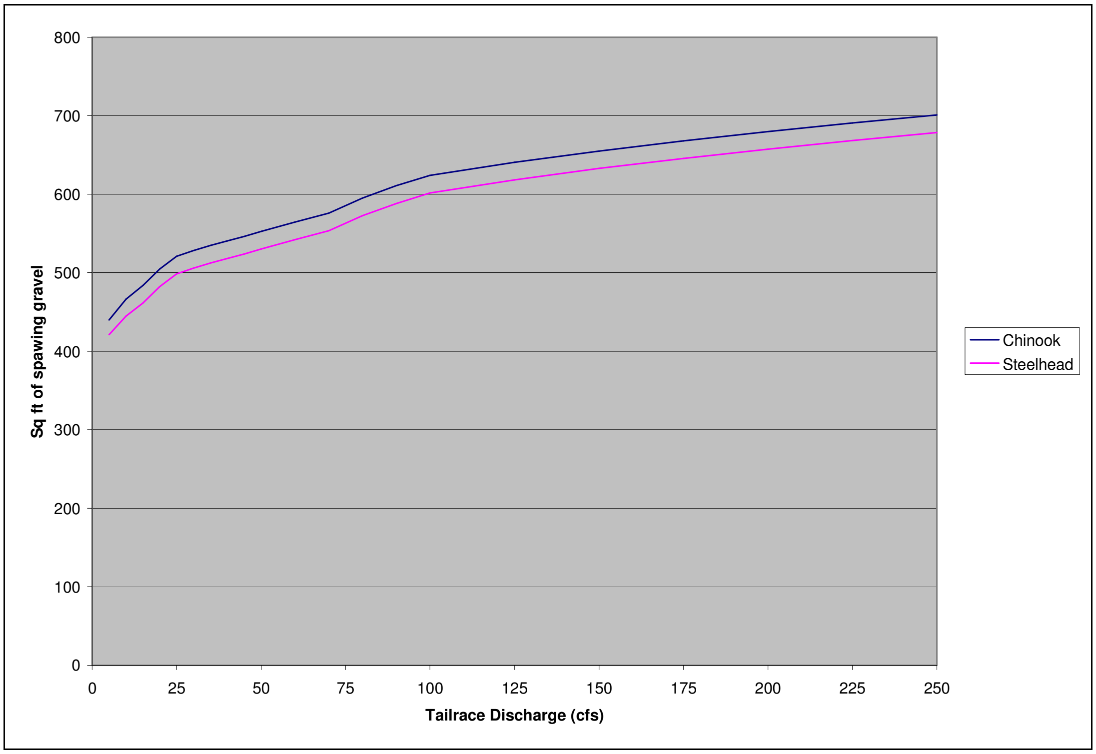


**Figure 26. Amount of salmon and steelhead spawning gravels immediately below the Project tailrace (Transect 8).**

Flow conditions in the tailrace slough can change every year. Since 2004, the tailrace slough configuration has changed 4 times: in the fall 2004; in the fall 2005; in the fall 2006, and in the spring 2007. In 2004, 2006 and 2007, Cowlitz River flows configured the tailrace slough as to make it highly dependent upon the Project in low-flow conditions. In 2005, however, a much larger percentage of the Cowlitz River was diverted into the tailrace slough, and it was not dependent upon the Project at all in the fall.

Whether and how, Project flows may be of benefit to the fish in the tailrace slough depends upon the following:

- The configuration of the Tailrace Slough by the Cowlitz River; in some years, a large enough percentage of the Cowlitz River courses through the Tailrace Slough so that Project flows are not required;
- Project flows, which are dependent upon
  - Instream flow requirement for Lake Creek below the Drop structure;
  - Inflows to Packwood Lake, which affect Packwood Lake elevations and storage requirements
- Flexibility of the Project to adjust the timing of the scheduled maintenance outage

**Level of Certainty**

Level of certainty is moderate. Data may vary from year to year given the dynamic configuration of the tailrace side channel as a whole.

### 4.4.2 Water Quality Issue 2 – Project Effects at the Tailrace Terminus

**Inputs**

- Hydrology
- Temperature (energy)

**Project Effects**

Colder but reduced stream flows in Lake Creek
Surface water from Packwood Lake entering the Cowlitz River at the tailrace terminus

**Non-Project Effects**

Other development within Cowlitz River basin upstream of the tailrace terminus affects water temperature regimes for Cowlitz River. Residential development along the banks of Lake Creek near its mouth locally reduces riparian stand density.

