SACRAMENTO MUNICIPAL UTILITY DISTRICT
UPPER AMERICAN RIVER PROJECT
(FERC NO. 2101)

DEEPWATER INTAKE ENTRAINMENT TECHNICAL REPORT

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4.5 Deepwater Intake Entrainment Study Plan

This study is designed to provide information regarding the potential for fish to be entrained at Sacramento Municipal Utility District's (SMUD) Upper American River Project (UARP) deepwater intakes in the UARP reservoirs. The study is based on the hypothesis that most of the UARP reservoirs have deepwater intakes (more than 50 feet deep when a reservoir is full) and the general fish species composition in the reservoirs are fish which exhibit pelagic behavior during some portion of the year. To evaluate the combination of these facts relative to Project effects, a paper study is proposed. Note that entrainment at UARP shallow water intakes (Gerle Creek Canal, Robbs Peak Reservoir intake, Rubicon Reservoir intake and Buck Island Intake) are addressed in a separate study plan. At an April 25, 2002 meeting, the Aquatics Technical Working Group (TWG) agreed that entrainment at the intakes in Pacific Gas and Electric Company's Chili Bar Reservoir would be addressed by PG&E in a separate study plan.

4.5.1 Pertinent Issue Questions

The Deepwater Intake Entrainment Study Plan will be used, in part, to address the following Aquatics/Water Issue Question:

4. Do Project diversions have an effect on aquatic biota (e.g., are fish screens or low flow channels in dams necessary)?

4.5.2 Background

As described in Section A, Project Description, of the SMUD's Initial Information Package (IIP), most of the UARP intakes are located in the deepest part of the reservoirs, and therefore could be considered deepwater intakes (Table 1). A review of the literature indicates that when water temperatures are suitable, trout are found near the surface of large reservoirs due to preferences for temperature, dissolved oxygen, food and cover (May 1973, Warner and Quinn 1995, Baldwin *et al.* 2000, Rowe and Chisnall 1995, McAfee 1966, Raleigh *et al.* 1984. The likelihood of fish entrainment at the UARP deepwater intakes is a function of the actual depth of the intake at different times of the year, the probability that a significant number of fish are in the vicinity of the intake, and the ability of fish to avoid entrainment (approach velocity at the intake as compared to the fishes' swimming speed).

TABLE 1. Elevations and depths of power, diversion and low level intakes at Sacramento Municipal Utility District's Upper American River Project Reservoirs. Number in parenthesis is the depth of the intake at normal maximum water surface elevation.

Reservoir	Normal Max. Water Surface El. (feet)	Intake Invert El. (feet)		Intake Type
		Power/Diversion Intake	Low Level Valve	
Rubicon	6,545	6,533.50 (-11.50)	6,523.00 (-22.00)	Shallow
Buck Island	6,436	6,425.00 (-11.00)	6,420.00 (-16.00)	Shallow
Loon Lake	6,410	6,318.50 (-91.50)	6,325.50 (-84.50)	Deep
Gerle Creek	5,231	5,230.85 (-0.15)	5,186.50 (-44.50)	Shallow
Robbs Peak	5,231	5,201.50 (-29.50)	5,196.00 (-35.00) & 5,206.00 (-25.00)	Shallow
Ice House	5,450	5,363.50 (-86.50)	5,414.00 (-36.00)	Deep
Union Valley	4,870	4,504.68 (-365.32)	None	Deep
Junction	4,450	4,376.00 (-74.00)	4,335.00 (-115.00)	Deep
Camino	2,915	2,842.83 (-72.17)	2,840.00 (-75.00)	Deep
Brush Creek	2,915	2,826.50 (-88.50)	2,775.00 (-140.00)	Deep
Slab Creek	1,850	1,673.91 (-176.09)	1,680.00 (-170.00)	Deep

4.5.3 Study Objectives

The study objective is to determine how likely it is that fish are entrained at each of the UARP's reservoir deepwater intakes.

4.5.4 Study Area and Sampling Locations

The study area includes Loon Lake, Ice House, Union Valley, Junction, Camino, Brush Creek and Slab Creek reservoirs. The intakes at Gerle Creek Canal and Rubicon, Robbs Peak and Buck Island reservoirs, which are considered shallow water intakes (less than 50 feet deep) and are addressed in a separate study plan. No fieldwork is proposed at the deepwater intakes, so no sampling locations are identified. Also, note that the study area does not include Chili Bar Reservoir. Entrainment at the intakes in Pacific Gas and Electric Company's Chili Bar Reservoir may be addressed by PG&E in a separate study plan.

4.5.5 Information Needed From Other Studies

Information needed from other studies includes 1) the composition of fish species in UARP reservoirs and downstream from the reservoirs from the Fish Survey Study; 2) reservoir elevations, storage and fluctuation from the Hydrology Study; 3) water temperature in the UASRP reservoirs from the Water Temperature Study; and 4) water quality information, especially dissolved oxygen, in the UARP reservoirs from the Water Quality Study Plan.

4.5.6 Study Methods And Schedule

Study methods will include: 1) reviewing the scientific literature (note that Aquatic TWG participants will be contacted to solicit germane information, especially with regards to catastomids in Union Valley Reservoir) to determine how fish species in each of the Project reservoirs likely utilize the reservoir (movement and habitat preference); 2) describe the location of any intakes in the UARP reservoirs including elevation and flow at different times of the year; and 3) when fish are likely to be in the vicinity of the intake, relate the approach velocity into the intake to the fishes' ability to avoid entrainment (swim speed). It is anticipated that a white paper on this subject will be developed for review by the Aquatic TWG and Plenary Group by late 2002. If the Aquatic TWG or Plenary Group conclude that additional information is needed at any intake (such as an entrainment study), the study will be developed by the Aquatic TWG and fieldwork will occur in 2003.

