Revised

Gravel Transport Study Plan for Energy Northwest's Packwood Lake Hydroelectric Project FERC No. 2244 Lewis County, Washington

Submitted to

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1.0 INTRODUCTION

Energy Northwest's Packwood Lake Hydroelectric Project (Project), FERC No. 2244, received its initial license in 1960. Much of the Project is located within the Gifford Pinchot National Forest and consists of an intake canal, a concrete drop structure (dam) and intake building on Lake Creek located about 424 feet downstream from the outlet of Packwood Lake, a 21,691-foot system of concrete pipe and tunnels, a 5,621-foot penstock, a surge tank, and powerhouse with a 26,125 kW turbine generator.

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

1.1 Study Goals and Objectives

The goal of this study is to develop sufficient information regarding gravel transport in Lake Creek to support Energy Northwest's application to FERC for relicensing the Packwood Lake Hydroelectric Project. The gravel transport study will assess how operation of the Packwood Lake Hydroelectric Project affects the transport of gravel in the size range suitable for use by spawning fish in Lake Creek downstream of the drop structure. Project operation does not affect the gravel supply to the creek. The work will be conducted in consultation with the members of the Water Quality and Aquatic Resources Committee (Energy Northwest, EES Consulting, Watershed GeoDynamics, Washington Department of Fish and Wildlife, Washington Department of Ecology, NOAA Fisheries, U.S. Fish and Wildlife, USDA Forest Service, the Cowlitz Indian Tribe, and the Yakama Nation).

Study objectives include:

- Document the relative amount of spawning gravel and its longitudinal distribution in Lake Creek downstream of the drop structure.
- Determine the flows that are necessary to transport spawning-sized gravel down Lake Creek from the drop structure to the mouth of Lake Creek at its confluence with the Cowlitz River.
- Determine if flows that transport spawning-sized gravel from the reaches of Lake Creek upstream of RM 1.0 will maintain spawning gravel pockets in the lowest one mile of Lake Creek (the anadromous reach).
- Evaluate the project-induced change in magnitude and frequency of peak flows that are capable of transporting gravel in lower Lake Creek.

2.0 AGENCY AND TRIBE RESOURCE MANAGEMENT GOALS AND OBJECTIVES

The USDA Forest Service (2005) requested this study. Their resource management goals, as provided by the Forest Service, are listed below:

The Aquatic Conservation Strategy (ACS), a core component of the Northwest Forest Plan, provides Forest Service management direction aimed at maintaining or restoring the ecological health and function of watersheds (defined as HUC 5th field) and the aquatic ecosystems contained within them. Lake Creek drainage area is one sub-watershed (defined as a HUC 6th field) of the Upper Cowlitz River Watershed. Specifically, objectives 5, 6, and 9 are the most relevant to the gravel transport study. These objectives are stated as follows:

- *Objective 5 – Maintain and restore the sediment regime under which aquatic ecosystems evolved. Elements of the sediment regime include the timing, volume, rate, and character of sediment input, storage, and transport.*
- *Objective 6 – Maintain and restore instream flows sufficient to create and sustain riparian, aquatic and wetland habitats and to retain patterns of sediment, nutrient, and wood routing. The timing, magnitude, duration, and spatial distribution of peak, high, and low flows must be protected.*
- *Objective 9 – Maintain and restore habitat to support well-distributed populations of native plant, invertebrate, and vertebrate riparian-dependent species.*

The Forest Service's desired future condition is the maintenance of a sediment and flow regime in Lake Creek similar to pre-development conditions:

- Mimic the flow and sediment regimes which provide for the maintenance and enhancement of channel structure and habitat for aquatic and riparian dependent species.
- Re-establish and maintain the connectivity of the creek and lake system including physical and biological processes so that native aquatic species in the Lake Creek sub-watershed can utilize all available habitats and maximize their productivity levels.

3.0 EXISTING INFORMATION AND NEED FOR ADDITIONAL INFORMATION

Gravel is an important component of aquatic habitats because it provides spawning substrate for fish and habitat for other aquatic organisms. The Forest Service has identified spawning-sized gravel, particularly in the lower mile of Lake Creek where anadromous fish have access, as an important resource. 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 (452 acres) and deep (over 100 feet deep) enough that it traps all sand, gravel, and larger material that is 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 drop structure does not increase the trap efficiency of sand and larger particles in the lake.

