Final Report

Henry M. Jackson Hydroelectric Project (FERC No. 2157)

Relicensing Study Plan No. 4

Potential for Resident Trout Entrainment in Spada Lake, Washington

Phase I

Prepared for

Public Utility District No. 1 of Snohomish County

and

City of Everett, Washington

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Executive Summary

During the Jackson Hydroelectric Project (Project) relicensing process, Public Utility District No. 1 of Snohomish County (District) and the City of Everett (City), as co-licensees, agreed to undertake several studies to determine the potential for Project effects on the environment in the Project vicinity. One of these studies is to assess the potential for entrainment of trout into the Project facilities that release water from Spada Lake.

The study is structured in two phases. Phase I is to assess the potential for trout entrainment. This report documents the results of Phase I, a trout entrainment literature review, which, in conjunction with other Project specific fisheries information, was used to determine the likelihood for entrainment to have a significant adverse effect on the Spada Lake trout population and associated recreational fishery. Phase II would be a field study to sample the actual Project outflow(s) if the potential risk for trout entrainment was determined in Phase I to be great enough to adversely affect the trout population in the lake.

The conclusion from this Phase I review is that the risk of trout becoming entrained into the powerhouse intake at Spada Lake appears to be very low based on the results of several recent studies at similar sites coupled with an understanding of what is known about the trout population, physical conditions, and operations at Spada Lake. The normal depth of the intake and the tendency for trout to not occupy those depths are the major contributing factors to this general conclusion. The fact that very few small-sized juvenile trout rear in Spada Lake also is a contributing factor because studies elsewhere have shown that larger fish with greater swimming capabilities and perhaps more fidelity to their rearing habitat are much less likely to become entrained. Furthermore, there has been no observational evidence that trout have previously been entrained and passed through either the outlet works or the powerhouse intake structure. Thus, trout entrainment is not considered likely to occur at a level great enough to have a substantial adverse effect on the Spada Lake trout population. Therefore, further investigation of trout entrainment at Spada Lake does not appear to be warranted.

1.0 Study Objectives and Description

The Jackson Hydroelectric Project reservoir, Spada Lake, supports a resident trout population consisting of approximately half rainbow trout (*Oncorhynchus mykiss*), a third cutthroat trout (*Oncorhynchus clarki*), and a fifth hybrids of the two species (Pfeifer et al. 1998). The trout population, which in turn supports a recreational fishery, is managed by the Washington Department of Fish and Wildlife (WDFW) as a naturally reproducing population without hatchery supplementation. Although trout fishing was superb in the 1980s following enlargement of the reservoir, the fishery has deteriorated over the past decade, and harvest rates have dropped to nearly zero (Pfeifer et al. 1998). Potential causes for the decline include low productivity due to reduced nutrients (from aging of the reservoir), competition with a large population of non-native brown bullhead (*Ictalurus nebulosus*), and, of most concern, the high infection rate of a parasite (*Diphyllobothrium ditremum*).

The Project powerhouse intake structure, Culmback Dam diversion tunnel, and morning glory spillway (the outlet works) are all unscreened. Therefore, trout that rear or migrate in Spada Lake have the potential to become entrained into the Powerhouse, diversion tunnel outlet valves, and spillway. The Spada Lake outlet works lead to extremely harsh conditions which do not facilitate survival of passage. The Powerhouse has approximately 1000 feet of pressure (500 psi) on the Pelton turbines and 700 feet of pressure on the Francis turbines. Safe passage through a Pelton turbine is problematic and unlikely. Fish that might pass through the Francis turbines would exit out into Lake Chaplain or enter the Sultan River at the Diversion Dam. The exits from the diversion tunnel outlet valves at Culmback Dam are equally harsh, with the spray exiting the outlet valves at high velocity and intersecting the spillway tunnel at approximately a 70 degree angle. Water entering the spillway is pooled by a thrust block barricade and then flows into the Sultan River canyon below Culmback Dam. Fish that might survive passage through the Culmback Dam diversion tunnel outlet valves or morning glory spillway would contribute to the resident trout population in the 6-mile bypass reach below the dam. Fish that are entrained into the power tunnel and survive turbine passage would either enter the lower river, which is managed for anadromous fish, or would enter Lake Chaplain, another major reservoir for the City's water supply.

On the basis of consultation with WDFW, there is a concern that some numbers of Spada Lake trout may become lost from the reservoir through entrainment at the various reservoir outlet works. While it is not believed that entrainment loss has caused the recent trout population decline, some knowledge of trout entrainment potential would be useful in determining Project effects and mitigation needs, if any. The issue is not one of fish passage but rather a desire to keep most of the trout in the lake. In response to this issue, the co-licensees proposed to conduct an assessment and possible field study of fish entrainment at Spada Lake. A study plan specific to this assessment was prepared in consultation with resource agencies and filed with the Federal Energy Regulatory Commission (FERC) in accordance with the regulations guiding relicensing activities at the Project.

During entrainment study planning, it was determined that a two-phased approach would be most prudent. Phase I would consist of a review of available literature on fish entrainment at other projects having similar structures, fish communities, and operating conditions. This information, coupled with available data on trout behavior and distribution provided in Pfeifer et al. (1998), and Stables and Thomas (1992), would be used to characterize the potential for trout entrainment and effects on the trout population and recreational fishery in the lake.

If the Phase I assessment suggests that entrainment may be occurring at a level potentially detrimental to the trout population and sport fishery within Spada Lake, then a Phase II field study would be considered. The Phase II study would involve sampling outflow from Jackson Project structure(s) identified as likely to entrain fish and deemed safe and feasible to sample. This report presents findings of Phase I.

Figure 2-1. Sultan River Basin and Spada Lake, with Culmback Dam in the Foreground

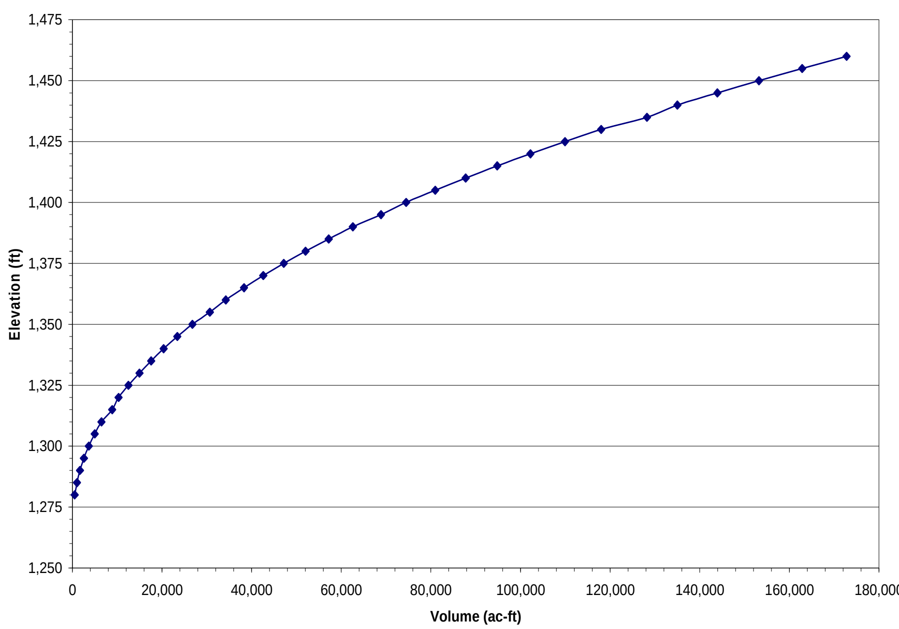

Figure 2-2. Spada Lake Volume – Elevation Relationship

2.0 Background Information

The following sections describe the Project features and their operations that are important to understand in order to assess the potential for trout entrainment in Spada Lake.

2.1 Spada Lake

Spada Lake, the reservoir created by Culmback Dam, has a surface area of 1,870 acres when full, making it the largest lake in Snohomish County (Figure 2-1). Its maximum depth near the dam is over 200 feet. Under normal operations its volume varies from 87,748 acre-feet (at 1,410 feet mean sea level [ft msl]) to 153,260 acre-feet (at 1,450 ft msl) (Figure 2-2). The lake has a flushing rate of approximately three times a year. This flushing removes nutrients, which, coupled with low nutrient inputs, makes the lake's fish production potential quite low (Pfeifer et al. 1998).

Spada Lake begins to thermally stratify in April, reaches maximum stratification in late summer, and then de-stratifies typically by early November (Figure 2-3). Bottom temperatures range from approximately 4°Centegrade (°C) in winter to 10°C in October. Mean surface temperatures reach approximately 18°C in July and August while maximum surface temperatures often exceed 20°C during this period. The temperature differential between mean surface and mean bottom temperature is about 10°C in the summer.

2.2 Outlet Works

Spada Lake has three primary outlets through which trout could become entrained. The primary outlet for Project operation is the powerhouse intake structure that draws over 90% of the water entering Spada Lake from various depths near Culmback Dam. The second most used outlet of water is the controlled-flow diversion tunnel through the dam, and the third is the uncontrolled morning glory spillway located in the dam forebay. The structures and operations of these three outlets are described below.

2.2.1 Powerhouse Intake Structure

The powerhouse intake structure is located near the south abutment of Culmback Dam, approximately 250 feet upstream of the dam (pictured in Figure 2-4). The 110-foot-tall concrete structure has three 20-foot movable panels at different elevations (Figure 2-5 and Appendix A). The positioning of these movable panels allows the selective withdrawal of stored water from various depths to facilitate the control of water temperature below the Powerhouse and Diversion Dam in the Sultan River. The maximum flow capacity of the intake structure is 1,300 cubic feet per second (cfs). At this discharge, the water velocity approaching the intake at the trash racks averages approximately 3.5 feet per second (fps).

The Project is operated to maintain water temperatures in the Sultan River, as measured at the Diversion Dam, within its historical ranges without exceeding state water temperature criteria. Temperature control is achieved by positioning the movable panels of the intake structure based on the reservoir water temperature profile (which is

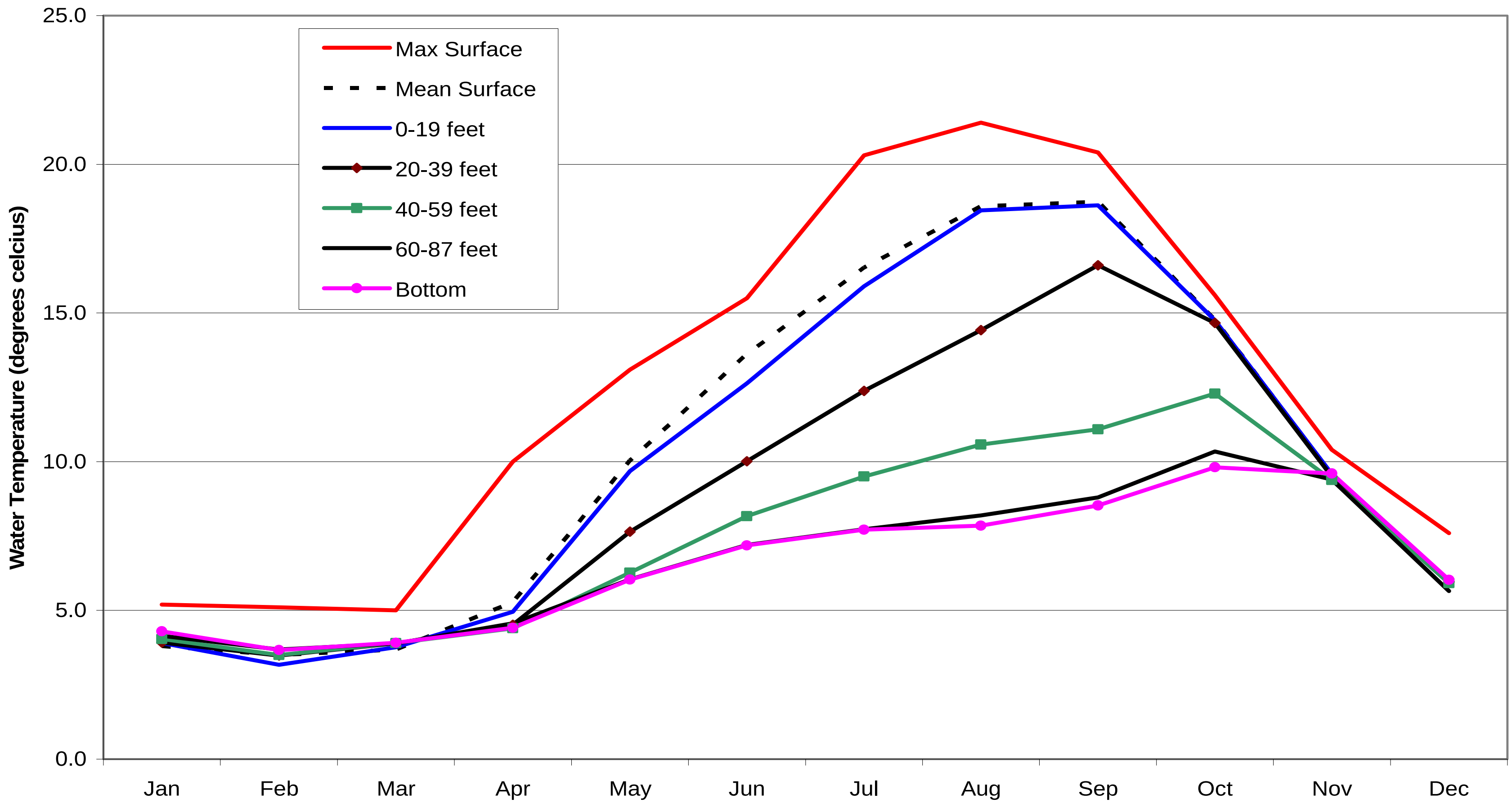

Figure 2-3. Spada Lake Average Monthly Water Temperature Profile and Maximum Monthly Surface Temperatures at the Intake Control Structure from 1997 to 2004 (Depth in Feet from Water Surface)

Figure 2-4. Photograph of Spada Lake Powerhouse Intake Structure

2.2.2 Controlled-Flow Diversion Tunnel

measured monthly) to achieve the desired temperature downstream at the Diversion Dam. Based on operating experience, a panel setting schedule is used to describe which panel settings will most likely be needed throughout the year. (Table 2-1).