4.5.7 Analysis

Data analysis will include a discussion of the above data, and postulate an effect on fish populations in the reservoir.

4.5.8 Study Output

The white paper will be presented to the Aquatic TWG and Plenary Group by late 2002. Additional studies, if needed, will occur in 2003. The ultimate study output will be a written report that includes the issues addressed, objectives, study area including sampling locations, methods, analysis, results, discussion and conclusions. The report will be prepared in a format so that it can easily be incorporated into the Licensee's draft environmental assessment that will be submitted to FERC with the Licensee's application for a new license.

4.5.9 Preliminary Estimated Study Cost

A preliminary cost estimate for this study will be developed after approval by the Plenary Group.

4.5.10 Plenary Group Endorsement

The Aquatics TWG approved this plan on April 25, 2002. The participants at the meeting who said they could "live with" this study plan were PCWA, El Dorado County, BLM, CDFG, USFS, USFWS, SMUD, SWRCB and PG&E. None of the participants at the meeting said they could not "live with" this study plan. The Plenary Group approved the plan on June 5, 2002. The participants a the meeting who said they could "live with" this study plan were PCWA, El Dorado County, BLM, BOR, USFS, CSPA, SMUD, FOR, PG&E. None of the participants at the meeting said they could not "live with" this study plan.

4.5.11 Literature Cited

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DEEPWATER INTAKE ENTRAINMENT TECHNICAL REPORT

SUMMARY

The Aquatic Technical Working Group (TWG) and Plenary Group identified seven UARP reservoirs that the Aquatic TWG considered to have associated "deepwater" intakes: Loon Lake, Ice House, Union Valley, Junction, Camino, Brush Creek and Slab Creek. Ice House, Junction, Camino and Slab Creek have both a power intake and a low level outlet. Loon Lake and Brush Creek reservoirs also have a power intake and a low level outlet, but the Loon Lake intakes are housed in one intake structure, and the Brush Creek Reservoir power intake is rarely used. Union Valley Reservoir has only a power intake. With the exception of the Ice House Power Tunnel intake, the power intakes transport water to UARP powerhouses that use Francis-type turbines. The Jaybird Powerhouse uses a Pelton turbine. The low-level intakes are controlled by globe, cone or Howell-Bunger valves, or some combination of these. Based on historic percent exceedance flows through the Loon Lake, Jones Fork, Union Valley and White Rock power tunnel intakes, median approach velocities to these intakes range from 0.14 fps at the Loon Lake Penstock Intake to 0.41 fps at the Union Valley Penstock Intake, and ten percent exceedances range from 0.96 fps to 1.18 fps. The range of possible approach velocities was calculated for other power intakes based on median historic monthly flows, and for low-level intakes based on the current downstream minimum flow requirements. Approach velocities at the other power intakes ranged from 0.22 fps to 0.61 fps, both at the Jaybird Power Tunnel Intake. Approach velocities at the low-level intakes ranged from 0.05 fps at the Brush Creek Dam low-level intake to 2.25 at the Slab Creek Dam low-level intake.

The Loon Lake, Ice House and Union Valley reservoirs, the three primary UARP storage reservoirs, intakes are normally deepest (between about 71 and 214 feet deep) in the summer and shallowest (39 to 159 feet deep) in winter as the reservoirs are drawn down. The depths of the intakes in the re-regulating reservoirs (Junction, Camino, Brush Creek and Slab Creek) show little variation over the year (about 1-3 foot change), but can change by up to ten feet in a day.

Each of the seven reservoirs shows some level of stratification, with strongest stratification occurring at Union Valley and Ice House reservoirs (in summer, about 20°C on the surface and 7°C on the bottom with a thermocline at about 60 feet), and the weakest stratification at Brush Creek, Camino and Slab Creek reservoirs.

California Department of Fish and Game (CDFG) currently stocks trout in the UARP storage reservoirs, and naturally-reproducing special-status fish species that may occur in the reservoirs include rainbow trout and brown trout (Forest Service Management Indicator Species and found in most of the seven reservoirs) and hardhead (California Species of Concern and found only in Slab Creek Reservoir).

A review of the life history of rainbow trout, brown trout, hardhead as well as smallmouth bass and Sacramento sucker suggests that adult trout generally prefer the upper portions of reservoirs, and young-of-the-year and juvenile trout, smallmouth bass and Sacramento sucker prefer nearshore habitat. In reservoirs, hardhead prefer the shallow areas at the upstream end of the reservoir.

A general literature review suggests that 3-inch-long trout are able to maintain a cruising speed of about 1 fps and a burst speed of about 2.5 fps, while a 6-inch-long trout can maintain a cruising speed of 2 fps and a burst speed of 5 fps.

Applying the approach used by Pacific Gas and Electric Company (PG&E) to estimate potential entrainment of stocked fish for its large Mokelumne River, UARP deepwater intakes (as requested by the Aquatic TWG) were studied, and in 2004 between 2,610 and 6,350 stocked fish may have been entrained collectively at Loon Lake, Ice House and Union Valley reservoirs. No estimate of entrained resident fish was made since the necessary data are not available for these reservoirs.

1.0 INTRODUCTION

This technical report is one in a series of a reports prepared by Devine Tarbell & Associates, Inc., (DTA) for the Sacramento Municipal Utility District (SMUD) as an appendix to SMUD's application to the Federal Energy Regulatory Commission (FERC) for a new license for the Upper American River Project (UARP or Project). The report provides information regarding the potential for fish entrainment to occur at UARP deepwater intakes and includes the following sections:

- **BACKGROUND** – Summarizes the applicable study plan approved by the UARP Relicensing Plenary Group; a brief description of the issue questions addressed, in part, by the study plan; the objectives of the study plan; the study area, and agency information requests. In addition, requests by resource agencies for additions to this technical report are described in this section.
- **METHODS** – A description of the methods used in the study, including a listing of study sites.
- **RESULTS** – A description of the salient data results. Raw data where copious and detailed model results are provided in a separate compact disc (CD) for additional data analysis and review by interested parties.
- **ANALYSIS AND DISCUSSION** - An analysis and discussion of the results, where appropriate.
- **LITERATURE CITED** – A listing of all literature cited in the report.