**Affected Resources**

Water quality

**Hypotheses**

(1) Water from Packwood Lake diverted to enter Cowlitz River at the tailrace confluence is not subject to thermal cooling that would occur if the water were routed down a shaded channel in Lake Creek.
(2) The combined net thermal loading from cooler groundwater in Lake Creek and warmer tailrace water results in a net thermal increase to the Cowlitz River during July through mid-September.
(3) Natural flow down Lake Creek does not cool significantly before reaching the Cowlitz River when the effect of groundwater inflow is NOT factored in.
(4) The magnitude of flow from the tailrace during July through mid-September relative to the flow in the Cowlitz River is not large enough to increase temperature in the Cowlitz River more than 0.3°C

**Most Scientifically Viable Hypothesis**

The majority of the outflow from Packwood Lake during summer months is used for power production (a minimum of 3 cfs is released to Lake Creek below the drop structure). The temperature of flow from the lake that is routed through the tailrace remains relatively constant between the lake and the tailrace outlet. A slight cooling would occur if this water were routed down Lake Creek to the Cowlitz River. The net effect on water temperature of the Cowlitz River from the combined flow from Lake Creek and the tailrace during summer months is negligible.

**Summary Statement and Documentation**

The QUAL2kw water quality model developed by Washington Department of Ecology was used to model water temperature in lower Lake Creek. Local climate data were reviewed to identify the median and 90% exceedence values for maximum daily air temperatures at Packwood. Dates within summer 2004 and 2005 were then identified that had climate regimes that approximated the median and 90% exceedence climate values. The model was then used to model water temperatures in lower Lake Creek for these dates. Model scenarios included with the Project (3 cfs release below the drop structure) and without the Project (natural flow in Lake Creek). The greatest potential Project effect would be expected to be associated with a model period that is representative of the 90% exceedence climate data and a 7Q10 low flow in Lake Creek. The measured and model predicted maximum daily water temperature at the mouth of Lake Creek for these conditions is approximately 5$^{o}$C cooler with the Project, since the flow is primarily from cold groundwater accretion. Model results indicated the maximum daily temperature was approximately 2$^{o}$C cooler at the mouth relative to the temperature for outflow from Packwood Lake for the without Project scenario (natural flow).

A weighted average of temperature for the mix of Cowlitz River and Lake Creek flow (weighted by flow) was calculated for both with and without Project. A weighted average temperature was also calculated for the combined Cowlitz River/Lake Creek flow and the tailrace flow. The net Project effect on temperature downstream of the tailrace confluence with the Cowlitz River (not accounting for the slough and assuming instantaneous mixing) was negligible. The total outflow from Packwood Lake in the summer is small relative to the flow in the Cowlitz River. Model results support a conclusion that the net temperature loading to the Cowlitz River due to the Project is neglible. A full description of model approach and results will be included in the report on water quality modeling.

**Level of Certainty**

The level of certainty is high. Two years of temperature and flow data are available to support the finding and modeling was completed.

### 4.4.3 Effects on Rare Plants

**Inputs**

Hydrology

**Project Effects**

Lake Creek and tailrace flows

**Non-Project Effects**

Cowlitz River flow

**Affected Resources**

Oregon goldenaster populations, which are on and adjacent to the Cowlitz River

**Hypotheses**

(1) Storm events that create high flows in Lake Creek and the tailrace are not of significant magnitude to negatively impact erosion.

(2) The Project negatively effects the Oregon goldenaster populations by altering the normal flows of Lake Creek.

**Most Scientifically Viable Hypothesis** - Storm events that create high flows in Lake Creek and the tailrace are not of significant magnitude to negatively impact erosion that would impact Oregon goldenaster populations on the Cowlitz River via Lake Creek, relative to peak flows of the Cowlitz River.

**Summary Statement and Documentation**

The Study area was surveyed for rare plants in 2005 and 2006 (Beck Botanical Services 2007b). Project related high flows and storm events that create high flows in Lake Creek and the tailrace are not of a significant magnitude to negatively impact Oregon goldenaster subpopulations in the Study area. Both subpopulations of Oregon goldenaster are located upstream of, or are elevationally higher than Project related high flows at either the tailrace or Lake Creek. Seasonal river flooding is probably important in maintaining the habitat for this species (WNHP 2007). Population dynamics of Oregon goldenaster subpopulations are inter-dependent on the hydraulics of the Cowlitz River with which they are associated.