The controlled-flow outlet works at Culmback Dam consist of two 48-inch-diameter conduits embedded in a concrete plug of the original diversion tunnel built through the right abutment. This diversion tunnel allowed for the bypass of water while Culmback Dam was under construction. The downstream end of each conduit is equipped with a large control valve. On one is a 42-inch slide-gate valve and on the other is a 48-inch Howell-Bunger valve. In addition, a pipe is attached upstream of the Howell-Bunger valve to allow for water to flow to the on-site 60 KW hydro generator (about 5cfs) and to a 10-inch cone valve for a nearly continuous discharge of up to 20 cfs. The large outlet valves are used to control discharges up to 2,300 cfs from the reservoir. Their primary purpose is for emergency lowering of the reservoir, or for use when additional water is needed downstream, such as when the Powerhouse is not operating. From a potential fish entrainment perspective, it is important to note that water enters the diversion tunnel from near the bottom of the reservoir (at elevation 1,220 ft msl, i.e. 200 to 230 feet deep) and that the large outlets are typically used for short term water discharge only one day a year during the annual maintenance inspection.

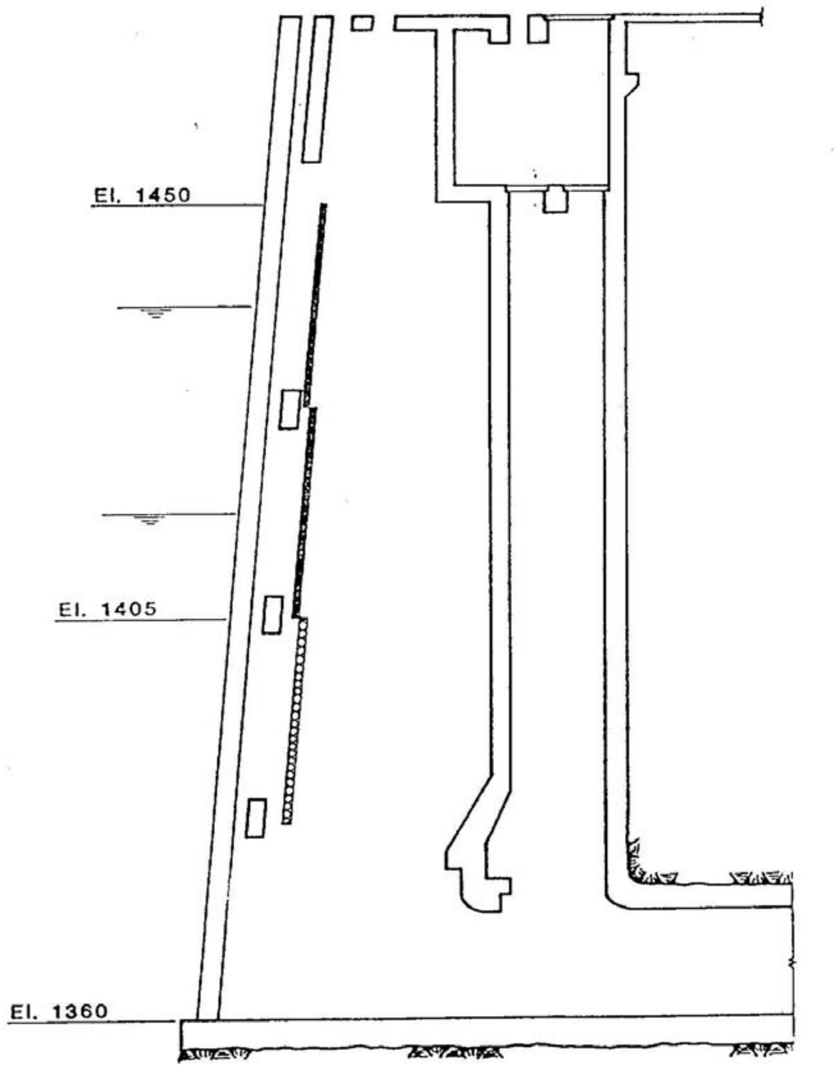

Figure 2-5. Spada Lake Powerhouse Intake Structure – in Withdrawal Configuration E (See Appendix for other configurations)

2.2.3 Morning Glory Overflow Spillway

Culmback Dam also is equipped with a concrete morning glory spillway that is located approximately 250 feet from the north bank near the dam (pictured in Figure 2-6). The spillway crest is at 1,450 ft msl and is designed to accommodate the maximum probable flood of 57,790 cfs. The structure has no control gates. The spillway is 94 feet in diameter at its highest point and narrows to a vertical shaft 38 feet in diameter. The character of the flow is to drop vertically 250 feet and through a 90 degree elbow and then enter a 700 feet long horizontal tunnel that is 34 feet in diameter. Flow velocity is

121 feet per second as it enters the horizontal tunnel. At the end of the tunnel is a thrust block that facilitates either pooling of the water to dissipate energy in the tunnel or launching of the flow safely into the canyon below Culmback Dam. Flood flows pass through the spillway when the reservoir has filled and inflows exceed the flow capacity of the Powerhouse. As such, the morning glory spillway is typically used only for a few days every few years. Project history has documented 83 spill days in the past 23 years. However, changes in rule curves and operating strategy have minimized spill frequency; there were no spills between October 1997 and November 2006.

Table 2-1. Panel Setting Schedule

	Panel Setting				
Month	C	D	D-E	E	Comments
March	X				Move to setting "C" when reservoir is on the rise and reaches Elev. 1430'
April	X				
May		X			Move to setting "D" once average daily temperature at the Diversion Dam reaches 9 deg C
June		X			
July			X		Move to setting "D-E" once average daily temperature at the Diversion Dam reaches 11 deg C
August			X		
September				X	Move to setting "E" on or as close as possible to September 1
October				X	

2.3 Reservoir Operations

The reservoir rule curves are the centerpiece of the Project's operating plan. Spada Lake is divided into four operational states that shift throughout the water year to provide winter flood storage, water for municipal supply, minimum instream flows, and higher summer lake levels for recreation (Figure 2-7). In States 1 and 2, the Project is required to release the maximum discharge of 1,300 cfs into the Sultan River in order to quickly draw the reservoir down to reduce the likelihood of flood events. In State 4, the Project is operated primarily to maintain Lake Chaplain within a specified range of elevation and to provide minimum instream flows for aquatic resources below the Diversion Dam and Powerhouse (power production is therefore minimal and incidental). State 3 is a discretionary zone where the Project may be operated between the extremes of States 2 and 4 depending on the needs for power supply and equipment maintenance, consideration of Project effects on aquatic resources, and subject to minimum instream flow requirements and downramping limitations.

On average, the reservoir water surface elevation is maintained within State 3, except during August and September, when reservoir inflows may be less than the flows required to maintain Sultan River instream flow requirements and meet the City of Everett's water demands. Although reservoir surface elevations are generally within State 3, they vary widely seasonally and from year to year, with large variations in the fall to spring but much less variation during the summer (see Figure 2-7).

Figure 2-6. Photograph of Morning Glory Overflow Spillway

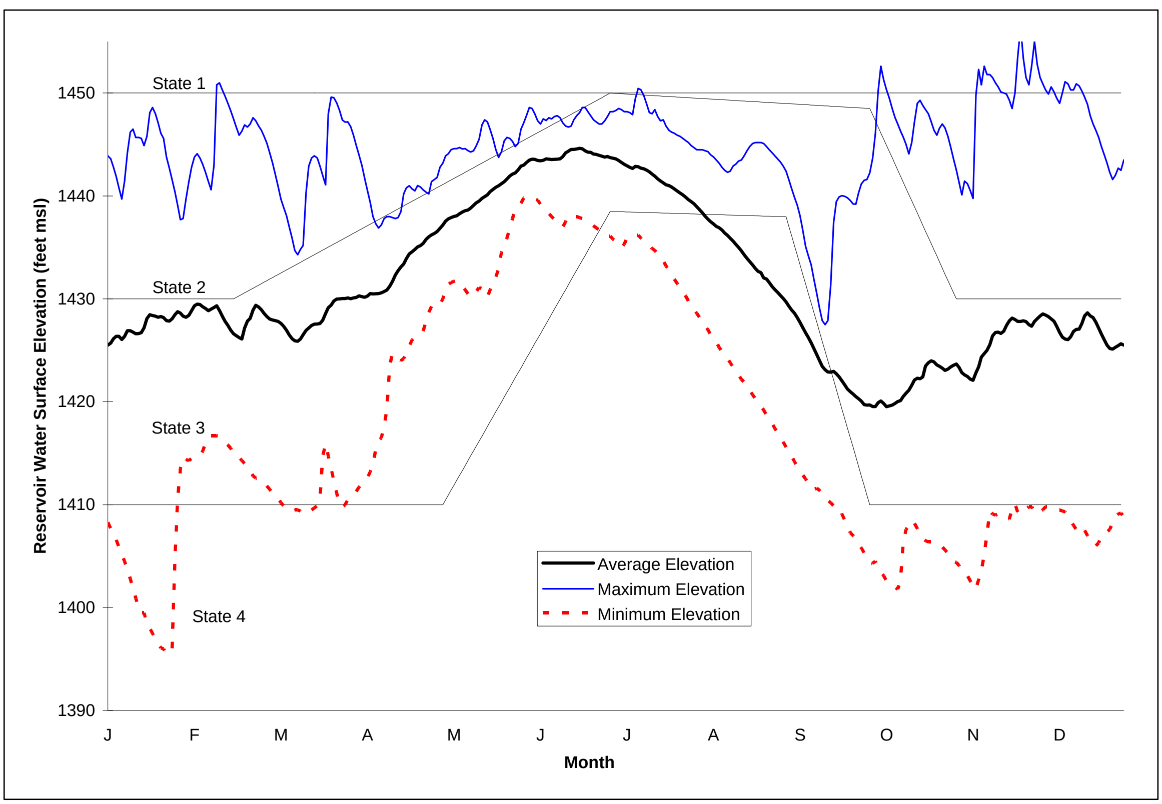

Figure 2-7. Spada Lake Minimum, Maximum and Average Water Level Observed (1990 to 2005)

3.0 Methods

Site specific data on fish entrainment through the Project spillway, outlet works and intake structure are not available. Therefore, a review of study reports available from other projects with similar structures and trout populations was conducted. Also reviewed to identify general entrainment risk factors were several comprehensive entrainment summary reports and data bases compiled by FERC and the Electric Power Research Institute (EPRI). A comparison of these factors was then made on relevance to the conditions at Spada Lake.

Physical factors that could possibly affect entrainment such as dam height, intake and outlet depth, hydraulic capacity, intake flow characteristics and water velocities near outlet facilities, water level management, trash rack spacing, fish species composition and size were all considered during the Phase I review and assessment.

4.0 Results - Assessment of Entrainment Potential

4.1 General Entrainment Risk Factors

Numerous resident fish entrainment studies at hydroelectric projects have been conducted over the past several decades. Comprehensive reviews of these studies have been done by FERC (1995), EPRI (1992 and 1997), and Winchel et al. (2000). Nearly all of the reviewed studies were conducted on warm-water and cool-water fish species and at projects primarily east of the Mississippi River. Virtually none of the reviewed studies involved resident trout as a primary species. Most studies were conducted at relatively shallow reservoirs supporting resident fish that spawned and early-reared in the reservoir. Despite these potential limitations for application to Spada Lake, a number of general entrainment risk factors were identified in these study reviews that are applicable to trout in Spada Lake. These previously identified factors are described briefly below, with a statement regarding their relevance to entrainment potential at Spada Lake.

4.1.1 Fish Species

Fish species most commonly observed in entrainment studies include black crappie, bluegill, yellow perch, walleye, and shiners. Suckers are sometimes observed entrained in large numbers but in other cases they are not, even though abundantly present. In the few cases where trout were present, their susceptibility to entrainment was not evident relative to other species. Kokanee salmon, when present, can be susceptible to entrainment at projects with deep intakes and large discharges. Schooling pelagic species such as gizzard shad and landlocked alewife can be highly susceptible to entrainment where present.

Relevance to Spada Lake: Rainbow and cutthroat trout occurred only rarely in the previously-reviewed study sites described in FERC (1995), EPRI (1992 and 1997), and Winchel et al. (2000), so little can be concluded from them regarding Spada Lake. The brown bullhead in Spada Lake would be susceptible to entrainment based on findings of these other studies. In fact, dead brown bullheads have been observed by District staff in the Culmback Dam spillway tunnel and down stream of the powerhouse tailrace. However, no dead trout have been observed in the spillway, the exit to Lake Chaplain, or in the forebay of the Diversion Dam.

4.1.2 Fish Size

Small young-of-year (YOY) fish, regardless of species, make up the vast majority of observed entrainment. In some studies, more than 90 percent of the entrainment consisted of fish less than 4 inches. In part, this may due to the fact that YOY fish tend to be much more abundant than older individuals in lake environments, especially for the highly fecund species that are the ones most often seen in the entrainment samples. Also, smaller fish are less capable of swimming against the current velocities at the approach to the intakes.

Relevance to Spada Lake: The fact that smaller fish are more prone to entrainment is a conclusion of nearly all studies and is somewhat intuitive. The finding is likely applicable to trout as well. This is highly relevant to the circumstances in Spada Lake because small subyearling trout are rarely observed in Spada Lake (Stables and Thomas 1992; Pfeifer et al. 1998). Rather, the young fry and juveniles apparently remain in the tributary streams for one or more years before entering Spada Lake[1]. Studies in the 1980s using gillnets captured no trout less than 170 mm (6.7 inches), although the minimum mesh size (1-inch stretch) would have caught fish as small as 100 mm (3.9 in).

4.1.3 Fish Use and Distribution in Reservoir

It has been suggested that entrainment potential is greater for those species that prefer the type of habitat near the intakes. Many YOY fish prefer shallow and vegetated areas of the reservoir and thus may be less likely to venture near the deeper waters near the dam.

Relevance to Spada Lake: Trout are known to use all of Spada Lake, but preliminary results of 2007 sampling (RSP 16) indicate that trout densities are greatest in the eastern portion of the reservoir, farthest from the dam, where there is more shallow water and several tributary embayments which may offer better foraging opportunity (Jason Shappart, Meridian Environmental, personal communication).