This technical report does not include a detailed description of the UARP Alternative Licensing Process (ALP) or the UARP, which can be found in the following sections of the SMUD's application for a new license: The UARP Relicensing Process, Exhibit A (Project Description), Exhibit B (Project Operations), and Exhibit C (Construction).

Also, this technical report does not include a discussion regarding the affects of the UARP on fish, nor does the report include a discussion of appropriate protection, mitigation and enhancement measures. An impacts discussion regarding the UARP is included in the applicant-prepared draft environmental assessment (PDEA) document, which is part of the SMUD's application for a new license. Development of resource measures will occur in settlement discussions and will be reported on in the PDEA.

2.0 BACKGROUND

The UARP Relicensing Plenary Group approved one study plan that pertained specifically to fish entrainment at the UARP's deepwater intakes: the Deepwater Intake Entrainment Study Plan. This study plan is discussed in Section 2.1 below.

2.1 Deepwater Intake Entrainment Study Plan

On June 5, 2002, the UARP Relicensing Plenary Group approved the Deepwater Intake Entrainment Study Plan that was developed and approved by the Relicensing Aquatic Technical

Working Group (TWG) on April 25, 2002. The study plan was designed to address, in part, the following issue question developed by the Plenary Group:

Issue Question 4. Do Project diversions have an effect on aquatic biota (e.g., are fish screens or low flow channels in dams necessary)?

Specifically, the objective of the study plan was:

- Determine how likely it is that fish are entrained at each of the UARP's reservoir deepwater intakes.

The study area included Loon Lake, Ice House, Union Valley, Junction, Camino, Brush Creek and Slab Creek reservoirs. The intakes at Gerle Creek Canal and Rubicon, Robbs Peak and Buck Island reservoirs, which were considered shallow water intakes (less than 50-feet-deep) by the Aquatic TWG, are not addressed in this study plan. Also, the study area did not include Chili Bar Reservoir: entrainment at the intakes in PG&E's Chili Bar Reservoir is expected to be addressed by PG&E in the Chili Bar relicensing.

The study plan specified that the study output would be a written report prepared in a format that could easily be incorporated into SMUD's application for new license, and data analysis would include a discussion of the results.

2.2 Water Year Type

Since this study did not include any field sampling, the water year types during the study are irrelevant.

2.3 Agency Requested Information

In a letter dated December 17, 2003 to the Licensee, the agencies did not specifically address the contents of the *Deepwater Intake Entrainment Technical Report.*

In a May 13, 2004, letter, the agencies requested that SMUD revise the January 2004 *Deepwater Intake Entrainment Technical Report* to include:

1. On page 29, include data describing recommended approach velocities of hardhead and Sacramento sucker as being less than 1.3 fps (from the publication Environmental Biology of Fishes 58(3) p. 289-295. July 2000). The Report does not describe any specific velocities for these species. This publication was provided to SMUD's consultants last year. Explain whether the data from this publication affect the analysis results.

2. Provide data to support the conclusion that Sacramento suckers that reside in deep water during the daylight hours would not be affected by the deepwater intakes (page 28 of the Report).

3. State in the methods section how the approach velocities were determined for Table 4.1-8 (even though it may have been in study plan).

In addition, in a June 10, 2004 meeting, the Aquatic TWG requested that SMUD include in the revised report:

- Calculate flow exceedances for Loon Lake, Union Valley, Jones Fork and the White Rock powerhouses, and use these data to estimate approach velocities to the power tunnel intakes.

- Include Water Year 2001 Union Valley Reservoir water surface elevation in the report, and compare 2001 to other years to determine if it was particularly atypical.

- Provide an estimate of entrainment at Loon Lake, Union Valley and Ice House reservoirs using methods used by PG&E for the Mokelumne project.

This revised *Deepwater Intake Entrainment Technical Report* includes the information requested by the agencies and Aquatic TWG.

3.0 METHODS

The study methods conformed to those approved by the UARP Relicensing Plenary Group. These were that SMUD would: 1) describe the location of any intakes in the UARP reservoirs including elevation and flow at different times of the year; 2) describe when fish are likely to be in the vicinity of the intake; 3) review the scientific literature to determine how these fishes likely utilize the reservoir (movement and habitat preference); and 4) relate the approach velocity into the intake to the fishes' ability to avoid entrainment (swim speed and burst speed).

To determine the elevation and cross sectional area of intakes, DTA used the information contained on the current Exhibit L drawings filed with FERC. These data are shown in Table 3.0-1.

Table 3.0-1. Bottom invert elevation, height, width and cross-sectional area behind the trash rack for selected UARP deepwater intakes.

Intake	Bottom Invert Elevation (feet)	Height (feet)	Width (feet)	Cross-Sectional Area (square feet)
LOON LAKE RESERVOIR				
Loon Lake Powerhouse Penstock Intake/ Loon Lake Dam Low-Level Intake	6,317.0	16	28	448
Loon Lake Dam Howell Bunger Valve	6,301.5	5	5	25
ICE HOUSE RESERVOIR				
Jones Fork Power Tunnel Intake	5,363.5	9	18	162
Ice House Dam Low-Level Intake	5,326.0	3	3.33	7
UNION VALLEY RESERVOIR				
Union Valley Powerhouse Penstock Intake	4,628.0	20	50.0	1,010
JUNCTION RESERVOIR				

Table 3.0-1. Bottom invert elevation, height, width and cross-sectional area behind the trash rack for selected UARP deepwater intakes.