**Level of Certainty**

High level of certainty

## 4.5 Snyder and Hall Creeks

Snyder Creek travels through the Project boundary's western edge before emptying into Hall Creek. Prior to joining with Hall Creek, Snyder Creek is routed through a drain and culvert complex that crosses under the tailrace. Anadromous spawner surveys and a fish distribution and composition study were conducted on Snyder Creek from 2004 through 2006. Resident cutthroat, sculpin and juvenile coho have been observed upstream of the culvert and drain.

Heavy rains in November 2006 caused extremely high flows in Snyder Creek. This high water deposited large amounts of sediment and other debris near the drain, essentially precluding fish passage up or downstream. A temporary cleanout of enough debris to allow fish passage through the culvert occurred in April 2007. A comprehensive cleanout is scheduled for summer 2007 during the normal "fish window". This blockage, along with the investigations indicating presence of both resident and anadromous species upstream of the culvert raised potential questions regarding:

- Fish passage
- Blocked access to quality spawning habitat
- Sediment transport

Issues for the Snyder and Hall Creek areas include:

1. Fish Distribution and Species Composition #3

### 4.5.1 Fish Distribution and Species Composition #3

**Inputs**

Hydrology/Sediment

**Project Effects**

Configuration of Snyder Creek culvert may cause sediment to be retained.

**Non-Project Effects**

None

**Affected Resources**

Spawning and rearing coho and cutthroat

**Hypotheses**

The Snyder Creek culvert is impassable to some resident fish and salmonids (i.e., not all life stages and all fish that may be present in the creek).

**Most Scientifically Viable Hypothesis**

The Snyder Creek culvert can become blocked with large amounts of sediment that have eroded and settled out in the culvert, at the culvert outlet or near the drain. The blockage of the culvert can prevent spawning coho and cutthroat from accessing documented spawning and rearing habitat that extends up about 1900 feet from the tailrace crossing. If the culvert becomes blocked prior to downstream migration, juvenile coho and cutthroat can become stranded in Snyder Creek.

**Summary Statement and Documentation**

Energy Northwest cleaned out the upstream drain in April 2007, allowing downstream passage of fish to lower Snyder Creek, Hall Creek, and potentially the Cowlitz River. The remainder of the culvert will be cleaned out during the low flow period in 2007.

Level A analysis indicated that a Level B analysis was required for Snyder Creek at the tailrace, because the culvert width (4 ft) is less than 75% of the average streambed toe width at the second riffle downstream of the culvert. Level B analysis indicated that the calculated depths and velocities at the upstream end of the culvert meet the Criteria for trout in WAC 220-110-070. Therefore, the culvert is deemed passable. Table 10 below summarizes the data from the Level B and Backwater Analysis.

**Table 10. Level B and backwater analysis for Snyder Creek culvert crossing under Packwood Hydroelectric Project tailrace.**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Site Information:** | | | | | | | | | **Source Worksheet:** |
| Stream: | | | | Snyder Creek Culvert | | | | | Hydrology |
| Site ID: | | | | 0 | | | | | " |
| Sequencer: | | | | 1 | | | | | " |
| | | | | | | | | | |
| Hydrology: | | | | | | | | | |
| Hydrology Method Selected: | | | | Regression Method. | | | | | Hydrology |
| Hydrologic Region: | | | | 3H | | | | | Hydrology |
| Basin Area (Square Miles): | | | | 0.91 | | | | | " |
| Precipitation, inches: | | | | 45 | | | | | " |
| Regression Coefficient a: | | | | 0.278 | | | | | " |
| Regression Coefficient b: | | | | 1.41 | | | | | " |
| Regression Coefficient c: | | | | 0.55 | | | | | " |
| | | | | | | | | | |
| Downstream Channel Cross Section | | | | | | | | | |
| | TopLB | ToeLB | Bed1 | Bed2 | Bed3 | ToeRB | TopRB | | X Section |
| Station: | 0 | 0.1 | 1.4 | 4.2 | 5.6 | 7 | 7.2 | | " |
| Elev.: | 1045 | 1044.59 | 1044.39 | 1044.45 | 1044.54 | 1044.49 | 1045.1 | | " |
| | | | | | | | | | |
| DS Control Water Surface Elevation: | | | | | 1044.79 | | | | X Section |
| Water Surface Elevation 50 ft DS: | | | | | 1044.3 | | | | " |
| Manning's "n" for channel | | | | | 0.03 | | | | " |
| Cross Section Water Surface Elevation at Qfp: | | | | | 1044.65 | | | | " |
| | | | | | | | | | |
| Culvert Length: | | | | | 75 | ft | | | Round |
| Maximum Velocity: | | | | | 4 | fps | | (WAC Criteria) | |
| Minimum Water Depth: | | | | | 1 | ft | | (WAC Criteria) | |
| Maximum hydraulic drop in fishway: | | | | | 1 | ft | | (WAC Criteria) | |
| Culvert Type: | | | | | Round Culvert | | | | X Section |
| | | | | | | | | | |