Gravel transport does not take place during normal low flows, but occurs during peak flows. Operation of the Packwood Lake Hydroelectric Project can affect transport of gravel through lower Lake Creek by changing peak flow magnitude and frequency. The lack of an abundance

of spawning gravel in the entire Lake Creek system increases the importance of transporting existing gravels. Peak flows have been altered by the Project. Flows greater or equal to bankfull flow occurred less often since the Project started operations (Figure 3-1). Bankfull flow is approximated as 285 cfs based from the USGS statistic of the annual peak flow exceedance probability of 0.8 (USGS 1984). Since 1967, only 12 of the 36 years had peak annual discharges greater than 285 cfs (Energy Northwest 2004), about a third as often since the Project started as in prior years.

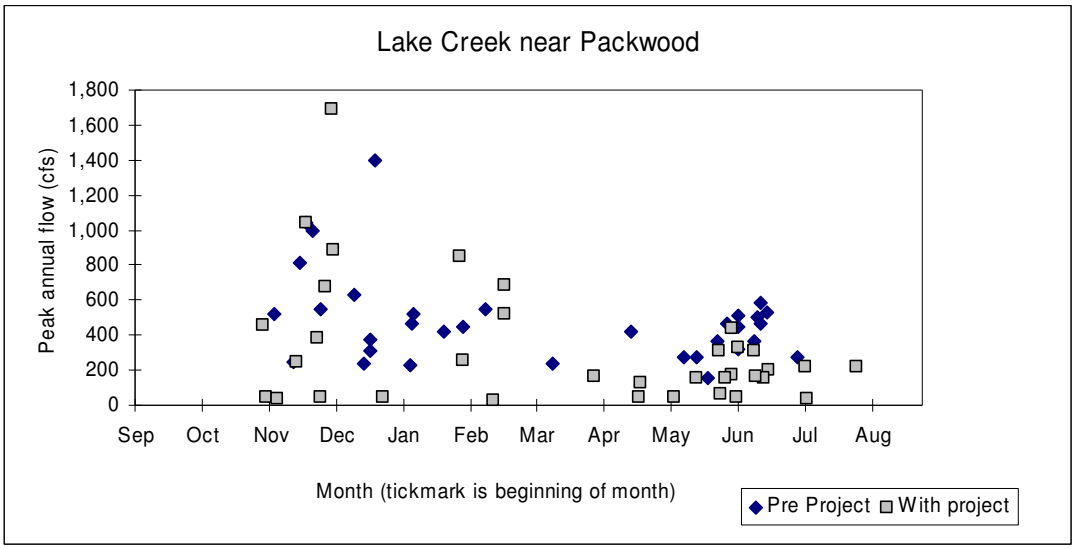

Figure 3-1. Annual Peak Flows at Lake Creek near Packwood Gage.

The lowest reach of Lake Creek is lower gradient, making it potentially useable as spawning habitat by anadromous species if suitable size substrate and flows are available. (Study of the flow needed to provide the depths and velocities for spawning habitat is addressed in the Instream Flow Study Plan). Transporting spawning gravels and capturing them in the lowest reach of Lake Creek may improve the anadromous fish spawning habitat. Reach 2 and Reach 3 are high gradient reaches, with mean slopes of 7.3% and 8.0%, respectively, and would carry gravels through to the lowest mile of Lake Creek. As presently operated, the Project may reduce the transport of spawning gravels to this lowest reach. Hill slopes and tributaries are the primary coarse sediment sources from the bypass reach drainage area. These sources have not been changed by the project.

3.1 Previous Gravel Surveys

Substrate characteristics were recorded during two previous surveys. The anadromous reach (downstream of RM 1.0) was characterized as small boulder and cobble dominated (USDA Forest Service 1993). Dominant and subdominant substrate for Lake Creek downstream of the drop structure were recorded during the Physical Habitat Assessment Surveys (EES Consulting 2004; Figure 2). Surveyors during that effort noted that there was very little gravel in the channel. The highest concentrations of gravel present in Lake Creek were observed in the lower half of Reach 4, in Reach 3 upstream of the falls, and in Reach 2 just downstream of the canyon. Even in these locations, however, gravels suitably sized for salmonid spawning are scarce. The

lowest mile of Lake Creek has low amounts of gravel. Gravel was the subdominant substrate type at only 5 of the 37 sites characterized in the lowest mile of Lake Creek. Gravel was very limited in all reaches.