Intake	Bottom Invert Elevation (feet)	Height (feet)	Width (feet)	Cross-Sectional Area (square feet)
Jaybird Power Tunnel	4,374.5	29	50.0	1,470
Junction Dam Low-Level Outlet Intake	4,333.0	4	4	16
CAMINO RESERVOIR				
Camino Tunnel Intake	2,841.33	28	47.5	1,330
Camino Dam Low-Level Intake	2,838.0	4	4	16
BRUSH CREEK RESERVOIR				
Brush Creek Tunnel Intake	2,825.0	30	46	1,385
Brush Creek Dam Low-Level Intake	2,773.5	6	8	42
SLAB CREEK RESERVOIR				
White Rock Power Tunnel Intake	1,670.0	32	74	2,370
Slab Creek Dam Low-Level Intake	1,678.32	4	4	16

To determine typical flows through the intakes, DTA calculated percent exceedance values for the Loon Lake, Jones Fork, Union Valley and Slab Creek power tunnels, as requested by the Aquatic TWG on June 10, 2004. For stand-alone low-level intakes, DTA used the range of minimum stream flow requirements in the existing UARP FERC license. For all other intakes, DTA calculated the mean monthly flows based on the period of record.

To calculate approach velocities, DTA divided the flow into the intake by the cross-sectional area of the intake provided in Table 3.0-1.

4.0 RESULTS

4.1 Description of Intakes and Fish Species Compositions

This section summarizes, by reservoir: reservoir fluctuation; flow through the deepwater intakes; depth of the deepwater intakes; and reservoir stratification and fish populations. This information is provided in summary format since a detailed discussion of the information is provided in the license application in Exhibit A, Project Description; Exhibit B, Project Operation; as well as the *Water Temperature Technical Report*; *Reservoir Shoreline Habitat Technical Report*, and the *Fish Survey Technical Report*.

4.1.1 <u>Loon Lake Reservoir</u>

4.1.1.1 Reservoir Fluctuation

The primary purpose of Loon Lake Dam is to store water captured from the Gerle Creek watershed upstream of the dam and water transported from the Buck Island Reservoir via the Buck Island-Loon Lake Tunnel. Loon Lake Dam can store about 69,308 ac-ft of water (65,786 ac-ft of usable storage) at normal maximum full pool (El. 6,410 feet).

Storage volume at Loon Lake Reservoir typically follows an annual cycle, with the reservoir elevation reaching its highest level during early summer months. The reservoir level gradually lowers throughout the summer as water is passed through the Loon Lake Powerhouse, generating electricity to meet SMUD's peak demand during this time period. This gradual lowering of the reservoir continues into the fall and winter months. In addition to providing water to generate energy flexibly to meet SMUD's fall and winter peak energy needs, this operational regime enables SMUD to create adequate space at Loon Lake Reservoir for storage of rain and snowmelt runoff during the winter/spring, thus minimizing potential seasonal spillage. The water elevation slowly rises during the spring and early summer as rain and snowmelt runoff refill the reservoir.

Figure 4.1-1 shows the historical reservoir elevations by month for the water years 1976 through 1998, including the 10 percent and 90 percent exceedance levels. Over this 23-year period, median high water elevations (El. 6,406 feet) for June and July were near full pool. Median low water elevation occurred in March, averaging 6,370 feet. This represents a typical seasonal change in water elevation at Loon Lake Reservoir of approximately 36 feet. Because SMUD manages the operating storage reservoir levels based, in part, on the projected runoff for the remainder of the water year, more significant seasonal fluctuation may occur in individual years. Average elevation change per day (beginning around June 1 of each year) in Loon Lake Reservoir is about 0.4 feet, as reported in Table 4.2-1 of the *Reservoir Shoreline Habitat Technical Report.*

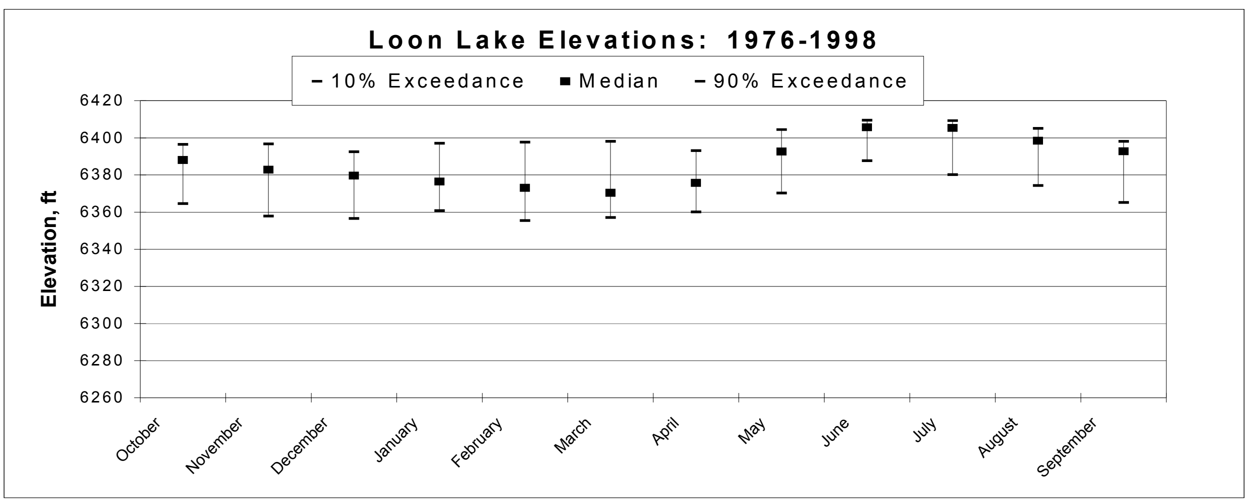

Figure 4.1-1. Loon Lake Reservoir monthly median, 10 percent exceedance and 90 percent exceedance water surface elevations, based on data from 1976 through 1998.