**Table 10. Level B and backwater analysis for Snyder Creek culvert crossing under Packwood Hydroelectric Project tailrace.**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Site Information:** | | | | | | | | | **Source Worksheet:** |
| Culvert Analysis | | | | | | | | | |
| Round Culvert Diameter (ft): | | | | | 4 | | | | Round |
| | | | | | | | | | " |
| Manning's n for culvert: | | | | | 0.0240 | | | | " |
| Culvert Length (ft): | | | | | 75 | | | | " |
| U/S Invert Elevation: | | | | | 1037.5 | | | | " |
| D/S Invert Elevation: | | | | | 1037.2 | | | | " |
| Normal Flow Depth (ft): | | | | | 0.55 | | | | " |
| Culvert Slope (ft/ft): | | | | | 0.004 | | | | " |
| Velocity w/o backwater (fps): | | | | | 1.92 | | | | " |
| Water Surface Elevation at DS end of culvert: | | | | | 1044.65 | | | | " |
| Flow Depth at DS end of culvert: | | | | | 7.45 | | | | " |
| Culvert Influenced by Backwater: | | | | | Yes | | | | " |
| Outlet Submerged: | | | | | Yes | | | | " |
| Length Submerged (ft): | | | | | 75 | | | | " |
| | | | | | 954.47 | | | | " |
| Backwater length plus submerged length (ft): | | | | | 1029.47 | | | | " |
| Maximum Velocity in culvert (fps): | | | | | 0.16 | | | | " |
| Minimum Depth in culvert (ft): | | | | | 7.45 | | | | " |
| | | | | | | | | | |
| Summary of Analysis | | | | | | | | | |
| | | | | | | | | | |
| 1. High Fish Passage Design Flow, Qfp was determined by the | | | | | | | Regression Method. | | |
| | Qfp = | 2.0 | cfs | | | | | | |
| | | | | | | | | | |
| 2. Next the culvert was analyzed at Qfp without backwater. | | | | | | | | | |
| | Max. Velocity (w/o backwater) = | | | | 1.92 | fps | Satisfies WAC criteria. | | |
| | Min. Depth (w/o backwater) = | | | | 0.55 | ft | Does not satisfy WAC criteria. | | |
| | | | | | | | | | |

**Table 10. Level B and backwater analysis for Snyder Creek culvert crossing under Packwood Hydroelectric Project tailrace.**

| **Site Information:** | | | | | | | | | **Source Worksheet:** |
|---|---|---|---|---|---|---|---|---|---|
| | Depth does not satisfy WAC criteria, check backwater. | | | | | | | | |
| | | | | | | | | | |
| 3. Finally, the backwater condition was analyzed. | | | | | | | | | |
| | Is the culvert influenced by backwater? | | | | | Yes | | | |
| | | | | | | The culvert is completely backwatered. | | | |
| | Is the culvert outlet submerged? | | | | | Yes | | | |
| | | | | | | The entire culvert is submerged. | | | |
| | | | | | | | | | |
| | Max. Velocity (w/ backwater) = | | | | 0.16 | fps | Satisfies WAC criteria. | | |
| | Min. Depth (w/ backwater) = | | | | 7.45 | ft | Satisfies WAC criteria. | | |
| | | | | | | | | | |
| 4. The Final Answer... | | | | | | | | | |
| | The culvert satisfies the WAC criteria due to backwater. | | | | | | | | |
| | The culvert is not a barrier. | | | | | | | | |

**Level of Certainty**

The level of certainty is high. Accurate, quantifiable data was collected on site.

**Additional Comments**

The culvert meets WAC criteria for depth and velocity for trout, and by extension, salmon. Routine maintenance may be required to maintain passage.