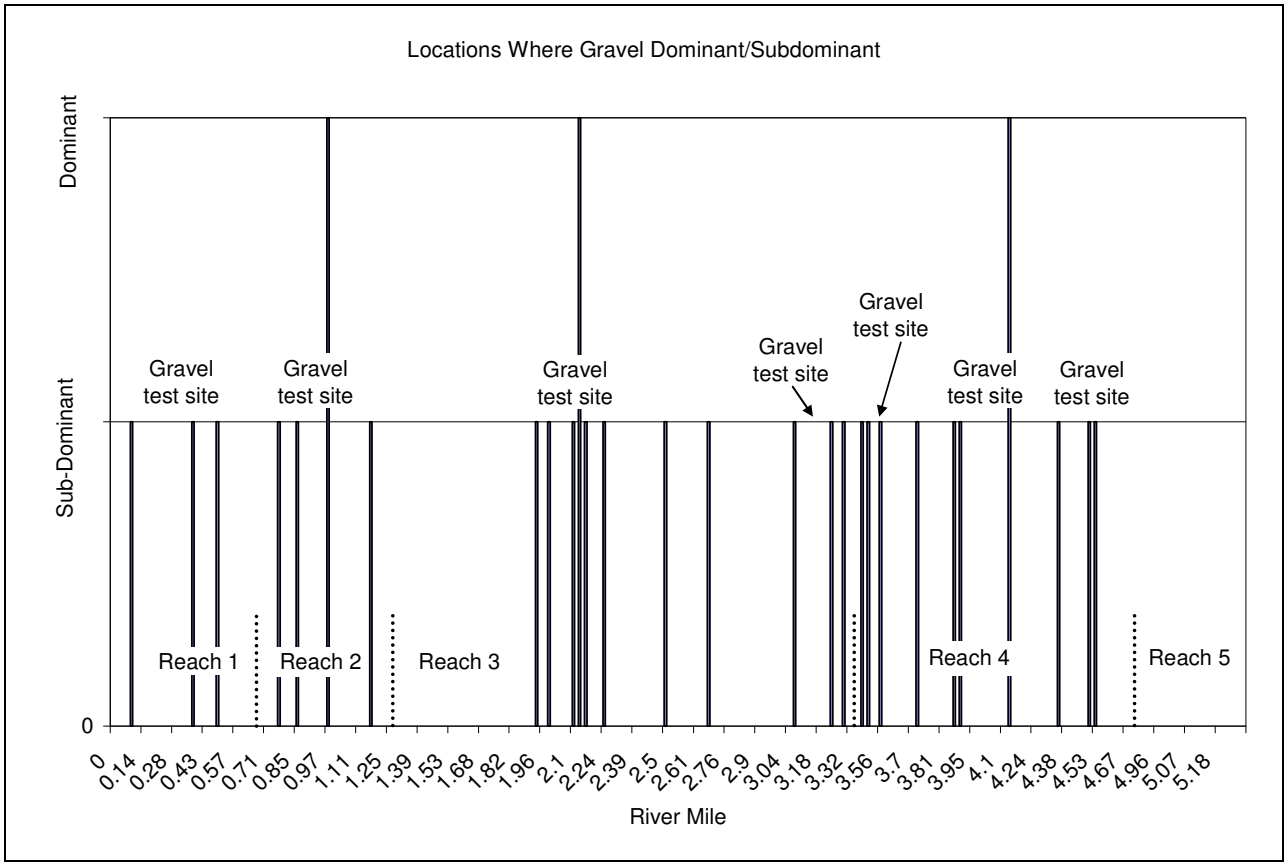

Figure 3-2. Gravel Locations Noted During Physical Habitat Assessment (EES 2004).
(Note: proposed approximate gravel test site locations are shown on Figure 3-2; see discussion in Section 5.)