4.1.1.2 Flow Through Deepwater Intakes

Water is released from Loon Lake Reservoir by either passing over the Loon Lake Dam spillway, through the Loon Lake Powerhouse Penstock or through one of the Loon Lake Dam low-level outlets. The Loon Lake Powerhouse Penstock can pass a maximum of 997 cfs of water from Loon Lake Reservoir to the Loon Lake Powerhouse and then into Gerle Creek Reservoir. The Loon Lake Dam low-level outlet is comprised of two 10-inch-diameter, globe valves (combined maximum capacity or 41 cfs at a full pool) and one 42-inch-diameter Howell-

Bunger valve (600 cfs). The invert elevation, height, width and cross-sectional area of the combined Loon Lake Power Tunnel and low-level outlet intakes behind the trashrack are shown in Table 3.0-1.

As described above, the maximum amount of flow that can be passed through the combined Loon Lake Powerhouse Penstock/Loon Lake Dam Low-Level Intake is about 1,038 cfs (997 cfs through the power tunnel plus 41 cfs through the two low level globe valves). The maximum amount of water that can be passed through the Howell Bunger valve is 600 cfs, however, this flow has never occurred. The Howell-Bunger valve is never opened, except for very brief periods for testing as required by FERC or the California Division of Safety of Dams (DSOD). Based on historic records from 1976 through 1999, the median flow (50% exceedance) through the power tunnel/low-level outlet is 53 cfs, with 10 and 90 percent exceedances of 421 cfs and 0 cfs. The maximum flow was 925 cfs (0.5% exceedance) (Figure 4.1-2).

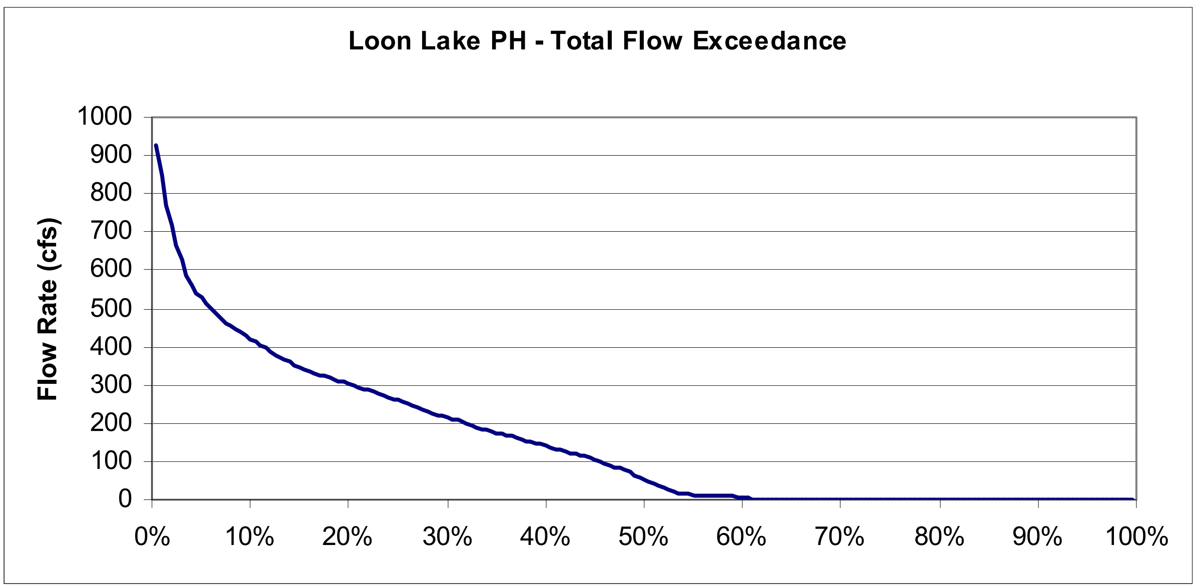

Figure 4.1-2. Loon Lake Powerhouse Penstock withdrawal exceedance curve based on period from 1976 through 1999.

Adding the power tunnel and minimum streamflows, one can assume that the median, 10 percent and 90 percent exceedance flows through the combined power tunnel/low-level intake structure are 61 cfs (53 cfs through the power tunnel plus 8 cfs through the low-level outlet), 429 cfs (421 through the power tunnel plus 8 cfs through the low level outlet) and 8 cfs (no flow through the power tunnel plus 8 cfs through the low-level outlet), respectively.

Based on the intake cross-sectional area of 448 square feet (Table 3.0-1), the approach velocities to the intake for the median, 10 percent and 90 percent exceedance flows are 0.14 feet per second (fps) (61 cfs divided by 448 sq ft), 0.96 fps (429 cfs divided by 448 sq ft) and 0.02 fps (8 cfs divided by 448 sq ft), respectively.

4.1.1.3 Depth of Deepwater Intakes

Figure 4.1-3 shows the average historical reservoir elevations by month for the water years 1976 through 1998 relative to the elevations of the top and bottom of the intake structure. Figure 4.1-3 also shows on the right-hand scale, the mean monthly power diversion intake flows in cfs. These flows not only represent average monthly withdrawals of water, but also relate directly to average monthly approach velocities at the intake structure.