4.1.4 Population Abundance

When a reservoir fish population is healthy and abundant, it has been found that a greater number of the fish, typically as YOY, are inclined to leave the reservoir due to density-dependant factors such as competition for food or space.

Relevance to Spada Lake: The trout population in Spada Lake currently is considered severely depressed as a result of a cestode parasite, which limits trout growth and recruitment into advanced age groups (Pfeifer et al. 1998). The estimated trout density

[1] Results of the Spada Lake Trout Production Study (RSP 16), currently in progress, will provide additional data on trout fry and juvenile movement in the reservoir and its tributaries and the affect of parasites on the resident trout population.

of 5.4 fish per acre in Spada Lake is considered very low. With such low densities, it is doubtful that competition for food or space would encourage trout to leave the lake via the outlets.

4.1.5 Intake Location Relative to Shoreline or Littoral Zone

It has been observed at some locations that an intake near the shore or in shallow waters will entrain more of the species that prefer those habitats.

Relevance to Spada Lake: The primary outlet (i.e., powerhouse intake structure) at Spada Lake is relatively close to shore but not in shallow water. Of more importance is the depth of water withdrawals at the intake, discussed below.

4.1.6 Depth of Water Withdrawal

Intake depth has been shown to be a significant factor in determining entrainment potential for certain fish species. Fish that prefer deep water, such as kokanee, are more prone to entrainment at locations with deep intakes. Similarly, fish species that prefer bottom habits, such as suckers and bullheads, are more often entrained through intakes near the bottom.

Relevance to Spada Lake: The fact that Spada Lake has a deep outlet structure and typically withdraws water from the lowest panel setting (i.e., depth of up to 90 feet) is one of the most relevant factors related to trout entrainment potential at the site. Studies of late-summer trout distribution near Culmback Dam using gillnets, setlines, and hydroacoustics indicated that the majority of the trout remained in the top 30 feet of the water column (Stables and Thomas 1992), which is considerably shallower than the top of the Powerhouse intake tunnel, as shown in Figure 4.1. This figure shows the depth distribution of trout in Spada Lake near Culmback Dam compared to the depth of the intake tunnel in late summer (most severe “seasonal” drawdown) and early summer (least “seasonal” drawdown). The trout depth distribution is based on relative density data collected in early September and thus represents the season when trout probably resided in the deepest water because of their avoidance of near-surface water temperatures that approached 24° C at the time of the study (Brock Stables, personal communication). The tendency for trout to be positioned deeper in the summer months in Spada Lake also was observed in 1997 by Pfeifer et al. (1998), as shown in Figure 4.2. Winter depth information is not available for trout in Spada Lake, however, the relative shallowness of trout observed in fall and early spring in Spada Lake as well as findings elsewhere (Idaho Department of Fish and Game 2003) suggest that trout would be very surface oriented in the winter months. Preliminary results from the April-November 2007 sampling in Spada Lake (RSP 16) also indicate that almost all trout occur in the upper water column (less than 50 feet), similar to what was observed by Stables and Thomas (1992) and by Pfeifer et al. (1998) (Jason Shappart, Meridian Environmental, personal communication).

Additional discussion of the interaction of seasonal lake elevation, intake depth, and vertical trout distribution in Spada Lake is presented in section 5.0.

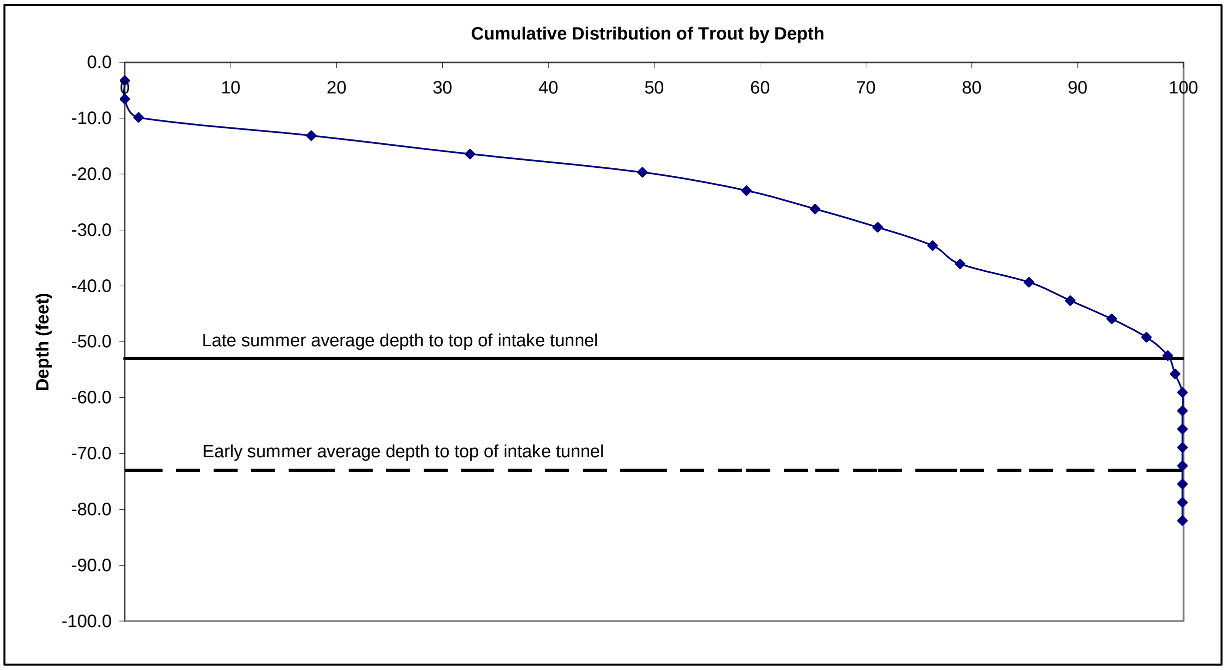

Figure 4-1. Cumulative Distribution of Trout by Depth in Spada Lake Near Culmback Dam Compared to Depth of Intake at Greatest Seasonal Drawdown (Late Summer) and Least Seasonal Drawdown (Early Summer). Trout Depth Data from Stables and Thomas (1992).

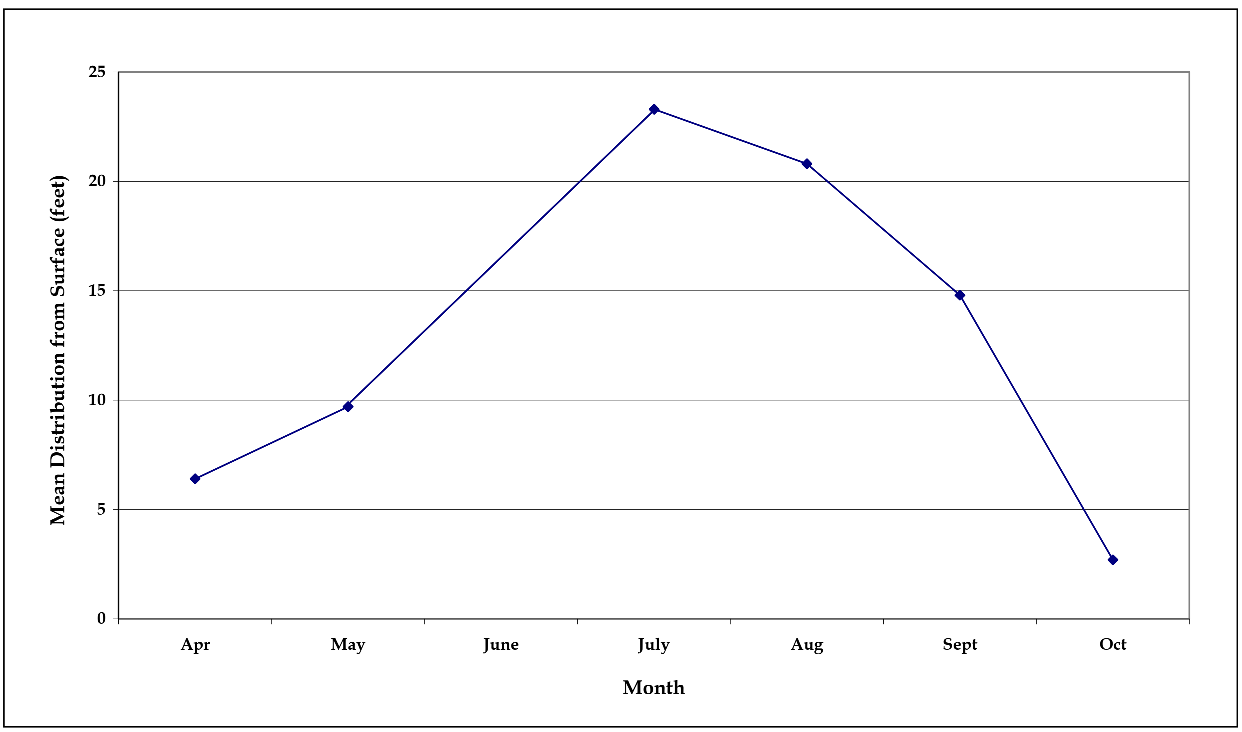

Figure 4-2. Mean Depth of Trout Caught in Vertical Gillnets Set in Spada Lake, 1997 (source: Pfeifer et. al., 1998)

4.1.7 Seasonal Drawdown

Extensive seasonal drawdowns of reservoirs may place fish in closer proximity to the intakes and may create density-dependent fish movements due to over-crowding.

Relevance to Spada Lake: Spada Lake does not experience dramatic drawdowns compared to many reservoirs. The average annual drawdown in Spada Lake equates to a minimum pool volume that is 67 percent of the full-pool volume. Consistent with the reservoir rule curves, the Project is operated such that the greatest drawdowns typically occur in the late summer and fall when water is being withdrawn from the deepest panel setting at the Powerhouse intake structure.

4.1.8 Hydraulic Capacity of Intake

In some reviews it has been suggested that entrainment potential is greater at projects with relatively high discharge rates. This may, however, be related to reservoir water-retention time or due to the tendency for higher-capacity projects to have higher intake velocities.

Relevance to Spada Lake: Spada Lake does not have a particularly high discharge rate (1,300 cfs) compared to most hydroelectric projects where entrainment studies have been conducted. Also, the relatively large size of the reservoir means that water retention times are long enough to prevent the “flushing” of fish from the reservoir, especially in the non-winter months when fish would be most active. There is no reason to conclude that the hydraulic capacity of the Spada Lake intake would directly influence the trout entrainment potential. However, hydraulic capacity does relate directly to the approach velocity at the intake, as discussed below.

4.1.9 Approach Velocity at Intake

Projects with high water velocities approaching the intakes (greater than 5 fps) are believed to be more apt to entrain fish. This assumption is valid for small fish that approach the intake area and are not inclined or able to fight the current. Susceptibility to entrainment at intakes can be highly dependent on how individual fish react to the water velocity at the intake. Some, especially small fish, may elect to simply go with the flow whereas others may have an opposite response to the current and swim away from the intake. For some species, including trout, their behavioral response to water current may differ depending on their physiological condition or season. Generally it is assumed that a fish can become involuntarily entrained if it enters an area near the intake where water velocities exceed their maximum burst speed. As a rule-of-thumb, a fish can swim for short bursts at a speed of about 10 fish-lengths per second (Clay 1961). Studies specific to rainbow trout indicate that they have a burst speed of 13.4 fish-lengths per second (Froese and Pauly, 2003). Using the more conservative 10 fish-lengths per second, a 6-inch trout would have a burst speed of 5 fps.

Relevance to Spada Lake: The maximum approach velocity at the Spada Lake intake structure is 3.5 fps at 1,300 cfs. Given that nearly all trout observed in Spada Lake are larger than 6-inches (Stables and Thomas 1992), there is little risk of trout becoming involuntarily entrained, even at maximum discharge.

4.1.10 Water Temperature and Dissolved Oxygen

All fish species have specific preferences and tolerances for temperature and dissolved oxygen. Deep intakes of cool hypolimnetic water generally do not entrain fish that prefer warmer water nearer the surface. In some cases, intakes may be located at depths where dissolved oxygen levels are so low that the presence of some or all fish species cannot be supported. It has been suggested that fish may be more inclined to become entrained during the winter when cold water retards metabolism and response to currents. However, except for pelagic species such as gizzard shad, entrainment generally has been observed to be lowest in the winter, perhaps due to lower fish activity.

Relevance to Spada Lake: Trout preference for surface water in Spada Lake may be associated with their preference for water temperatures in the range of 15 to 20°C as discussed in Stables and Thomas (1992). When near-surface water temperatures in Spada Lake exceed 20°C, typically in late summer, trout tend to reside deeper. This is a significant factor in assessing entrainment potential at Spada Lake because under these conditions the Project intentionally withdraws water from the deepest panel setting in order to maintain compliance with downstream temperature standards.

Dissolved oxygen levels in Spada Lake are high at all locations and in all depth strata (except right on the bottom during the summer) and would not be expected to influence trout distribution or behavior near the intake structure.

4.2 Review of Trout Entrainment Studies

The general peer-reviewed literature did not contain any reports specific to the entrainment of resident trout except for bull trout. The numerous studies reviewed by FERC and EPRI all were conducted at locations where trout was not the primary species. Therefore, FERC’s information filing system was queried and several utility and agency biologists in the Northwest were contacted regarding study reports on trout entrainment. A fair number of studies were identified, mostly recent, with good applicability to the Project.

In evaluating the usefulness of the various studies for the purposes of this assessment of trout entrainment potential, site conditions were sought that were most similar to those at Spada Lake. Therefore, the following factors were considered:

1. Project location (Northwest states preferred)
2. Primary fish community (rainbow or cutthroat trout, not anadromous)
3. Reservoir size
4. Reservoir depth
5. Intake depth
6. Flow capacity
7. General entrainment study design (sampling locations, gear, and schedule)

Eight study reports (representing twelve sites) were identified that contained sufficient information to allow the potential for trout entrainment at Spada Lake to be characterized. While no single studied site was a perfect surrogate for Spada Lake, many had similar physical features (such as lake size and intake depth) and fish communities (mostly trout). Collectively, the studies adequately covered the range of conditions observed at Spada Lake. In addition, the studies demonstrated a surprising similarity in conclusions regarding trout entrainment, thus adding confidence to our conclusions for Spada Lake. The reservoirs where the reviewed entrainment studies were conducted, their location, and respective study report references are listed below, followed by a brief description of the site conditions and study results.