## 4.6 Roads and Trails

Roads and trails within the Packwood Lake Hydroelectric Project boundary were investigated in 2005 and 2006 (Beck Botanical Services 2007a and Watershed GeoDynamics 2007b). The roads and trails focused on were:

- Pipeline Road (FSR 1260-066)
- FSR 1260 from the surge tank to the junction with FSR 1260-066
- Trail #74, Latch Road (FSR 1262)
- Trails around Packwood Lake
- Mouths of all Type 1, 2 and 3 streams

A series of studies primarily examining noxious weed presence and erosion potential on and around the roads and trails raised a series of questions regarding:

1. Noxious weed intrusion due to road and trail maintenance
2. Erosion from roads and trails resulting in additional sediment deposition into streams
3. Detrimental water quality issues as a result of erosion

In-depth, collaborative discussions with the resource specialists involved in the Energy Northwest relicensing have resulted in a set of hypotheses for each of the issues in this section. For each issue, the most scientifically viable hypothesis has been established. Supporting data from relevant studies has been synthesized in support of each hypothesis.

### 4.6.1 Noxious Weeds Issue 1

**Inputs**

Vegetation disturbance, ground disturbance

**Project Effects**

- Road and right-of-way maintenance
- Operation of Project features (penstock, pipeline, tailrace, power line)
- Potential new construction, etc.

**Non-Project Effects**

- Recreation and horse use in the Project area are likely avenues of disturbance and noxious weed introduction and spread.
- Forest Service use and road maintenance in the Project area is also an avenue of possible noxious weed introduction and spread.

**Affected Resources**

Forest and other types of native plant habitat within the Project boundary.

**Hypotheses**

No alternative hypotheses; see "Most Scientifically Viable Hypothesis."

**Most Scientifically Viable Hypothesis**

Ground disturbance and noxious weed introduction and spread in the Project area are caused by a variety of inputs that are both Project related and non-project related. Project related and non-project related maintenance of right-of-ways, roads, penstock, pipeline, tailrace, trails, and power lines create disturbed habitat in the Project area where weeds have a competitive advantage over native plant species. Once noxious weeds are established in an area, they are often self-sustaining regardless of whether the disturbance continues. Continued operation of the Project may provide avenues for noxious weed introduction, establishment and spread. Other uses of the Project area, including recreation may also provide avenues for noxious weed introduction, establishment and spread.

**Summary Statement and Documentation**

The Study area was surveyed for noxious weeds in 2005 and 2006 (Beck Botanical Services 2007a). Noxious weeds present in the Project area include: meadow knapweed, Japanese knotweed, butterfly bush, diffuse knapweed, Canada thistle, and reed canary grass. These weeds are associated with various types of disturbance, whether or not they are a direct result of Project related activities. It is not known how long these populations have been present in the Project area. Energy Northwest has a noxious weed control plan which establishes responsibilities and requirements for the control of noxious weed infestations, and which addresses noxious weed species currently present in the Project area (Energy Northwest 2007). These control efforts will be done in conjunction with the USDA Forest Service and the Lewis County Noxious Weed Control Board.

**Level of Certainty**

There is a high level of certainty that the Project can affect noxious weed populations.

### 4.6.2 Roads and Trails Issue 1

**Inputs**

- Sediment (road erosion)
- Hydrology (runoff)

**Project Effects**

Project-related roads, trails and right-of-way maintenance and use increase sediment input to hydrologically connected streams.

**Non-Project Effects**

Non-Project related use of roads and trails also increase sediment input to hydrologically connected streams.

**Affected Resources**

- Water quality (turbidity)
- Aquatic habitat

**Hypotheses**

Project-related use and maintenance of roads and trails is higher than non-Project uses and contributes major amounts of sediment to streams in the watershed.

Project and non-Project related use of roads both result in erosion and sediment input to hydrologically connected streams, but relatively little sediment is delivered to streams.

**Most Scientifically Viable Hypothesis**

Project and non-Project related use and maintenance of roads and trails results in erosion and sediment input to hydrologically connected streams. Increased sediment input increases turbidity and could degrade aquatic habitat. The estimated total erosion (Project and non-Project use) from Project-related roads is estimated to be relatively minor; 7 tons/year from over 14 miles of forest road/trail. No indication of water quality or aquatic habitat concerns from sediment inputs were noted during Project-related studies.