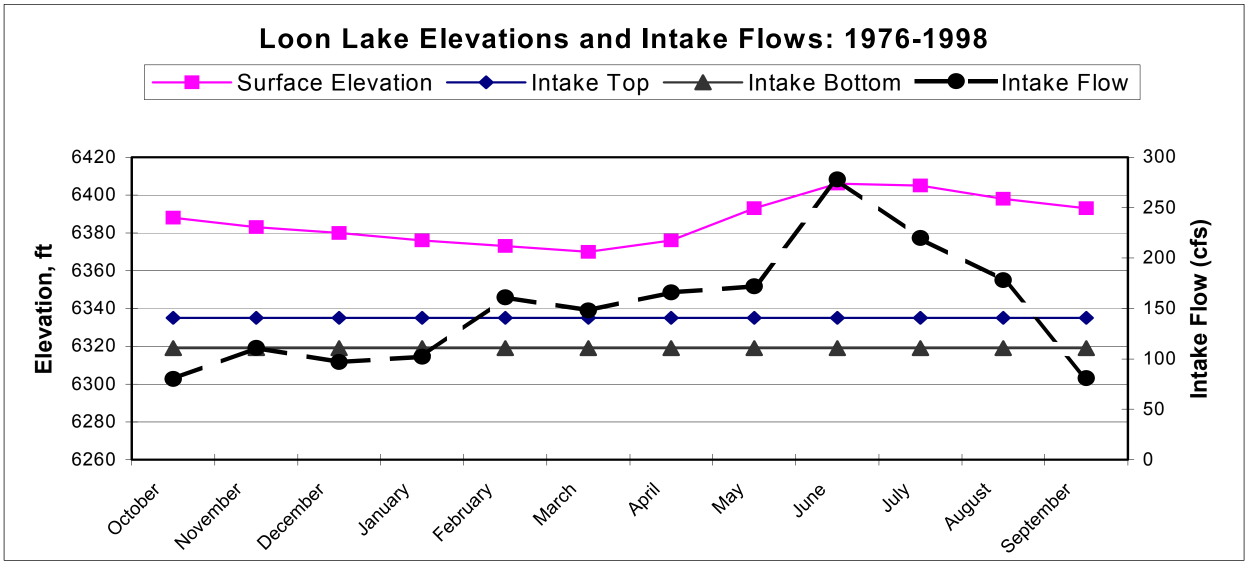

Figure 4.1-3. Loon Lake Reservoir median monthly water surface elevation, depth of deepwater intakes, and flow through the deepwater intakes based on data from 1976 through 1998.

4.1.1.4 Reservoir Stratification and Fish Populations

In general, Loon Lake Reservoir is a cold, clear, well-oxygenated reservoir. The reservoir is isothermal in fall and winter, with water temperatures between 11° and 12 °C. In early summer, the reservoir is weakly stratified with maximum surface temperatures between 13° and 15°C, and minimum temperatures at the bottom of the reservoir of approximately 8°C. A broad metalimnion gradually drops to low temperatures (8°C). A poorly defined hypolimnion also exists. Dissolved oxygen (DO) concentrations appear to be at or near saturation throughout the reservoir. See Section 4.1.4 of the *Water Temperature Technical Report* for a more detailed discussion of water temperature in Loon Lake Reservoir.

The *Reservoir Fisheries Technical Report* shows that fish species in Loon Lake Reservoir include rainbow trout, brown trout, California roach, chubs, Sacramento suckers, and green sunfish (Table 4.0-1 of the *Reservoir Fisheries Technical Report*). In 2002, SMUD's fish surveys collected 39 brown trout, 37 California roach, seven rainbow trout, and two Sacramento sucker (Table 4.0-2 of the *Reservoir Fisheries Technical Report)*. All trout species were evenly distributed throughout the reservoir. Brown trout, the numerically dominant fish collected, ranged in length from 300 to 499 mm and rainbow trout, with one outlier, ranged in length from

450 to 499 mm. Sacramento suckers were 250 to 350 mm in length. (Figure 4.1-2 of the *Reservoir Fisheries Technical Report.)*

4.1.2 Ice House Reservoir

4.1.2.1 Reservoir Fluctuation

The primary purpose of Ice House Dam is to store water inflowing from the South Fork Silver Creek. The maximum gross storage capacity of the reservoir is 43,504 ac-ft of water (35,065 ac-ft of usable storage) at the top of the spillway gates (El. 5,450 feet). DSOD requires that the gates be open from November through April 1, at which time the maximum elevation is 5,436.5.

Like Loon Lake, storage volume at Ice House Reservoir typically follows an annual cycle, with the reservoir elevation reaching its highest level typically in early June. The reservoir level gradually lowers throughout the summer as water is passed through the Jones Fork Power Tunnel, generating electricity at the Jones Fork Powerhouse to meet SMUD's peak demand during this time period. This gradual lowering of the reservoir continues into the fall and winter. SMUD's preferred minimum pool operating elevation in Ice House Reservoir is 5,380 feet to avoid vortexing. In addition to providing water to generate energy flexibly to meet SMUD's fall and winter peak energy needs, this operational regime also enables SMUD to create adequate storage space at Ice House Reservoir for storage of rain and snowmelt runoff during the winter/spring months, thus minimizing spillage. The water elevation slowly rises during the spring and early summer as the rain and snowmelt runoff refill this reservoir.