Reservoir Name	Location	Reference
Lake Lemolo	North Umpqua River, Oregon	RTG Fishery Research 1998
Tieton Dam	Tieton River, Washington	Kalin et al. 2002
Timothy Lake	Upper Clackamas River, Oregon	Shibahara and Filbert 2003
Cooper Lake	Alaska	Long View Assoc. and Northern Ecological Services 2004
Libby Reservoir	Kootenai River, Montana	Skaar et al. 1996
Butt Valley Reservoir	NF Feather River, California	PG&E 2002
Lake Almanor	NF Feather River, California	PG&E 2002
Barney Reservoir	Trask River, Oregon	USACE 1994
Florence Lake	Upper San Joaquin R., California	S. California Edison 2005
Huntington Lake	Upper San Joaquin R., California	S. California Edison 2005
Shaver Lake	Upper San Joaquin R., California	S. California Edison 2005
Mammoth Pool	Upper San Joaquin R., California	S. California Edison 2005

4.2.1 Lake Lemolo

Lake Lemolo is a 415-acre reservoir on the North Fork Umpqua River in southern Oregon. It is operated as a storage-release reservoir for hydropower generation. Its intake depth is 110 feet when the reservoir is full and 60 feet deep at low pool elevation in the fall. Therefore, its intake depth is similar to that at Spada Lake.

Lake Lemolo supports a self-sustaining population of mostly brown trout. Angler catches of brown trout (>8 inches) in 1992 and 1996 were estimated to be 7,732 and 9,010, respectively. Assuming an annual harvest rate of 50 percent provides a population estimate of approximately 17,000 trout larger than 8-inches. An assumed ratio of two smaller fish (<8 inches) to one larger fish would yield a total brown trout population estimate of 51,000.

Trout entrainment was evaluated with the use of fyke nets that sampled the entire flow in the diversion canal leading to the powerhouse. The net was deployed 2 to 4 days a week seasonally over a 5-year period, for a total of 226 weeks. In terms of sampling frequency and sampling gear efficiency, this was one of the best-designed and best-implemented trout entrainment studies reviewed.

Results compared annual entrainment estimates for high drawdown years (36 to 44 feet) to low drawdown years (11 to 22 feet). For the high drawdown years, the annual entrainment estimate was 1,632 trout. For the low drawdown years, the average entrainment estimate was 1,005 trout. By far, most of the entrainment occurred in the fall just as the reservoir was reaching maximum drawdown. In the high drawdown years the lake volume at low pool was only 12 percent of the volume at the year's maximum pool elevation.

Most (86 percent) of the entrainment occurred at night, and the average size of entrained trout was 4 inches. Based on average entrainment of 1,319 trout for the years studied and an estimated trout population of 51,000, the annual entrainment would equate to a rate of 2.6 percent of the population.

4.2.2 Tieton Dam

Tieton Dam forms Rimrock Lake on the Tieton River, a major tributary of the Yakima River in Washington. The reservoir, with 2,526 surface acres and a total storage volume of 198,000 acre-feet, is similar to Spada Lake. The intake depth is 200 feet at full pool. The intake capacity is 2,760 cfs, but flows ranged from 300 cfs to 2,200 cfs during the entrainment study. In regards to these physical conditions, the reservoir and outlet works are similar to those at Spada Lake. At the time of the study in 2001, the discharge was through a jet valve.

The dominant fish species in Rimrock Lake is kokanee salmon, which is self-sustaining. The second most common species is rainbow trout, which is supported by hatchery plants. WDFW plants approximately 60,000 rainbow trout fingerlings every few years. The lake also contains bull trout.

Entrainment sampling was done by deploying fyke nets on each side of the river in the tailrace approximately 400 meters below the dam. The investigators were not able to estimate the proportion of flow sampled. The sampling occurred from August 27 through October 17, 2001 to coincide with the maximum seasonal water withdrawal for downstream irrigation. This was also the season when kokanee were most susceptible to entrainment based on previous studies at the site.

During the 7-week sampling period, a total of 10,943 mostly sub-adult kokanee salmon were captured. Of these, 81 percent were dead, indicating the probable mortality rate associated with passage through the jet valve. During the sample period, 37 rainbow trout also were captured. Of these, only 9 were dead, suggesting that most of the live trout had been residing in the tailrace rather than entrained.

The study results indicate that sub-adult kokanee are highly susceptible to entrainment through the deep intake at Tieton Dam due to their preference for deep water. Kokanee entrainment was minimal at the low discharge rates when approach velocities were less than 4 fps. Kokanee entrainment increased significantly as approach velocities reached their maximum of 10 fps. The study concluded that rainbow trout entrainment was minimal.

4.2.3 Timothy Lake

Timothy Lake is on the upper Clackamas River system in Oregon. The lake surface area is 1,280 acres and has an outlet structure 80 feet deep at full pool. In these regards it is similar to Spada Lake. Water passes through a Howell-Bunger valve with a maximum discharge capacity of 300 cfs. The reservoir is used for seasonal storage of water that eventually passes through several downstream powerhouses of the Clackamas River Hydroelectric Project. The reservoir level is maintained near full during the summer recreation season and then is drawn down in the fall. The lake supports a popular trout fishery.

The most common fish in Timothy Lake is brook trout, which are maintained through natural reproduction. Rainbow trout is the second most common fish, but they are supported entirely by hatchery plants. The Oregon Department of Fish and Wildlife plants 12,000 to 34,000 catchable-sized rainbow trout in the lake annually. The lake also contains cutthroat trout and kokanee salmon, both supported by natural reproduction.

Entrainment sampling was conducted at Timothy Lake in August, September, and October, 2000, April 2001, and May and June 2002. Sampling gear included a screw trap and several gill nets deployed in the tailrace just downstream of the dam discharge. After a total sampling effort of 211 hours of gill netting and 814 hours of screw trapping, only one trout (cutthroat) was determined to have been entrained through the outlet works. This is a remarkably small number considering that Timothy Lake supports a trout population that probably exceeds 100,000 fish.

4.2.4 Barney Reservoir

Barney Reservoir is a water supply reservoir on the upper North Fork Trask River in Oregon’s coastal range. It stores water for transfer to the upper Tualatin River, where it is withdrawn for municipal water supply. The 200-acre reservoir supports a naturally reproducing population of cutthroat trout as well as non-native yellow bullhead. Water is withdrawn at a maximum rate of 68 cfs from the bottom of the reservoir at a depth of 70 feet. As part of studies to assess impacts of enlarging the dam, discharge water was sampled with an inclined-plane trap positioned in a concrete receiving basin below the outlet. Approximately half of the discharge passed through the fish trap. Continuous sampling from June through October collected 26 yellow bullheads (4- to 7-inches) but no cutthroat trout. The study concluded that trout were not susceptible to entrainment, probably because of the depth of the intake.

4.2.5 Cooper Lake

Cooper Lake is a reservoir in Alaska that supplies flow to a hydroelectric project. The reservoir surface area is 2,800 acres. The powerhouse intake is set back from the lake shore by about 100 feet. The intake flow capacity is 380 cfs, and the top of the intake is 32 feet deep at full pool and 8 feet deep at minimum pool. Maximum approach velocity at the intake trash racks is 1.57 fps.

Cooper Lake supports populations of naturally reproducing arctic char and rainbow trout. Population estimates are 109,000 char >180 mm (7 inches) and 6,000 rainbow trout >180 mm.

Entrainment studies were done with use of an underwater camera positioned in the intake channel. In conjunction with the entrainment studies, other observations were made of fish depth and shoreline preference in the lake and near the intake. During the study period, the camera observed a few char but no trout. The investigators concluded that there was some low-to-moderate risk of char entrainment because of char's use of the shoreline, preference for depths similar to the intake depth, and possible spawning in the intake channel. For rainbow trout they concluded that entrainment risk was low because of that species' preference for shallow water, lack of observations in the intake area, and low approach velocity at the intake structure.

4.2.6 Libby Reservoir (Lake Koocanusa)

Libby Dam is a large dam on the Kootenai River in Montana that creates Lake Koocanusa. While it hardly resembles Spada Lake, extensive entrainment sampling at the dam conducted from 1992 to 1994 provides useful information regarding the potential for trout entrainment. The reservoir is 29,000 acres, and the powerhouse has a discharge capacity of 28,000 cfs. Like Spada Lake, the powerhouse has a selective withdrawal intake. Typical intake depths are about 50 feet in the spring and summer, 140 feet in the winter, and 90 feet in the autumn.

Lake Koocanusa supports large populations of kokanee salmon as well as rainbow and cutthroat trout. While there is some natural reproduction of trout, Montana and British Columbia combined release about 100,000 rainbow and cutthroat trout into the lake annually.

Entrainment sampling was conducted using fyke nets at the exits of the powerhouse draft tubes. Hydroacoustic monitoring also was deployed in the forebay to observe fish behavior. Following 501 hours of netting, distributed from January 1992 through June 1994, a total of 13,186 fish were captured. Of these, 97.5 percent were kokanee, of which 74 percent were subyearlings. Only nine rainbow trout and seven cutthroat trout were captured. However, most of the trout were believed to have been tailrace residents rather than entrained individuals. The study concluded that kokanee are highly susceptible to entrainment at Libby Dam, especially as subyearlings, but that trout are not.

4.2.7 Butt Valley Reservoir (North Fork Feather River)

Butt Valley Reservoir is a large reservoir in northern California on Butt Creek, a tributary to the North Fork Feather River. The reservoir size (1,600 acres), powerhouse intake depth (60 feet), and intake capacity (1,114 cfs) are similar to Spada Lake. The primary fish species in the lake are rainbow trout and non-native pond smelt. Fish entrainment sampling was conducted using a rigid-framed fyke net deployed in the tailrace below the powerhouse. It was estimated that 40 to 60 percent of the discharge flow passed through the net. Sampling was done for two 24-hour periods per month from June through November 2001.

During the study period, 35,656 pond smelt and 4 prickly sculpin were captured. No trout were captured.

4.2.8 Lake Almanor (North Fork Feather River)

Lake Almanor is a large reservoir (28,252 acres) impounding the North Fork Feather River. The powerhouse intake has a flow capacity of 2,000 cfs and is located at a depth of 100 feet (maximum), both similar to conditions at Spada Lake. Primary fish species include rainbow trout, pond smelt, smallmouth bass, and sculpin. Entrainment sampling was conducted using tailrace netting during two 24-hour periods per month from June through October 2001.

During the 5-month sampling period fish captures included 91,616 pond smelt and only 3 rainbow trout.

4.2.9 Florence Lake (Big Creek Hydro Project)

Florence Lake is a 970-acre reservoir in the upper San Joaquin River basin of central California. Its intake depth (107 feet) and flow capacity (1,500 cfs) are very similar to those at Spada Lake. Florence Lake supports populations of brown trout and rainbow trout.

Entrainment sampling was conducted using fyke netting in the powerhouse tailrace. The sampling schedule consisted of one day per month in December, January, March, July, August, and September (2001 to 2003). During the total sampling period, only two brown trout and one rainbow trout were captured.

4.2.10 Huntington Lake (Big Creek Hydro Project)

Huntington Lake is a 1,538-acre reservoir on Big Creek, a tributary of the San Joaquin River. Maximum depth of the intake is 128 feet. The powerhouse intake capacity is 675 cfs.

The lake supports brown trout, hatchery-planted rainbow trout, Sacramento sucker, and sculpin. Sampling was conducted using tailrace netting three days per month, every other month, between July 2003 and August 2004. During the sampling period no fish of any species were captured.

4.2.11 Shaver Lake (Big Creek Hydro Project)

Shaver Lake is on Stevenson Creek, a tributary of the San Joaquin River. Its size (2,141 acres) and powerhouse intake depth (136 feet) are similar to those at Spada Lake. The intake flow capacity is 670 cfs. The lake supports rainbow trout, Sacramento sucker, smallmouth bass, bluegill, and crappie.

Entrainment sampling was conducted using tailrace netting for three days every other month, from 2003 to 2004. No fish of any species were captured.

4.2.12 Mammoth Pool (Big Creek Hydro Project)

Mammoth Pool is an impoundment on the upper San Joaquin River. Its size (1,287 acres) and intake capacity (2,110 cfs) are similar to Spada Lake. The intake at full pool is 225 feet deep. The lake supports mostly brown trout and some hatchery-planted rainbow trout.

Entrainment sampling was conducted using tailrace netting for three days every other month, from 2003 to 2004. No fish of any species were captured during the study period.

4.3 Summary of Reviewed Trout Entrainment Studies

For the sites that have physical and environmental conditions similar to those at Spada Lake, very few, if any, trout were observed to be entrained. Although several factors undoubtedly contribute to this conclusion, a deep intake is the most notable factor. Trout tend to be surface oriented in lakes, and thus would not be expected to occur normally near deep intakes. Of the 10 sites with similarities to Spada Lake (excluding Libby and Barney reservoirs), none showed significant trout entrainment. Only at Lake Lemolo were there notable numbers of any trout entrained. At that site, however, most of the entrainment involved brown trout and occurred when the lake level was approaching its seasonal drawdown limit, which equates to a pool volume of only 12 percent of its full-pool volume; a condition never reached in Spada Lake.

5.0 Discussion and Conclusions

On the basis of our review of trout entrainment studies at other sites and our understanding of environmental conditions and facility operations at Spada Lake, we conclude that the risk of resident trout entrainment at Spada Lake is very low under most conditions currently occurring in the lake. The primary reasons for reaching this conclusion include the following:

- Trout, compared to other species, appear less apt to leave their rearing reservoir, especially if the trout are naturally produced within the system (i.e., non-hatchery).

- The powerhouse intake tunnel near Culmback Dam typically withdraws water from a much deeper depth than that preferred by trout in Spada Lake (see Figure 4.1). Results of other entrainment studies clearly indicate the low risk of rainbow or cutthroat trout being entrained at deep intakes.