**Summary Statement and Documentation**

Project-related roads and trails include Snyder Road (USFS 1260), Pipeline Road (USFS 1260-066), the Pipeline Trail (#74), Latch Road (USFS 1262), and the Latch Trail (short segment that connects Latch Road to the Pipeline Trail). These roads are used by Project and non-Project users, and the percentage of Project use varies by season, from 0.3% of Snyder Road use during the peak recreation season to 83% of Pipeline Trail use during November when few recreationists use the area (Howe 2007).

The total length of Project-related roads and trails is 14 miles. A total of 1.6 miles (11%) of the roads and trails are hydrologically connected to streams. Total sediment delivered to streams from Project related road and trail erosion is low, with an estimated average of 7 tons/yr (Watershed GeoDynamics 2007a).

The November 7, 2006 slide along Pipeline Trail (# 74) did not deliver sediment to Lake Creek. The terminus of the slide was approximately 1,100 ft from Lake Creek. Runoff from the slide was channeled down the west side of the drainage parallel to Latch Road and infiltrated into the low gradient depression and did not deliver to Lake Creek (Bill Kiel, personal communication).

Turbidity in lower Lake Creek is low except during high spring flows (EES Consulting 2007b). There is no indication of macroinvertebrate impairment due to high sediment load (EES Consulting 2006c). Gravel samples in Lake Creek did not show evidence of high fine sediment content (Watershed GeoDynamics 2007b).

**Level of Certainty**

The level of certainty in the conclusions is high, based on the complete road inventory, measurements of traffic levels, and measurements of water quality.

## 5. CONCLUSIONS

Synthesis issues were grouped by geographical area. Table 11 summarizes issues and conclusions for each geographic area.

**Table 11. Summary of Issues by Geographic Area.**

| | |
|---|---|
| **Packwood Lake and Tributaries** | |
| Drawdown Effects on Rearing Trout in Packwood Lake | No effect |
| Drawdown effects on Aquatic Vegetation in Packwood Lake | Winter drawdowns reduce aquatic plant density within littoral habitats |
| Drawdown effects on Archaeological/Cultural Resources around Packwood Lake | Continued Project and non-Project erosion at site 45LE285 |
| Drawdown effects on Amphibians Associated with Wetlands Adjacent to Packwood Lake | No effect |
| Drawdown effects on Wetland Vegetation | Hydrology in a portion of the wetland complex at the head of the lake is affected by the fall drawdown. The timing occurs at the end of the growing season so effects on vegetation are minimal |
| Fish Distribution and Species Composition Issue 1-Effects on Migration of Spawning Rainbow Trout | No effect |
| Fish Distribution and Species Composition Issue 2-Effects on Migration of Juvenile Rainbow Trout | No effect |
| Recreation Resources | No effect |
| **Lower Lake Creek** | |
| Fish Population Characterization Near the Drop Structure Issue 1 | Some rainbow trout pass over drop structure, which benefits downstream population with little to no impairment of lake population |
| Instream Flows Issue 1 | Magnitude and frequency of peak flows has been altered; however, gravel and large woody debris transport are mostly unaffected. |

| Table 11. Summary of Issues by Geographic Area. | |
|---|---|
| Instream Flows Issue 2 | There is a reduction in wetted area and alteration of depths and velocities. |
| Water Quality Issue 1 – Water Temperature in Lake Creek | Lake Creek exhibits cooler summer water temperatures with the Project. |
| Flow Effects on Lake Creek Amphibians | Existing flows suitable for species are present. |
| **Tailrace** | |
| Fish Use of Lined Tailrace and Stilling Basin | Construction of permanent barrier eliminates this issue |
| **Cowlitz River/Tailrace Slough** | |
| Tailrace Slough Use by Anadromous Salmonids | Anadromous fish rearing, spawning and incubation affected in years when tailrace flow contributes large proportion to total flow in slough |
| Water Quality Issue 2 – Temperature | No effect |
| Rare plants | No effect |
| **Snyder Creek** | |
| Fish Distribution and Species Composition #3 | Sedimentation at the culvert crossing of the tailrace channel can cause blockage for anadromous fish passage. |
| **Roads and Trails** | |
| Noxious weed intrusion due to road and trail maintenance | Road and trail maintenance can affect noxious weed population. |
| Erosion from roads and trails resulting in additional sediment deposition into streams | There is little impact related to sediment deposition into area streams as a result of Project related road and trail use. |
| Detrimental water quality issues as a result of erosion | No detrimental water quality issues were identified. |