Despite differences in average gradient between the five reaches, the channel characteristics of habitat areas with gravel as dominant or subdominant substrate are quite similar throughout Lake Creek (Table 3-1). Channel gradients where gravel was noted ranged from 2-4 percent in Reaches 1, 2, and 4, with higher gradients in Reach 3. Average wetted width was between 35-40 feet in all reaches. This suggests that the local channel characteristics necessary to store gravel in Lake Creek are similar throughout Lake Creek downstream of the drop structure. The higher gradients noted in Reach 3 may be due to the very high overall gradient of this reach, and the dominant large boulder channel, which creates different hydraulic conditions than other reaches. The majority of gravel in Reach 3 was located just upstream of the falls.

Table 3-1. Average Channel Characteristics in Habitat Units with Gravel Substrate		
Reach	**Average Gradient (%)**	**Average Wetted Width (ft)**
1	3	40
2	3.4	39
3	6.4	41
4	2.8	36
5	no gravel noted	no gravel noted

3.2 Need for Additional Information

Information on the effects of Project operations on gravel transport through Lake Creek is needed to determine the best ways to manage gravel movement under the new license. Previous habitat surveys have not focused on gravel resources, and have not included a complete gravel inventory or information to estimate gravel transport.

4.0 NEXUS BETWEEN PROJECT OPERATIONS AND EFFECTS ON RESOURCES

The regulation of peak flows by the Project may limit the movement of spawning gravel in lower Lake Creek. The curtailment of sediment movement by the reduction of peak flows through Lake Creek could potentially result in two primary effects: 1) reduction or alteration of sediment storage and transport to downstream reaches including their floodplains; and 2) change in substrate character in the lower gradient anadromous reach at the base of the sub-watershed.

The study results would document existing gravel resources in Lake Creek below the dam and assess how operation of the Project under the present operational plan would affect gravel transport in Lake Creek during the period of the new license.

5.0 STUDY AREA AND METHODS

5.1 Study Area

The study area includes Lake Creek from the drop structure to the confluence with the Cowlitz River.

5.2 Summary of Modifications to Study Methods Requested by the Forest Service

Several deviations from the Forest Service study request are proposed in the present study plan.

1. A complete inventory of existing spawning-sized gravel resources in Lake Creek downstream of the drop structure is proposed since previous surveys noted gravel only as dominant or subdominant, and information was collected every 150 feet. Because gravel is located in pockets in Lake Creek, it is likely that the every 150 feet sampling scheme did not document all gravel in the creek.

2. Pebble counts, painted rock studies, and hydraulic modeling are proposed to be conducted at seven sites (three sites in Reach 4 two sites in Reach 3, one site in Reach 2 and one site in

Reach 1) instead of the 14 sites proposed by the Forest Service. This will concentrate effort on the areas with the most gravel in the system and target the anadromous area where the Forest Service is most interested in improving gravel resources.

3. Re-visits of the painted rock sites are proposed at higher flows than the Forest Service suggested based on preliminary hydraulic analysis and field observations, described in Section 5.5.

5.3 Spawning-sized Gravel Survey in Lake Creek

A survey will be made of existing spawning-sized gravel in Lake Creek downstream of the drop structure in conjunction with the large wood study. Gravel will be considered suitably sized for spawning if it is 0.5-4 inches median diameter based on the size range used by anadromous fish that have access to Reach 1. In each 100-foot long reach of stream, the area of each gravel patch larger than 25 square feet will be recorded. Gravel patches will be recorded if more than 50% of the surface area is composed of spawning-sized gravel based on a visual assessment. The results of this survey will document the location of existing gravel resources throughout the study area.

5.4 Gravel Study Sites

At seven gravel study sites (shown on Figure 3-2), more intensive study of gravel size and hydraulic conditions will be made. These sites are located where gravel was most abundant during the physical habitat inventory.

At each of these sites, the following information will be collected:

1. Grain Size Characteristics. The grain size distribution of existing patches of spawning-sized gravel (0.5-4 inches median diameter) will be sampled. Information on surface and subsurface sediment size distributions of alluvial gravel patches will be obtained using grid pebble counts for surface grain size and volumetric sampling techniques for subsurface sediment as described in Bunte and Abt (2001). Grain size will be collected at three locations at each study site.

2. Hydraulic Characteristics. At each grain size sample location (3 per gravel study site), channel cross section and slope will be measured to provide information for hydraulic calculations. The cross section will extend above bankfull depth. Wetted and bankfull channel edges will be noted, and any high water markers will also be noted to help calibrate hydraulic calculations.