- The likelihood of density-dependent downstream dispersal is less for trout compared to other species because they tend to be less fecund than most other species, and their young are not “produced” in the reservoir. The rainbow trout population in Spada Lake is currently limited by a parasite and low nutrients, thus making it less likely that the population is density-dependent (i.e., over-crowded or past its carrying capacity), which may otherwise make fish inclined to leave the reservoir.

- Small subyearling trout are rarely observed in Spada Lake because they apparently remain in the tributary streams for one or more years before entering Spada Lake

(Stables and Thomas 1992; Pfeifer et al. 1998). This is important because all studies of other species and the few studies of trout indicate that smaller fish are much more likely to become entrained.

- Seasonal drawdown of Spada Lake is relatively minor compared to that at many other projects. At the maximum average annual drawdown occurring in late summer (approximate elevation 1,420 feet) Spada Lake retains 67 percent of its full-pool volume (see Figure 2-2).

Although entrainment risk at Spada Lake is very low under most circumstances, there is a short time period in March and April when trout may be more likely to enter the intake tower than at other times of the year. This potential is best demonstrated by understanding the relationships among seasonal lake elevation, intake panel settings, and average trout depth, as depicted in Figure 5-1. Up until a few years ago, water at Spada Lake was withdrawn into the intake at the lowest elevation panel year round (configuration E). In recent years, however, operators have been withdrawing water via panel C nearer the surface (but not at the surface) at times in March and April (Table 5-1). This has been done to conserve the deeper cool water for use in late summer to maintain target temperatures downstream of Culmback Dam and the Diversion Dam. If instream flow requirements increase in the future for these reaches, the need to conserve the cooler deep water during the spring will become even more important. It is during this time period that some trout may enter the intake tower, although they may not necessarily become entrained into the power tunnel.

Even though there may be a higher possibility for exposure at this time of year, the following considerations further suggest that any trout entrainment into the power tunnel still may be minimal.

- The water withdrawal rates during the spring average ~800 cfs and, therefore, the corresponding withdrawal velocities (2.15 fps) are still far below the maximum escape velocity of a trout.

- Most trout at this time of year tend to be in water less than 7 feet deep (see Figure 4-2).

- Any trout that would enter the intake structure would still have to willingly swim downward about 40 feet to enter the power tunnel.

- The total annual number of “exposure” days under Panel Configuration C conditions is small, and, therefore, effects on the trout population, if any, would likely be insignificant.

By mid-May most of these conditions have changed (see Figure 5-1). The lake level rises about 10 feet, making the water withdrawal deeper. Also, the intake panel configuration changes to lower and deeper elevations by early May. From July through March water is typically withdrawn from the deepest panel setting.

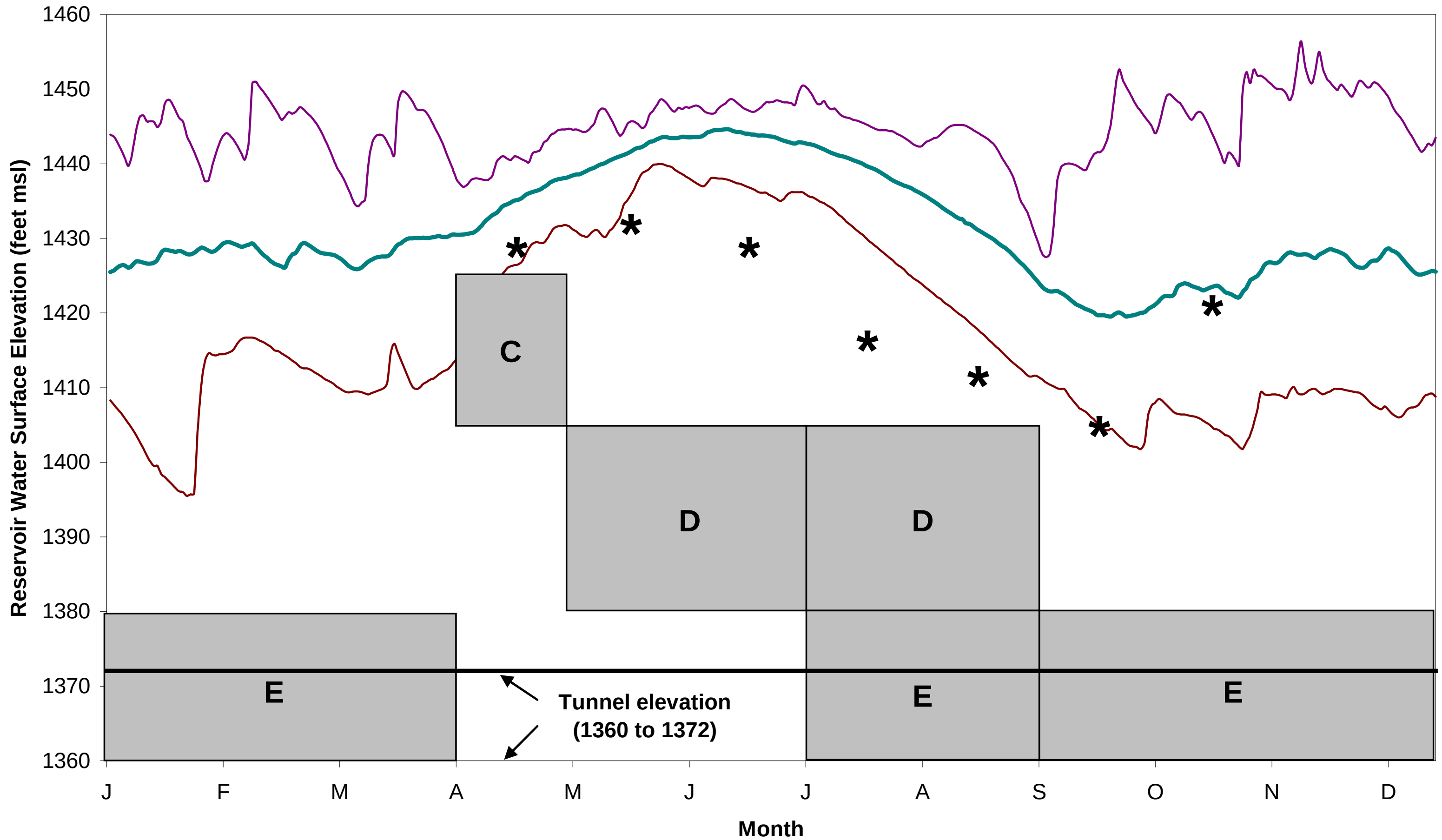

Figure 5-1. Spada Lake Minimum, Maximum, and Average Water Levels Observed (1990 to 2005). Relative to Elevations of Typical Outlet Panel Configurations C, D, and E and Outlet Tunnel. Also, Shown as Asterisks are Average Depths of Trout (below Average Lake Level) Based on April – October Data from Pfeifer et. al. (1998).

Table 5-1. Operation in Panel Configuration C

Year	Dates	Total Days
2004	3/30-5/03	33
2005	4/11-4/28	17
2006	4/20-5/15	25
2007	3/12-3/16	4

In summary, the risk of trout becoming entrained into the powerhouse intake or other outlet structures at Spada Lake appears to be very low based on the results of several recent studies at similar sites coupled with an understanding of what is known about the trout population, physical conditions, and current operations at Spada Lake. The major contributing factors to this general conclusion are: 1) exposure to spillway overflow is very infrequent, 2) the depth of the Culmback Dam diversion tunnel, at greater than 200 feet, is far below the range of the resident trout population, and 3) the normal depth of the power tunnel intake structure inlet is approximately 50 feet, a depth at which most trout are not found. The fact that very few small-sized juvenile trout rear in Spada Lake also is a contributing factor because studies elsewhere have shown that larger fish with greater swimming capabilities and perhaps more fidelity to their rearing habitat are much less likely to become entrained. While there is a possibility for some trout to enter the intake tower in the early spring, we believe that the number actually entrained into the power tunnel, if any, would be low and not likely enough to be detrimental to the trout population or associated recreational fishery in Spada Lake.

Based on the above analysis the co-licensees do not consider a Phase II field study of trout entrainment to be warranted at this time.