Figure 4.1-4 shows the historical reservoir elevations by month for the water years 1985 through 1998. Over this period, which starts after the completion of the 11.5 MW Jones Fork Powerhouse, median high water elevations for June and July were near full pool, averaging 5,446 feet. Median low water elevation occurred in March, averaging 5,404 feet. This represents a typical seasonal change in water elevation at Ice House Reservoir of about 42 feet. Because SMUD manages the operating storage reservoir levels, based in part on the estimated future runoff for the remainder of the water year, more significant seasonal fluctuations may occur in individual years. Average elevation change per day in Ice House Reservoir is about 0.3 feet, as reported in Table 4.2-1 of the *Reservoir Shoreline Habitat Technical Report.*

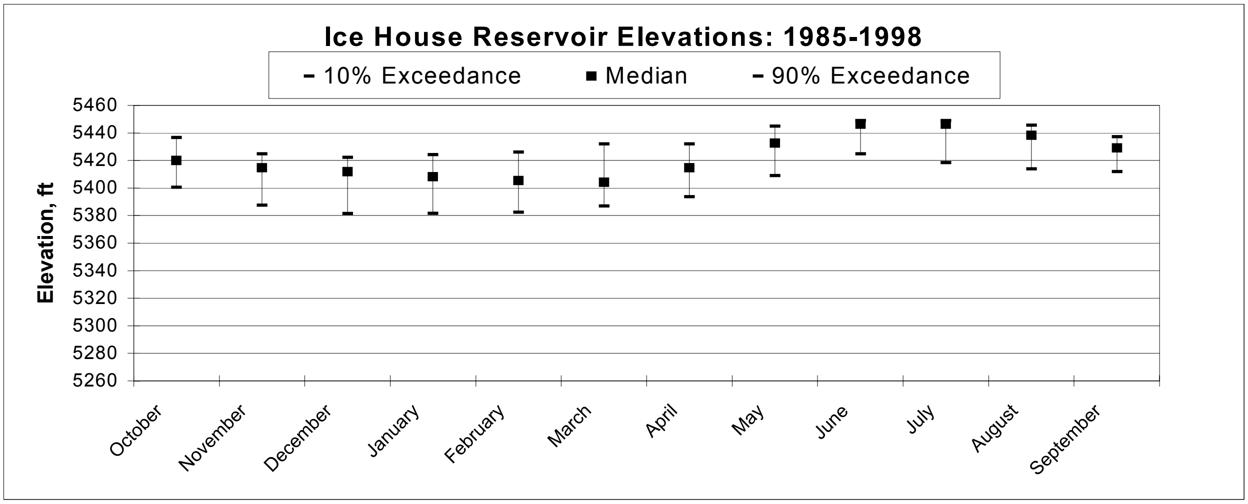

Figure 4.1-4. Ice House Reservoir monthly median, 10 percent exceedance and 90 percent exceedance water surface elevations, based on data from 1985 through 1998.

4.1.2.2 Flow Through Deepwater Intakes

Water is released from Ice House Reservoir by either passing over the Ice House Dam spillway, through the Jones Fork Power Tunnel or through the Ice House Dam low-level outlet. The Jones Fork Power Tunnel has a maximum capacity of 287 cfs. The Ice House Dam low-level is comprised of two 10-inch-diameter globe valves (combined maximum capacity or 47 cfs) and one 42-inch-diameter Howell Bunger valve (695 cfs). The invert elevation, height, width and cross-sectional area of the Jones Fork Power Tunnel intake and the Ice House Dam low-level intake behind the trashracks are shown in Table 3.0-1.

As described above, the maximum amount of flow that can be passed through the Jones Fork Power Tunnel is 287 cfs. Based on historic records from 1985 through 1999, the median flow through the power tunnel is 39 cfs, with 10 and 90 percent exceedances of 191 cfs and 0 cfs. The maximum flow was 280 cfs (0.5% exceedance). (Figure 4.1-5.)

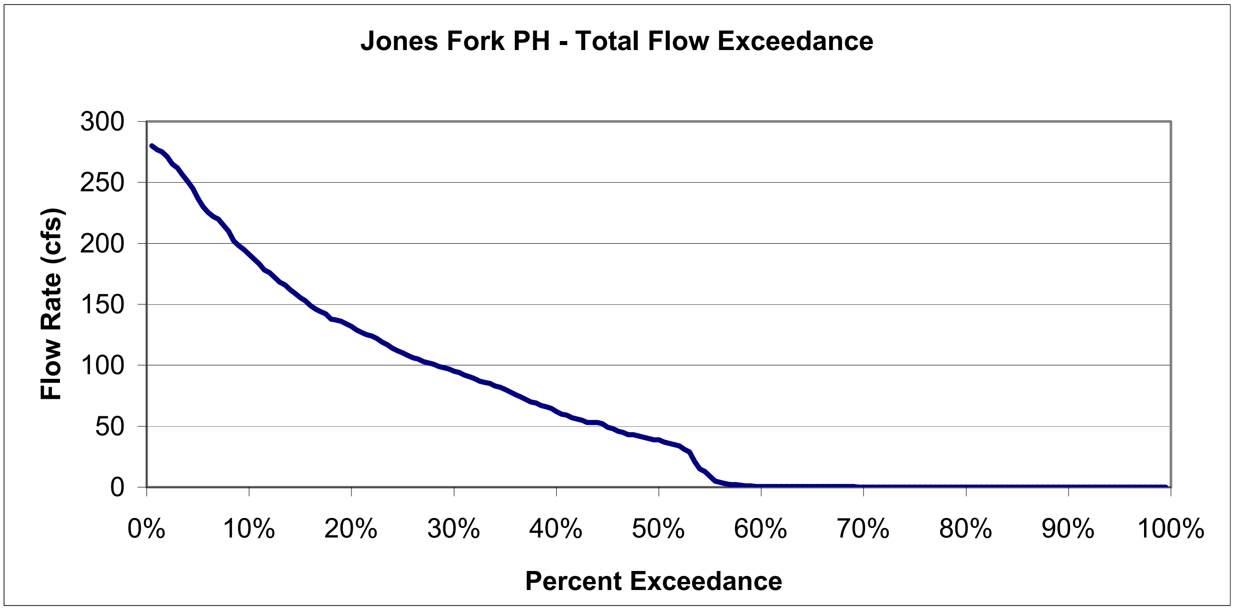

Figure 4.1-5. Jones Fork Power Tunnel withdrawal exceedance curve based on period from 1985 through 1999.