3. Painted Gravel Markers. Painted rocks will be deployed at the gravel study sites to document channel bed surface mobility thresholds. The results will bracket the range of flows that result in mobility of the size class of painted rock. These results can also be used to calibrate the models as uncertainties exist in how much of the hydraulic energy from slope will be transferred to moving particles versus dissipated around boulders and wood.

Painted rocks in the following size classes representing spawning-sized gravel will be used: 0.5-1 inch; 1-2 inches; 2-3 inches; 3-4 inches. A group of these four gravel sizes will be placed at

approximately 2-foot intervals across existing gravel deposits on the study site transect. The 3-4 inch rock will be placed on the cross section, the 2-3 inch rock one foot upstream of the 3-4 inch rock, the 1-2 inch rock will be placed one foot upstream of the 2-3 inch rock, etc. This placement scheme prevents artificial shielding of the smaller marked rocks by the larger ones. If the size of the gravel patch precludes this spacing, adjustments to the spacing will be made in the field. Each marked rock will be placed on the bed surface so that its exposure mimics that of the surrounding rocks. To do this, each marked rock will be placed on the bed surface by removing a similar sized rock from the bed and setting the marked rock in its place. This technique allows the marked rocks to reasonably approximate natural bed surface conditions and avoid unnatural over- or under-exposure.

Based on observations by the instream flow field crew, gravel-sized sediment was mobilized when flows reached approximately 35 cfs. This is consistent with initial analysis of gravel mobility described in Section 5.5. Flows in excess of 35 cfs occur when Packwood Lake fills and the drop structure is overtopped, or a large rainfall event results in peak flows in the lower part of the study area from runoff in the lower watershed.

The marked rock sites will be revisited to document mobility following a controlled release of 15-17 cfs. If no movement of painted rocks is noted, the sites will be visited following a controlled release of 30-35 cfs. If no movement of painted rocks is noted, the sites will be revisted following a natural flow event of 35 cfs or greater and/or after the planned overtopping of the drop structure tentatively scheduled for June 2006. Release flows noted in this paragraph are measured at the drop structure.

Movement will be considered to have occurred if a rock moved more than 2 feet downstream from its set position. Any movement less than 2 feet will be considered “not mobilized” because the flow caused the rock to readjust its placement location slightly rather than “mobilize”. Marked rocks that move downstream farther than 2 feet will be noted and the distance they moved recorded.

4. Photos. Photos will be taken at each site during each field visit to document channel conditions and gravel locations.

5.5 Assess Potential Gravel Transport in Lake Creek

A number of different gravel transport formulas have been developed to compute initiation of substrate movement and bedload transport rates in gravel-bedded rivers. Much of this work was done in alluvial rivers with pool/riffle profiles and gravel beds because these rivers have relatively uniform flow characteristics across the channel. Steep, boulder-bedded channels with cascades such as Lake Creek are very difficult to model because the large roughness elements result in non-uniform flow and turbulent eddies (Wohl 2000). Most transport and hydraulic formulas perform poorly in these conditions. However, it can be useful to use transport formulas to estimate differences in gravel movement between river reaches, particularly if field evidence such as that collected in the painted rock study is used to calibrate and check the results.

The Andrews Formula is a variant of Parkers bedload transport function (Andrews 1983, Andrews 1984) and can be used to estimate initiation of substrate movement. The equation has the form:

$\tau^*_{ci} = 0.0834(d_i/d_{50})^{-0.872}$
where τ^*_{ci} =critical Shields stress for mobility of particle size d_i
d_i=particle size at threshold of mobility
d_{50}= median particle size of *subsurface*

From this value of τ^*_{ci} , the depth D for mobility is computed using the relationship:

$\tau^*_{ci} = DS/((\gamma_s/\gamma_w - 1)d_i)$
where D = depth
S = slope
γ_s and γ_w are the specific weights of sediment and water, respectively.