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Appendix A

Spada Lake Powerhouse Intake Structure, Movable Panel Configurations

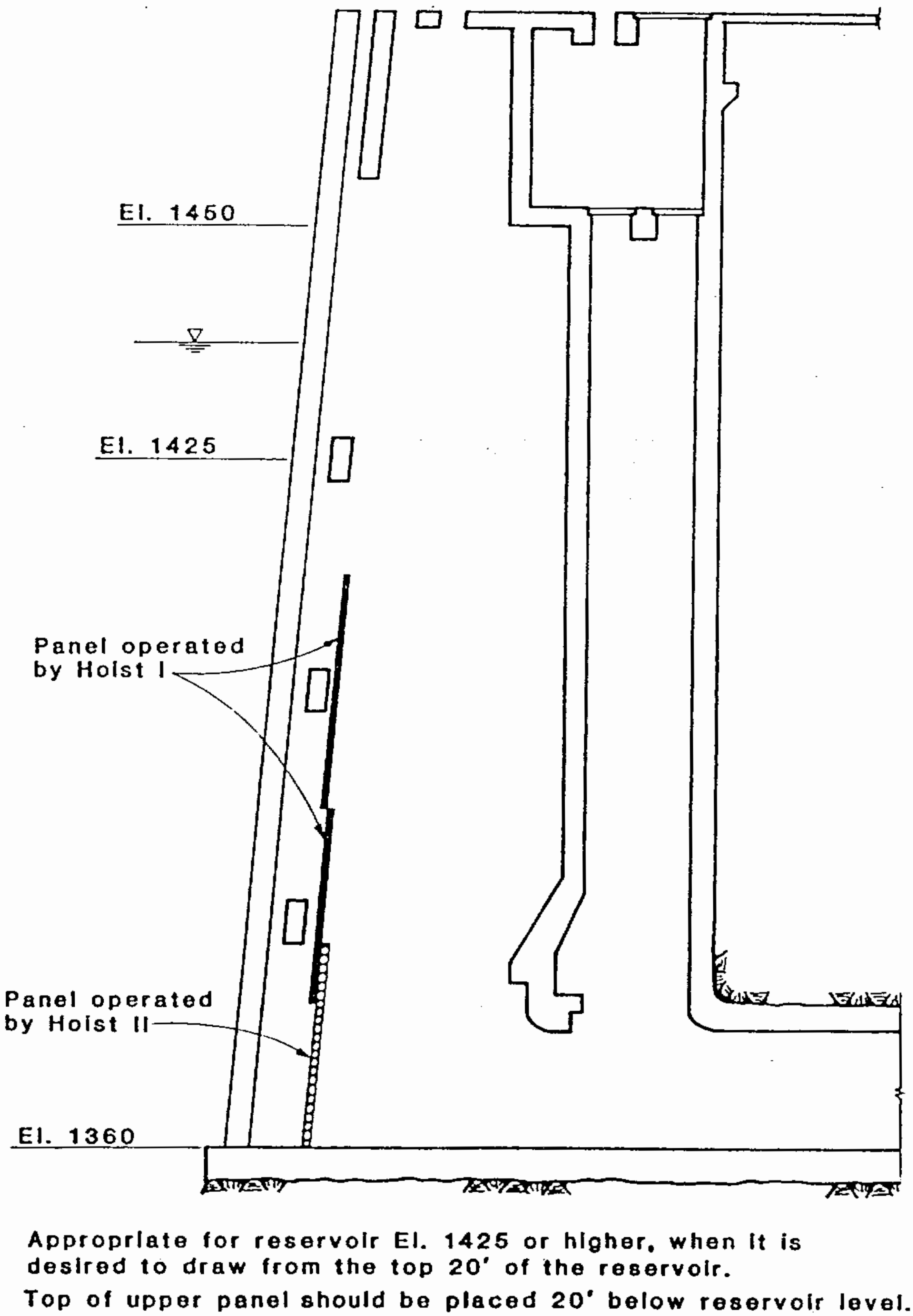


Figure 2. Powerhouse Intake Structure Moveable Panel Configuration A

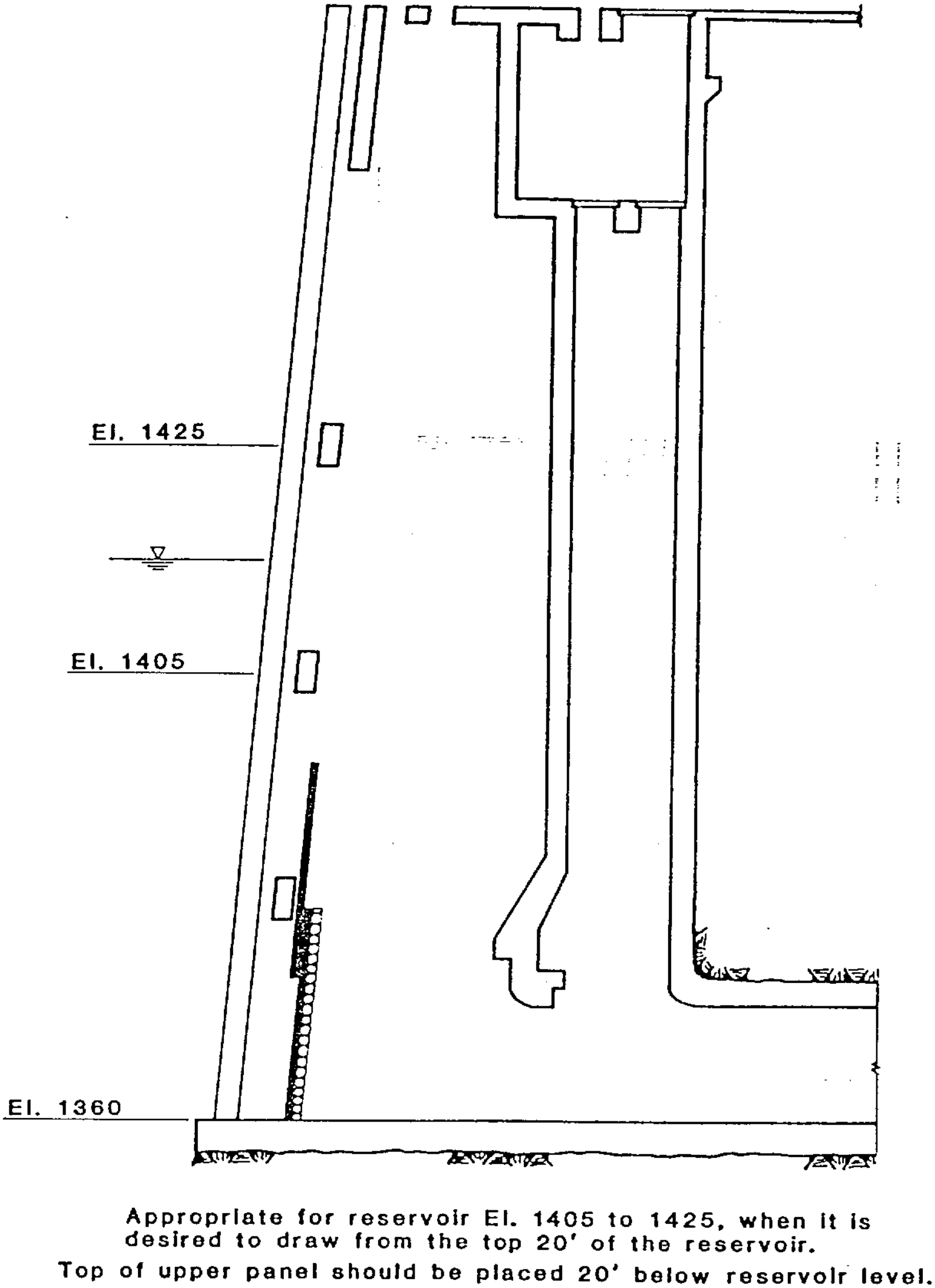
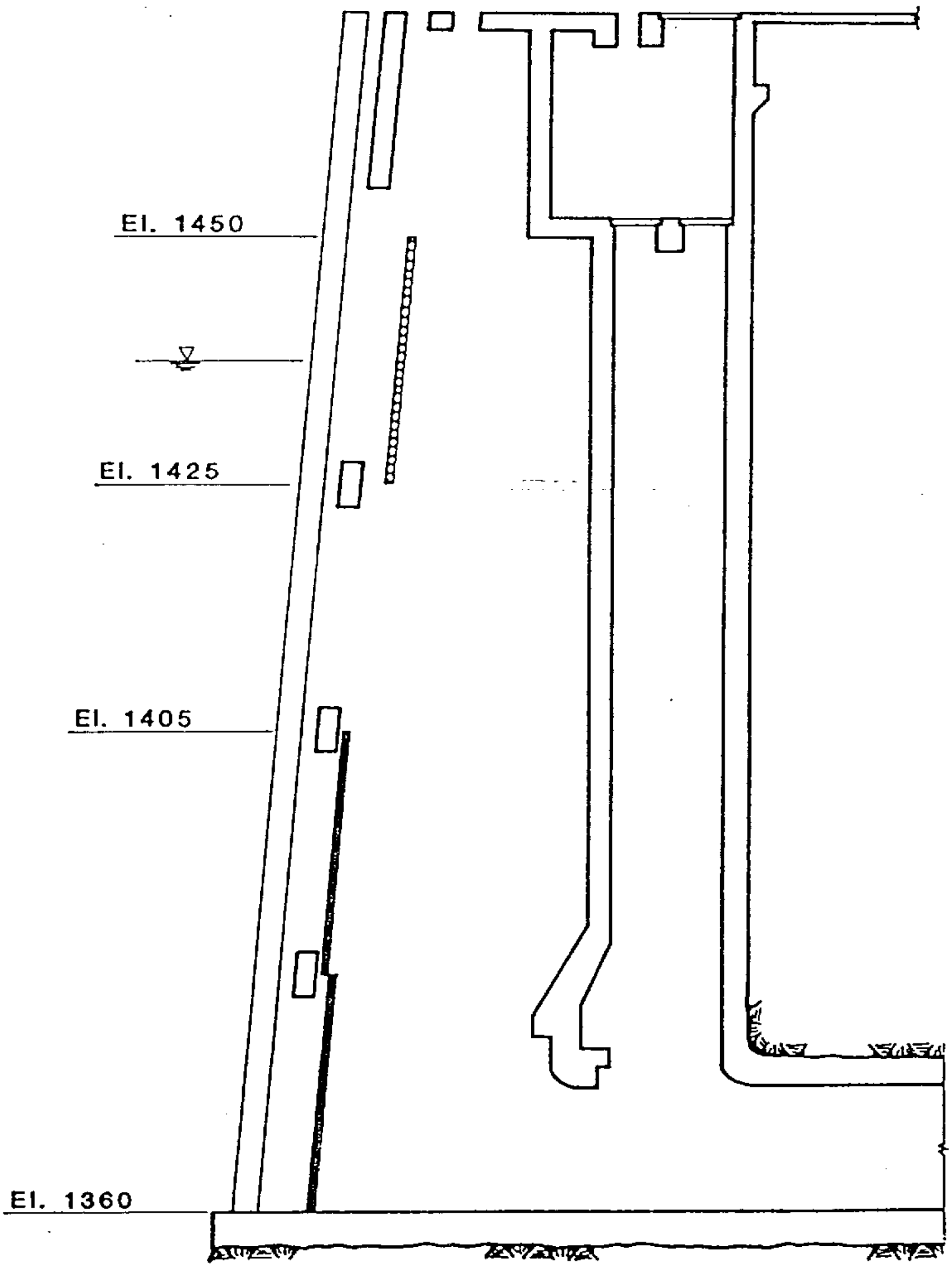
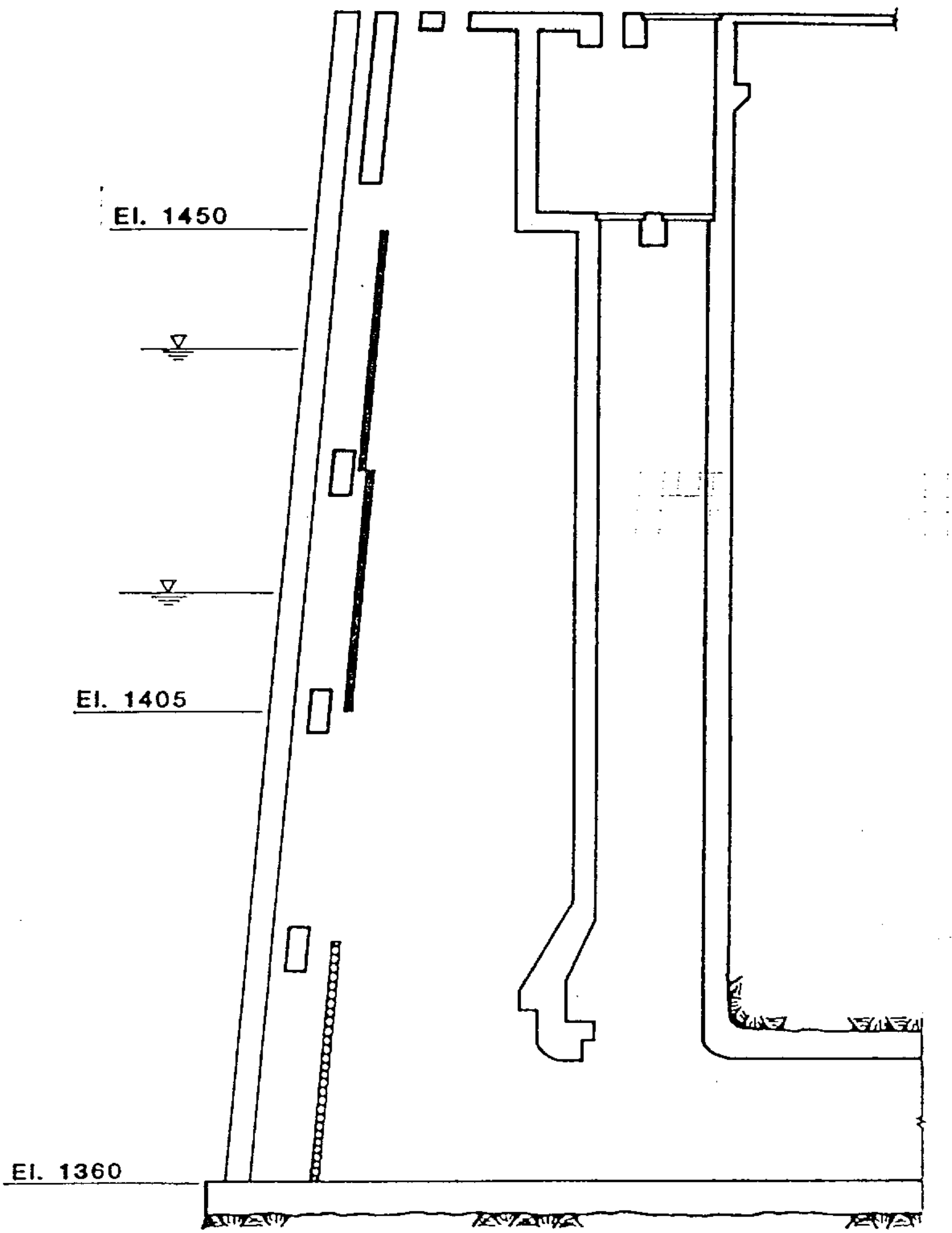


Figure 3. Powerhouse Intake Structure Moveable Panel Configuration B.



Appropriate for reservoir El. 1425 or higher, when it is desired to draw water from the band between El. 1405 and El. 1425.

Figure 4. Powerhouse Intake Structure Moveable Panel Configuration C.



Appropriate for any reservoir level, when it is desired to draw water from the band between El. 1380 and El. 1405.

Figure 5. Powerhouse Intake Structure Moveable Panel Configuration D.

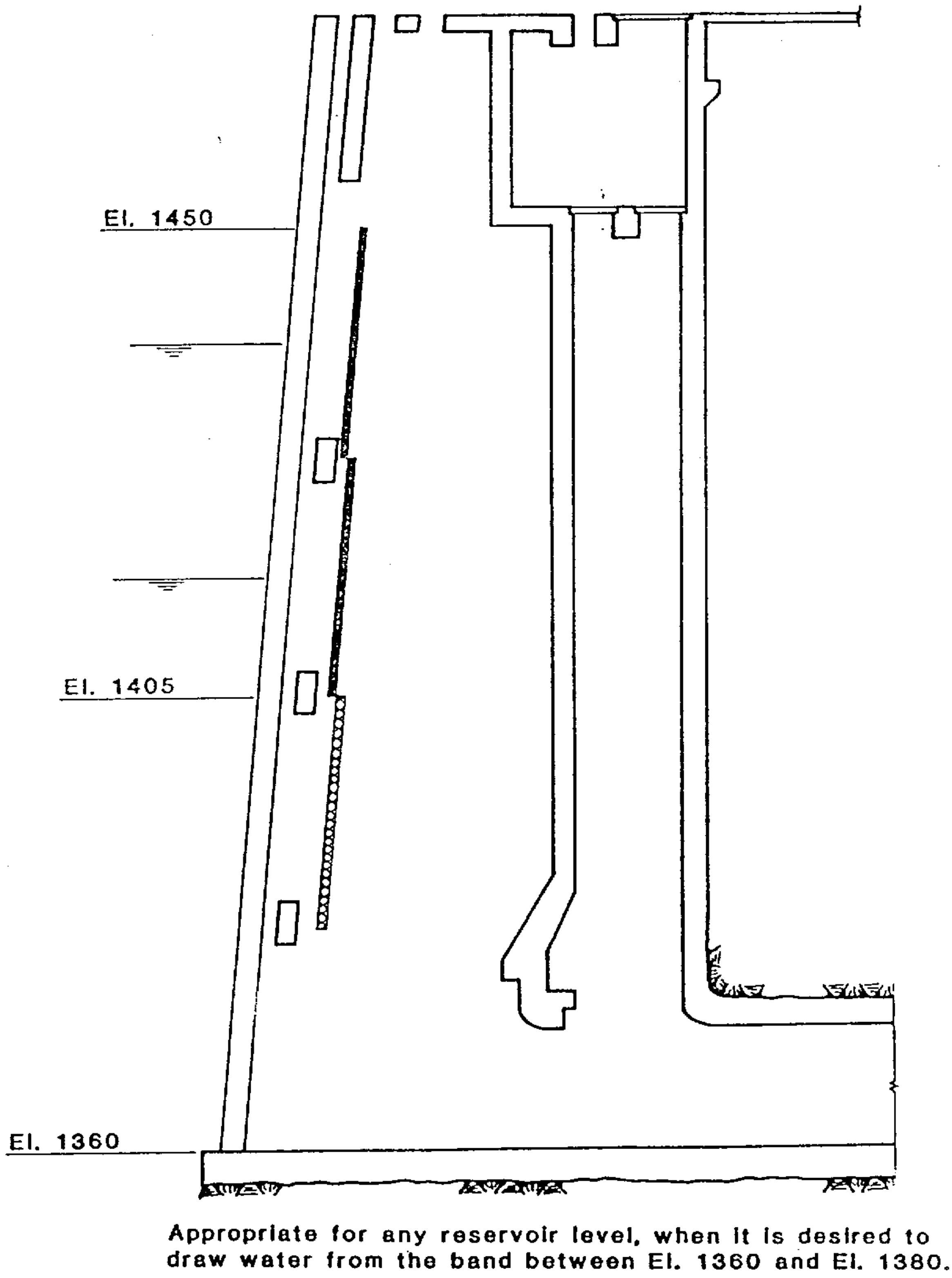


Figure 6. Powerhouse Intake Structure Moveable Panel Configuration E.

Appendix B

Stakeholder Comments on Draft Report

Potential for Trout Entrainment

From: Meaker, Bruce [BFMeaker@snopud.com]
Sent: Wednesday, October 03, 2007 10:24 AM
To: Olson, Forrest/SEA; Pam Klatt
Cc: Presler, Dawn; Moore, Kim; Binkley, Keith
Subject: FW: Jackson Project (FERC No. 2157) - RSP4 Asmt of Spada Lk Trout Entrainment DRAFT technical report for your review

Forrest/ Pam,

Here is the comment made by Tim Romanski on the entrainment study. On the DD tour I told Tim that even with the lake stocked at higher population levels, the report was saying that the CD facilities are not conducive to entrainment because of the depth of withdrawal. He said he would look at it again.