Several issues were initially considered during the synthesis process and it was determined that the Project was not affecting these resources. Construction and operation of the Packwood Lake Hydroelectric Project does not affect or induce recreation use at Packwood Lake. Recreation/visitor use at Packwood Lake was influenced by the Forest Service-permitted facilities at Packwood Lake, not by the Project. Terrestrial wildlife issues were not discussed in Synthesis; however, it appears that the existing Project has minimal effect on terrestrial wildlife. There are no rare plant occurrences in the vicinity of Lake Creek, so flow changes will not have an effect on rare plants. Changes in tailrace flows will not have an effect either because of the location and elevation of rare plants nearby. Historical timber harvest practices along lower Lake Creek affect the availability for recruitment of large woody debris to the channel.

Other than road related issues, Project effects on resources as discussed in the Synthesis report are related either to lake level management or instream flows in Lake Creek and the tailrace/tailrace side channel.

The Synthesis analysis focused on existing conditions with the Project. Where appropriate, a without Project scenario was also considered. Table 11 compares the effects of several scenarios for Project operation. No specific Protection, Mitigation or enhancement measures are being proposed at this time. The scenarios presented in Table 11 show how a modification of Project operation to benefit resources within one geographic area may affect resources within other geographic areas.

Project effects identified during synthesis that merit further consideration as to how the Project could be operated to minimize or avoid these effects include:

- Timing and magnitude of drawdown of Packwood Lake for annual maintenance,
- Protection from erosion of the identified archeological site on the shore of Packwood Lake,
- Instream flow in lower Lake Creek,
- Instream flow in the tailrace slough, and
- Fish passage at the culvert crossing on Snyder Creek.

**Table 12. Comparison of Project Effects for Alternate Scenarios.**

| | Resources | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Water Quality** | **Macro-invertebrates** | **Fish** | **Wildlife** | **Amphibians** | **Rare Plants** | **Wetlands** | **Noxious Weeds** | **Cultural** | **Erosion** | **Recreation** | **Power Production** |
| **SCENARIOS** | | | | | | | | | | | | |
| No change to project operations | Summer water temperatures in Lake Creek are cooler than without project | Increased EPT and total taxa richness primarily due to increased habitat for intolerant taxa | Reduced resident and anadromous species habitat in lower Lake Creek. Increased habitat in tailrace slough. | No effect | No effect | No effect | Fall drawdown lowers water table for small part of wetland at upper end of lake | No effect | Continued Project and non-Project erosion at site 45LE285 | Continued slow erosion of shorelines and drawdown zone | No effect | |
| Increased flow in Lake Creek | Increase in summer water temperatures | Possibly extend range of tolerant taxa further downstream | Potential for increase in resident and anadromous species habitat | No effect | Potential for negative effect | No effect | No effect | No effect | Unlikely to affect archaeological site 45LE285 | Continued slow erosion of shorelines and drawdown zone | No effect | Reduced production |
| Peaking flow in Lake Creek | Higher turbidity if coincides with spring runoff | No effect | Additional movement of gravel | No effect | No effect | No effect | No effect | No effect | Unlikely to affect archaeological site 45LE285 | Continued slow erosion of shorelines and drawdown zone | No effect | Dependent upon timing; possible reduced production |
| Change timing of drawdown | A drawdown in late July or early August that is consistent with natural flows may result in a temperature increase to the Cowlitz River but no greater than without the project. | No effect | Potentially provide supplemental water in the tailrace side channel during low flow periods for spawning and rearing fish. | No effect | Could affect amphibian larvae occupying depressional pools at lake edge (el. 2857 ft) | No effect | Wetland biota could be affected within portion of wetland at upper end of lake | Possible effect | Could result in changes (either positive or negative) to shoreline erosion at archaeological site 45LE285, depending on the nature and extent of changes to the drawdown schedule | Possible slight change to erosion in drawdown zone and along Packwood Lake shoreline depending upon amount and timing of change | No effect | Variable dependent upon timing |
| Reduce tailrace flows | No effect | No effect | Potentially dewater redds and reduce habitat by decreasing the amount of water in the tailrace side channel during spawning and rearing periods. | No effect | No effect | No effect | No effect | No effect | No effect | Continued slow erosion of shorelines and drawdown zone | No effect | Reduced Production |

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