Then, using D, S, the channel cross section and an estimate or measurement of hydraulic roughness, the discharge for threshold of motion of size d_i can be computed using a formula such as the Manning equation:

$v = 1.486\ R^{0.667}\ S^{0.5}/n$ (in English units)

where v = average water velocity
R = hydraulic radius (cross section area/cross section perimeter)
n = roughness coefficient, approximately 0.065 for boulder channels

and

$Q = vA$

where Q = discharge
A = cross sectional area

Based on the average channel characteristics of wetted width and gradient in the habitat units where gravel was dominant or subdominant, and the grain size of gravel preferred by spawning anadromous fish (0.5 – 4 inches), an initial assessment of the flows necessary to transport gravel in Reaches 1, 2, and 4 of Lake Creek can be made (Table 5-1). The discharge estimated to initiate gravel movement is much more dependent upon the average grain size of the bed material (first column) rather than the particle size being entrained, since the Andrews formula predicts equal particle mobility (all grain sizes are entrained at approximately the same shear stress).

These initial estimates will be refined based on site-specific hydraulic and grain size information collected at each gravel study site and the results of the painted rock study. The results will be used to analyze the potential to determine a release flow that would allow the transport of gravel

sized sediments from RM 3.5 – 4.9 while retaining some gravel-sized sediments within the lowest mile of Lake Creek.

Table 5-1. Estimated Discharge to Initiate Spawning-sized Gravel Movement in Lake Creek (0.5-4 inches)

Average grain size of bed (d_{50} in.)	Discharge (cfs) for a 30-foot wide channel at 2% slope	Discharge (cfs) for a 30-foot wide channel at 4% slope
0.5	12-19	5-8
1	33-52	15-23
1.5	60-93	27-41
2	91-141	40-63
3	163-255	73-113
4	248-387	111-172

5.6 Describe Potential for Spawning Habitat Improvements in the Anadromous Reach of Lake Creek

Based on the results of the gravel transport study, the effects of Project operations on gravel transport and deposition in Lake Creek will be discussed. The Forest Service is particularly interested in gravel in the anadromous reach of Lake Creek (lowest 1 mile of creek). It is likely that many non-Project-related channel changes have taken place in the lower mile of Lake Creek that could affect gravel retention in the anadromous reach. Any existing information on the extent of these stream channel alterations, such as berms, narrowing the channel, or removal of large wood will be collected. Based on the analysis of all these factors, potential anadromous spawning habitat improvements related to any Project effects will be determined.

5.7 Products

A report summarizing the results of the field inventory and analysis of the effects of Project operations on gravel transport in Lake Creek will be prepared.

5.8 Consistency with Generally Accepted Scientific Practice

The methods described for the gravel inventory and transport analysis are similar to those used for the Oak Grove – Clackamas, FERC No. 135, Carmen-Smith FERC No. 2242, North Umpqua Project FERC No. 1927, and Lewis River Hydroelectric Projects.

6.0 CONSULTATION WITH AGENCIES, TRIBES AND OTHER STAKEHOLDERS

Energy Northwest initiated agency consultation in December 2003. The integrated licensing process (ILP) provides for numerous meetings with stakeholders to discuss, revise, and finalize the proposed study plan. Stakeholder representatives will also be invited to provide information for the study and technical reviews of the draft report.

7.0 PROGRESS REPORTS, INFORMATION SHARING AND TECHNICAL REVIEW

Technical reports, including the draft and final Gravel Transport Report will be shared with stakeholders. Energy Northwest and its consultant will also report on the methods, progress, and results of the study at stakeholder meetings.

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

8.0 SCHEDULE

The gravel survey and deployment of painted rocks will be conducted in early September 2005. Controlled releases for 12 hours will be conducted (water-dependent) in early September 2005. The planned overtopping of the drop structure is tentatively scheduled for June 2006. A preliminary draft report will be prepared in mid-September 2006. The final results of the gravel transport study will be reported in 2007.

9.0 LEVEL OF EFFORT AND COST

The level of effort includes finalization of the study plan, study implementation, and report preparation as well as consultation with agencies, tribes and stakeholders.

Level of effort to inventory gravel resources in the study reach, measure grain size and hydraulic conditions and deploy and re-visit painted rocks is estimated to be 24 field days (9 days for a geologist and 15 days field technicians). Level of effort to compile field data, analyze gravel transport, write a draft and final report and consult with stakeholders is estimated to be 16 days.

Total level of effort for all tasks in this study plan is 24 field days and 16 analysis/report/ meeting days with a total estimated study cost of approximately $35,182.

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