Also on the tour I asked Rich Johnson of WDGW about the report. He said that his concern was what if they want to change the fish stock in the reservoir to kokanee, which do run at deeper levels. I said I would assume that they would have to do an environmental assessment on such a change in management.

Bruce

-----Original Message-----
From: Presler, Dawn
Sent: Monday, September 10, 2007 8:31 AM
To: Meaker, Bruce; Binkley, Keith; Moore, Kim
Cc: 'Julie Sklare'; 'Tom Thetford (tthetford@ci.everett.wa.us)'
Subject: FW: Jackson Project (FERC No. 2157) - RSP4 Asmt of Spada Lk Trout Entrainment DRAFT technical report for your review

Fyi...comments on SP4 tech rpt below...

-----Original Message-----
From: Tim_Romanski@fws.gov [mailto:Tim_Romanski@fws.gov]
Sent: Monday, September 10, 2007 8:08 AM
To: Presler, Dawn
Subject: Re: Jackson Project (FERC No. 2157) - RSP4 Asmt of Spada Lk Trout Entrainment DRAFT technical report for your review

Dawn,

I do not have many comments on the report, but I think the report misses a key issue. The report basically states that trout are not likely to get entrained because there are not many of them to entrain. How would results of the report change if numbers were increased during the term of the license. I think that is the question that needs to be answered by any study. If the lake is fully stocked, would entrainment be an issue or would other factors in the report (depth of tunnel, preference by fish to remain in lake, etc) affected entrainment more?

Tim Romanski
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Western Washington Fish and Wildlife Office
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Subject
Jackson Project (FERC No. 2157) -
RSP4 Asmt of Spada Lk Trout
Entrainment DRAFT technical
report
for your review

Dear Aquatic Resources Working Group:
Please see attached RSP4: Assessment of Spada Lake Trout Entrainment cover letter and draft technical report.

Comments on the draft report can be emailed or mailed to me by Thursday October 4, 2007 (email and mailing addresses are identified in the cover letter). Thanks!

Dawn Presler
Relicensing Coordinator
Jackson Hydroelectric Project (P-2157)
Snohomish County PUD
Phone: 425-783-1709
Fax: 425-267-6369

[attachment "Jackson2157_SP4_draft_tech_rpt_083107.pdf" deleted by Tim Romanski/WWO/R1/FWS/DOI] [attachment "Jackson2157_CL_SP4_draft_tech_rpt_090407.pdf" deleted by Tim Romanski/WWO/R1/FWS/DOI]

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Comments by Steward and Associates on

DRAFT FINAL REPORT

Potential for Resident Trout Entrainment in Spada Lake, Washington – RSP4

28 September 2007

The authors of this study strongly conclude that the results of their literature review and data analysis do not warrant further field study of entrainment effects on trout in Spada Lake. While this study identifies information from many sources regarding entrainment in hydro project facilities, it is apparent that many of these studies are irrelevant and that some of the basic data needed to reach a conclusion on hydroelectric facility entrainment of trout in Spada Lake are missing from the analysis or not explained in enough detail to be truly meaningful to a well-informed reader.

Apart from a lack of solid information to support the report's conclusions, there are many errors present in the narrative. Typically, the occasional typo can be forgiven in a large document, but there are errors in this report that suggest a lack of technical rigor. Some examples of this include:

- The scientific names of rainbow trout and cutthroat trout used in the report are outdated by many years. They should be *Oncorhynchus mykiss* and *Oncorhynchus clarki*, respectively. (page 1, fourth paragraph)
- Several reference names are misspelled or misdated
- The hydroelectric facility's operational states in Section 2.3 appear to be explained backwards. For example, State 1, which is shown as constant full-pool elevation in Figure 2-7, is described as the State that provides winter flood storage. A full reservoir cannot provide any flood storage.

The following paragraphs provide detailed comments on particular sections that were used to support the authors' conclusions.

Section 4.1.1, a discussion of certain fish species' potential for entrainment, appears to have flawed conclusions and contradictory statements in several places. The section states that, "Pelagic species such as gizzard shad and landlocked alewife can be highly susceptible to entrainment where present." Rainbow trout are well-known to be pelagic species. This is not noted, however, and the section concludes by implying that rainbow trout are not susceptible to entrainment, despite the following text: "**Relevance to Spada Lake:** Trout occurred only rarely in the previously-reviewed study sites, so little can be concluded from them regarding Spada Lake." This seems to undermine the relevance of the entire section.

Section 4.1.1 ends by noting fish observations of district staff. These observations supposedly support the notion the trout are rarely entrained at Spada Lake, yet, the presence of dead brown bullhead downstream of the hydroelectric facilities and absence of rainbow trout is not sufficient evidence to conclude that trout are unlikely to be entrained. It may simply be that bullhead spines cause the fish to hang up more easily around structures and are more likely to be seen by staff or that the tougher flesh of bullheads holds up to entrainment abuse better than trout.

Section 4.1.6, a discussion of water withdrawal depth, seems to be the crux of the report. Its conclusions are used to support the notion that no further entrainment research is necessary, so it should also have the best scientific backing. Past research in Spada Lake may have shown that trout typically reside in depths above the intake areas, but more detail is required to reach this conclusion. If gillnet, setline, and hydroacoustic data exists, then figures displaying the known seasonal depth distribution of trout in comparison to seasonal intake depths should be utilized. This is a basic data need and essential for making preliminary entrainment conclusions.

In addition, Section 4.1.6 only uses two references: Stables and Thomas (1992), and Warner and Quinn (1995). Warner and Quinn's study took place on Lake Washington, which is a slow-flushing (once every two years), mesotrophic lake that is much more productive than Spada Lake and has an entirely different fish assemblage, including an abundance of piscivores. These differences make comparisons between Spada Lake and Lake Washington almost irrelevant. Section 4.1.6 may make the correct conclusions, but its discussion and data analysis need to be greatly expanded. The abstract for the Stables and Thomas paper appears to have the data required to make comparisons between seasonal depth distributions of trout and seasonal dam intake depths.

Section 4.1.7 states, "…the Project is operated such that the greatest drawdowns typically occur in the fall and winter months when fish activity and associated entrainment potential is expected to be the lowest." Yet, no reference, tables, or figures illustrating known fish activity or distribution is provided.

Section 4.1.8 states, "Spada Lake does not have a particularly high discharge rate compared to most hydroelectric projects where entrainment studies have been conducted." Yet, no tables or figures are presented to compare Spada Lake discharge rates to other projects. Section 2.2.1 states that the intake structure of the dam has a maximum flow capacity of 1,300 cubic feet per second. This seems like very significant flow to a trout. In addition, the relative difference between Spada Lake discharge and other projects is irrelevant if there is simply a discharge threshold that trout cannot withstand. There is no discussion of this possibility in Section 4.1.8, but the next section does begin to confront the issue.

The logic of Section 4.1.9 is flawed. In the first paragraph, the authors state that when challenged with intake flows, fish may elect to, "…simply go with the flow…" or, "…have an opposite response to the current…" While there is no reference discussing the known behavioral response of trout to flow challenges, the authors do admit that a choice to go with or against the flow was possible for trout. Yet, the second paragraph of this section concludes that the burst speed of a 6-inch trout can out swim the maximum intake velocity, therefore trout will not be entrained. What if the trout does not respond with a burst swim and simply follows the flow of the intake? What if the total burst time does not allow the trout to swim far enough to get out of the intake area? This Section's narrative could be greatly improved with an expanded literature discussion. If literature that discusses the behavioral response of trout to intake flow or other high velocity situations is not available, then further field research is warranted.

Section 4.2 is a review of trout entrainment studies. To determine which studies were relevant, six factors were considered: project location, primary fish community, reservoir size, reservoir depth, intake depth, and flow capacity. Although thermal profiles, dissolved oxygen profiles, and flow management regimes would also be very important to consider, the six listed factors are an excellent start for determining the relevance of other studies. Unfortunately, the authors did not consistently list the values of each of these factors for each study site referenced. Instead, factors were selectively chosen or described in different ways that made comparison between sites difficult.

For example, the discussion of the first study site, Lake Lemolo, did not include any discussion of the fish community outside of brown trout or flow capacity of the intake structure. It also does not discuss any behavioral or life history differences between brown trout and rainbow trout. They can have quite different feeding strategies and habitat preferences that would affect their entrainment potentials. Further into the review, it is also apparent that some of the study sites, such as Barney Reservoir, bear little limnological or hydroelectric facility resemblance to Spada Lake.

In summary, it is possible that the authors are accurate in concluding that trout entrainment susceptibility is minimal in Spada Lake. It is our belief, though, that the authors have made a very good case for entrainment issues being system-specific and dependent on many factors that are not comparable across watersheds. Without an expansion of the literature review and a more rigorous data analysis that addresses the concerns listed above, we find it impossible to support the conclusion that a field study to assess trout entrainment on Spada Lake is not warranted.

If Phase II field research is deemed to be important for the relicensing project, then many options exist to examine entrainment of trout. For example, the use and application of a DIDSON (Dual-frequency Identification Sonar) acoustic camera could provide extremely valuable information about the behavior and movement of Spada Lake trout near the intake structure during a series of flow release experiments. The acoustic camera would allow constant observation of fish as they approach the intake structure. The DIDSON acoustic camera technology has been successfully utilized in many research studies, including the implementation of juvenile salmonid passage technologies at the Cowlitz Falls Dam on the Cowlitz River in southwest Washington.

Tulalip Tribes' Draft Comments on the Jackson Hydroelectric Project (FERC No. 2157) Initial Study Report (ISR)

November 6, 2007

This memorandum summarizes the Tulalip Tribes' technical and policy review of the Initial Study Report (ISR) for the Henry M. Jackson Hydroelectric Project (FERC No. 2157) released by the Snohomish County Public Utility District (PUD) on October 12, 2007. Thank you for the opportunity to comment.

The Tribe has been supportive of the Integrated Licensing Process and has participated fully in the development and vetting of study plans. After reading the ISR, we are concerned with the lack of detail and actionable information conveyed by the report. Based on our understanding of 18 CFR 5.15, FERC requires the applicant to provide any data that have been collected as part of the individual studies to be included in the ISR. Many of the studies listed in the ISR provide a description of the type of data collected, and some provide a summary of the data collected, but nowhere do we see a compilation of the actual data. In order to be able to accurately assess the status of the studies, initial findings, the need to modify the approach taken during next year's field season, and, potentially, to amend or dispute the study plans and findings, we must have access to the information that FERC stipulates be included in the ISR. Therefore, we request that the data collected during the recently completed field studies be made available to the Tribe and other members of the Resource Working Groups, consistent with FERC requirements.

We recognize that modification of study plans is a practical and common response to conditions not anticipated during the planning phase. While many of the individual study descriptions in the ISR identify why and how approaches and tasks had to be altered in certain instances to meet the original study objectives, and acknowledge the occasional failure to implement elements of the study as originally planned, this type of information is for the most part lacking in the study descriptions. As a consequence, we were frequently forced to compare the ISR reports with the original (revised) study plans to ascertain what changes were made, to attempt to infer the reasons for doing so, and to consider the overall effect of these developments on the quality and interpretability of the studies.

RSP 2: Bypass Reach Cutthroat Trout Population Analysis

1. Chapter 2.0 of the ISR does not provide any preliminary data or enough description of the project status to determine whether the criteria for a population viability analysis are being met. We are left to assume that data leading to an estimate of abundance and the population's age-structure have been collected. Why not provide a simple summary table of the number of fish counted in the August fieldwork effort? At least some idea of species sampled would have been useful. When will the data become available? Maps of selected study sites would be helpful.

2. The RSP clearly outlined methods for estimating abundance in Reach 1a using multi-pass electro-fishing, and in Reach 1b using mark/re-sight snorkel surveys. The 'Method for Bounded Counts' (MBC) identified in the ISR is clearly a departure from the RSP's originally described methods. We understand the difficulty in accessing the bypass reach but is the MBC an appropriate censusing technique for the Sultan River? Our understanding is that MBC is ill-suited for larger streams like the Sultan River.

3. The fish from which genetics samples were to be taken were supposed to be collected from throughout the bypass reach. The ISR, however, indicates that samples were collected from only two locations. Further, despite the goal of 50 pure cutthroat, 50 pure rainbow, and 50 potential hybrids, a total of only 62 samples were taken with no indication of which category they belonged to. Was the shortfall in sample sizes due to a lack of fish, effort, time, or some other sampling issue?

RSP 3: Sultan River Instream Flow Study

1. Comments specific to the draft "proposed study approach for development habitat suitability index (HSI) curves for application in habitat-flow modeling for the Sultan River instream flow study" are included as Appendix A.

RSP 4: Assessment of Spada Lake Fish Entrainment

1. Comments specific to the RSP 4 final draft report "Potential for Resident Trout Entrainment in Spada Lake, Washington" were submitted to the applicants September 28, 2007 and are included as Appendix B.

2. As the comments in Appendix B indicate, we disagree with the conclusion that Phase I has adequately determined whether a field study of trout entrainment in Spada Lake is warranted. We contend that the information needed to make this decision, mainly seasonal trout depths versus seasonal water withdrawl depths, was not presented in the Draft Final Report or Chapter 4.0 of the ISR. A more thorough consideration of the site-specific characteristics of the Culmback project is necessary to determine entrainment potential at this location. Lessons learned from other projects through literature review will only provide some of the answers needed in this case.

3. One objective of the Phase I study listed in the ISR summary was to, "Be consistent with WDFW's Hydroelectric Project Assessment Guidelines…". However, these guidelines are not listed or mentioned in the Final Draft Report released earlier this year.

RSP 5: Life History, Distribution, and Relative Occurrence of Juvenile Salmonids in the Sultan River

1. Can we obtain copies of the primary data that were collected in the field? Are mapping products (e.g., study sites, etc.) available?

From: Presler, Dawn [DJPresler@SNOPUD.com]
Sent: Thursday, October 04, 2007 4:08 PM
To: Meaker, Bruce; Moore, Kim
Cc: Binkley, Keith; Pam Klatt; Olson, Forrest/SEA; Kallstrom, Jeffrey; Julie Sklare; tthetford@ci.everett.wa.us
Subject: FW: Jackson Project (FERC No. 2157) - RSP4 Asmt of Spada LkTrout Entrainment DRAFT technical report for

See email below for WDFW comment re: SP4 draft technical report.

Dawn

-----Original Message-----
From: Rich Johnson [mailto:JOHNSRJ@DFW.WA.GOV]
Sent: Thursday, October 04, 2007 4:00 PM
To: Presler, Dawn
Subject: Re: Jackson Project (FERC No. 2157) - RSP4 Asmt of Spada LkTrout Entrainment DRAFT technical report for

To: Dawn Presler, Snohomish County PUD No. 1
SUBJECT: RSP 4 Spada Lake Trout Entrainment

This draft report appears to meet the objectives set out in the study plan, although it is very brief and cursory in its descriptions of the water intake system, the trout population and life history, and in review of each entrainment study. It seems prudent to utilize the fish sampling information being gathered in Spada Lake as part of RSP 16 to further inform decision making prior to concluding that no field study to assess entrainment is needed.

Rich Johnson
Habitat Biologist
Washington Department of Fish and Wildlife

Appendix C

Responses to Draft Report Comments

Potential for Trout Entrainment

STAKEHOLDER COMMENT	LICENSEE RESPONSE
Rich Johnson, Washington Department of Fish and Wildlife	
E-mail from Rich Johnson 10/04/2007 It seems prudent to utilize the fish sampling information being gathered in Spada Lake as part of RSP 16 to further inform decision making prior to concluding that no field study to assess entrainment is needed.	The fish sampling information collected in 2007 has not yet been fully analyzed. The initial draft report for Revised Study Plan 16: Spada Lake Trout Production (RSP16) will be available in early 2008. However, preliminary results show that the trout were found to be mostly near the surface, and that the highest densities were observed in the eastern portion of the lake (away from dam), especially in the arms of the lake. These findings are similar to observations made in previous years and further support our conclusion that trout entrainment risk is likely to be low at the Project intake located near Culmback Dam at the west end of Spada Lake.
Rich Johnson, ISR Meeting Summary 10/29/2007 Rich Johnson (WDFW) suggested that the report identify the level of the intake compared to the water surface level throughout the year.	As suggested, we have now included in the final report additional information in the form of graphs (Figures 4-1, 4-2, and 5-1) to depict lake levels, intake depths, and trout depths for various times of the year. These data more clearly illustrate the fact that the intake is typically well below the depth of the trout.
Rich Johnson, ISR Meeting Summary 10/29/2007 Rich also pondered the potential entrainment effects that could be expected if WDFW were to introduce kokanee to the reservoir.	Regarding the potential for entrainment of kokanee salmon if they were to be introduced into Spada Lake, we note that the objective of the entrainment review of RSP 4 was only intended to cover resident trout. There are, however, several good studies available on kokanee entrainment. Generally, these studies have shown that kokanee are much more prone to entrainment than trout primarily because they reside in deeper water and the in-lake populations tend to be dominated by small young-of-year individuals. If WDFW seriously considers introducing a non-native fish such as kokanee salmon into Spada Lake, the Co-licensees would expect that the agency would have to consider not only entrainment

STAKEHOLDER COMMENT	LICENSEE RESPONSE
	losses from Spada Lake but also the potential effects that kokanee might have on downstream salmonid populations, especially those listed under the ESA.
Tim Romanski – US Fish and Wildlife Service	
Email dated 09/10/2007 The report basically states that trout are not likely to get entrained because there are not many of them to entrain. How would results of the report change if numbers were increased during the term of the license. I think that is the question that needs to be answered by any study. If the lake is fully stocked, would entrainment be an issue or would other factors in the report (depth of tunnel, preference by fish to remain in lake, etc) affected entrainment more?	If fish numbers in Spada Lake increase in the future, it is reasonable to assume that more fish numerically would become entrained. This may not be true for entrainment rate, however. The current depth of the intake and size structure of the trout population (few small fish) would still suggest that entrainment risk would be low even if the population increased.
Steward and Associates/Tulalip Tribes Comments on RSP 4 Draft Final Report 09/28/2007	
Paragraph 2 The scientific names of rainbow trout and cutthroat trout used in the report are outdated by many years. They should be Oncorhynchus mykiss and Oncorhynchus clarki, respectively. (page 1, fourth paragraph) • Several reference names are misspelled or misdated • The hydroelectric facility’s operational states in Section 2.3 appear to be explained backwards. For example, State 1, which is shown as constant full-pool elevation in Figure 2-7, is described as the State that provides winter flood storage. A full reservoir cannot provide any flood storage.	Edits/corrections have been made in the final report.

STAKEHOLDER COMMENT	LICENSEE RESPONSE
Paragraph 3 The section states that, “Pelagic species such as gizzard shad and landlocked alewife can be highly susceptible to entrainment where present.” Rainbow trout are well-known to be pelagic species. This is not noted, however, and the section concludes by implying that rainbow trout are not susceptible to entrainment, despite the following text: “Relevance to Spada Lake: Trout occurred only rarely in the previously-reviewed study sites, so little can be concluded from them regarding Spada Lake.” This seems to undermine the relevance of the entire section.	This section, 4.1.1, was the summary review of non-trout studies. Nevertheless, we believe it is important to understand entrainment risk factors at non-trout sites because some of those factors may pertain to all species, including trout. An example is the size selectively for entrainment. Regardless of species, smaller fish tend to be more prone to entrainment. We would expect this to be true for trout as well. Regarding our reference to pelagic species like gizzard shad and alewife, we have added to the report that these are *schooling* pelagic species. Trout are pelagic but do not tend to school.
Paragraph 4 Section 4.1.1 ends by noting fish observations of district staff. These observations supposedly support the notion the trout are rarely entrained at Spada Lake, yet, the presence of dead brown bullhead downstream of the hydroelectric facilities and absence of rainbow trout is not sufficient evidence to conclude that trout are unlikely to be entrained.	We did not intend to suggest that the observed absence of trout downstream of Project facilities was, by itself, sufficient evidence to conclude that trout are unlikely to be entrained. It is just one piece of evidence that, in conjunction with rather consistent findings at other sites, is useful in support of our conclusion of low entrainment risk for trout.
Paragraph 5 Section 4.1.6, a discussion of water withdrawal depth, seems to be the crux of the report. Its conclusions are used to support the notion that no further entrainment research is necessary, so it should also have the best scientific backing. Past research in Spada Lake may have shown that trout typically reside in depths above the intake areas, but more detail is required to reach this conclusion. If gillnet, setline, and hydroacoustic data exists, then figures displaying the known seasonal depth distribution of trout in comparison to seasonal intake depths should be utilized. This is a basic data need and essential for making preliminary entrainment conclusions.	As suggested, we have now included in the final report additional information in the form of graphs (Figures 4-1, 4-2, and 5-1) to depict typical lake levels, intake depths, and trout depths for various times of the year. These data more clearly illustrate the fact that the intake is typically well below the depth of the trout.

STAKEHOLDER COMMENT	LICENSEE RESPONSE
Paragraph 6 Section 4.1.6 only uses two references: Stables and Thomas (1992), and Warner and Quinn (1995). Warner and Quinn's study took place on Lake Washington, which is a slow-flushing (once every two years), mesotrophic lake that is much more productive than Spada Lake and has an entirely different fish assemblage, including an abundance of piscivores. These differences make comparisons between Spada Lake and Lake Washington almost irrelevant.	The citation to Warner and Quinn (1995) was included only as a reference to the fact that trout tend to be surface oriented in lakes when feeding pelagically. The fact that the studied lake (Washington) differs from Spada Lake in regard to flushing rate, fish community, and productivity should make little difference in how the trout generally distribute themselves vertically. However, because we do not expand on the topic of feeding behavior, we have removed the text that refers to Warner and Quinn.
Paragraph 7 Section 4.1.7 states, "…the Project is operated such that the greatest drawdowns typically occur in the fall and winter months when fish activity and associated entrainment potential is expected to be the lowest." Yet, no reference, tables, or figures illustrating known fish activity or distribution is provided.	We have modified Section 4.1.7 to indicate that greatest seasonal average drawdown occurs in late summer and fall when water is being withdrawn from the deepest panel settings. In addition, we have added figures elsewhere in the report that illustrate seasonal trout depth distribution in relationship to intake depths.
Paragraph 8 Section 4.1.8 states, "Spada Lake does not have a particularly high discharge rate compared to most hydroelectric projects where entrainment studies have been conducted." Yet, no tables or figures are presented to compare Spada Lake discharge rates to other projects. Section 2.2.1 states that the intake structure of the dam has a maximum flow capacity of 1,300 cubic feet per second. This seems like very significant flow to a trout. In addition, the relative difference between Spada Lake discharge and other projects is irrelevant if there is simply a discharge threshold that trout cannot withstand. There is no discussion of this possibility in Section 4.1.8, but the next section does begin to confront the issue.	Regarding a discharge threshold, we are unaware of any literature suggesting such a threshold. However, there have been studies suggesting that high intake velocities and extreme reservoir draw downs can contribute to higher entrainment rates. Both of these factors are indirectly related to discharge rate, but obviously are site specific. Thus our discussion focused on velocity rates as they relate to the Project intake and fish of various sizes that might be present in the vicinity of the intake.

STAKEHOLDER COMMENT	LICENSEE RESPONSE
Paragraph 9 While there is no reference discussing the known behavioral response of trout to flow challenges, the authors do admit that a choice to go with or against the flow was possible for trout. Yet, the second paragraph of this section concludes that the burst speed of a 6-inch trout can out swim the maximum intake velocity, therefore trout will not be entrained. What if the trout does not respond with a burst swim and simply follows the flow of the intake? What if the total burst time does not allow the trout to swim far enough to get out of the intake area? This Section's narrative could be greatly improved with an expanded literature discussion.	The report does not conclude as you state "that trout will not be entrained" because their burst speed exceeds the maximum intake velocity. Rather, the report states that "there is little risk of trout becoming *involuntarily* entrained even at maximum discharge." We are unaware of any literature regarding behavioral response to intake flows for resident trout. There is considerable information for migratory anadromous juveniles, but because they are actively migrating and seeking downstream routes through dams, their behavior would not be applicable to the situation in Spada Lake.
Paragraph 10 Section 4.2 is a review of trout entrainment studies. To determine which studies were relevant, six factors were considered: project location, primary fish community, reservoir size, reservoir depth, intake depth, and flow capacity. Although thermal profiles, dissolved oxygen profiles, and flow management regimes would also be very important to consider, the six listed factors are an excellent start for determining the relevance of other studies. Unfortunately, the authors did not consistently list the values of each of these factors for each study site referenced. Instead, factors were selectively chosen or described in different ways that made comparison between sites difficult.	Information regarding site-specific conditions for the reviewed study sites was included, when available, in the general description of each site. We considered including such information in a table but decided not to do so in order to discourage readers from making direct comparisons among sites for individual variables. As the literature suggests, there are many variables that can potentially influence entrainment risk, and to isolate individual variables without considering other confounding factors can lead to erroneous conclusions.
Paragraph 11 Further into the review, it is also apparent that some of the study sites, such as Barney Reservoir, bear little limnological or hydroelectric facility resemblance to Spada Lake.	We agree that Barney Reservoir does not resemble Spada Lake in many ways. However, the question raised at Barney Reservoir was whether trout (cutthroat) were inclined to swim downward to a depth of 70 feet to exit the lake via the outlet works. The study results were yet another example indicating that trout are rarely entrained at deep intakes.

STAKEHOLDER COMMENT	LICENSEE RESPONSE
Paragraph 12 In summary, it is possible that the authors are accurate in concluding that trout entrainment susceptibility is minimal in Spada Lake. It is our belief, though, that the authors have made a very good case for entrainment issues being system-specific and dependent on many factors that are not comparable across watersheds. Without an expansion of the literature review and a more rigorous data analysis that addresses the concerns listed above, we find it impossible to support the conclusion that a field study to assess trout entrainment on Spada Lake is not warranted.	We do not totally agree with your summary statement. It is true that the potential for fish entrainment (all species) can be system-specific and dependent of many factors. For resident trout, however, all of the studies at sites with deep intakes, regardless of other site variables, had consistent findings of little or no entrainment. We believe that this provides very compelling support for our conclusion of minimal trout entrainment risk in Spada lake. Note that we have modified the final report to include additional figures to better illustrate the relationships among lake level, trout depth, and intake depth at various times of the year.
Paragraph 13 If Phase II field research is deemed to be important for the relicensing project, then many options exist to examine entrainment of trout. For example, the use and application of a DIDSON (Dual-frequency Identification Sonar) acoustic camera could provide extremely valuable information about the behavior and movement of Spada Lake trout near the intake structure during a series of flow release experiments. The acoustic camera would allow constant observation of fish as they approach the intake structure. The DIDSON acoustic camera technology has been successfully utilized in many research studies, including the implementation of juvenile salmonid passage technologies at the Cowlitz Falls Dam on the Cowlitz River in southwest Washington.	The referenced acoustic technology certainly could be a useful tool if studying fish behavior at the Spada Lake intake tower was deemed necessary. However, such behavioral information is generally useful only in helping select types or designs of fish passage facilities, typically for anadromous fish. That is not an objective for the Jackson Project. We also note that acoustic technologies are not very useful in determining entrainment rates for specific species.
Steward and Associates/Tulalip Tribes Comments on ISR 11/15/07	
RSP 4: Item 1 **Comments specific to the RSP 4 final draft report "Potential for Resident Trout Entrainment in Spada Lake, Washington"**	Responses to these comments are addressed above.

STAKEHOLDER COMMENT	LICENSEE RESPONSE
were submitted to the applicants September 28, 2007 and are included as Appendix B.	
RSP 4: Item 2 We contend that the information needed to make this decision, mainly seasonal trout depths versus seasonal water withdrawal depths, was not presented in the Draft Final Report or Chapter 4.0 of the ISR.	See response to Steward paragraph 5.
RSP 4: Item 3 One objective of the Phase I study listed in the ISR summary was to, "Be consistent with WDFW's Hydroelectric Project Assessment Guidelines…". However, these guidelines are not listed or mentioned in the Final Draft Report released earlier this year.	The WDFW guidelines simply recommend gathering information necessary to assess potential impacts. While consistency with the WDFW guidelines was a procedural objective (as noted in the study plan RSP 4) it was not a specific scientific objective of the study. Therefore, we did not consider it appropriate to include in the study report.