Based on these flows and the 162 square foot cross-sectional area of the intake structure (Table 3.0-1), one can assume that the approach velocities associated with the median, 10 percent and 90 percent exceedance flows through the Jones Fork Power Tunnel Intake are 0.24 fps (39 cfs divided by 162 sq-ft), 1.18 fps (191 cfs divided by 162 sq-ft) and 0 cfs (0 cfs divided by 162 sq-ft), respectively.

The maximum amount of flow that can be passed through the Ice House Dam low-level intake is about 1,638 cfs (47 cfs through the two low level globe valves plus 695 cfs through the Howell-Bunger valve). However, this flow has not occurred since the Jones Fork Powerhouse went into operation. Now, the Howell-Bunger valve is not opened, except for very brief periods for testing as required by FERC or the DSOD or for specific studies, such as the recent Ice House Dam Reach Whitewater Boating Test Flow Study performed for the UARP relicensing. Minimum streamflow release requirement is from 5 to 15 cfs, depending on water year type, and is released through the globe valves. Based on the range of historic minimum streamflows and the seven square foot cross-sectional area of the intake structure (Table 3.0-1), one can assume that approach velocities at the Ice House Dam Low-Level Intake range from 0.71 fps (5 cfs divided by 7 sq ft) to 2.14 fps (15 cfs divided by 7 sq ft).

4.1.2.3 Depth of Deepwater Intakes

Figure 4.1-6 shows the historical average reservoir elevations by month for the water years 1985 through 1998 relative to the elevations of the top and bottom of the submerged intake structure. Figure 4.1-6 also shows on the right-hand scale, the mean monthly power diversion intake flows in cfs. These flows not only represent average monthly withdrawals of water, but also relate directly to average monthly approach velocities at the intake structure.

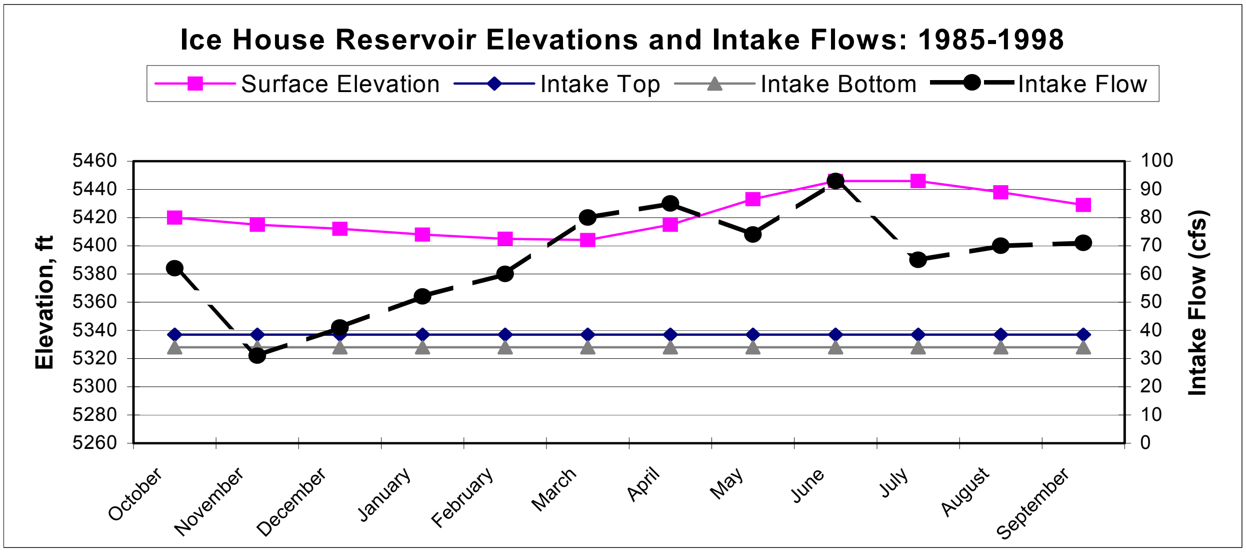

Figure 4.1-6. Ice House Reservoir median monthly water surface elevation, depth of deepwater intakes, and flow through the deepwater intakes based on data from 1985 through 1998.

4.1.2.4 Reservoir Stratification and Fish Populations

As described in Section 4.1.7 of the *Water Temperature Technical Report*, Ice House Reservoir is strongly stratified with surface water temperature highest in July and August at about 20°C and hypolimnetic bottom water at about 7°C. A thermocline, ranging from a depth of 15 to 60 feet, forms in June and persists into November. A strong metalimnion forms, with a deepening epilimnion throughout the summer. Ice House Reservoir exhibits an orthograde oxygen profile typical of moderately oligotrophic lakes. Dissolved oxygen levels in the epilimnion are close to saturation (8 to 9 mg/l), with dissolved oxygen (DO) levels at about 3 to 5 mg/l near the bottom. The reservoir is relatively clear with Secchi disk readings ranging from about 20 to 30 feet.

As described in the *Reservoir Fisheries Technical Report*, fish in Ice House Reservoir include rainbow trout, brook trout, brown trout, golden shiner, kokanee salmon and California roach (Table 4.0-1 of the *Reservoir Fisheries Technical Report)*. In 2002, SMUD collected 38 brown trout, 11 rainbow trout, and six California roach were collected by beach seining and gill netting (Table 4.0-2 of the *Reservoir Fisheries Technical Report)*. Brown trout were distributed across several size ranges, between 250-549 mm, and rainbow trout were predominantly observed between 250-399 mm with one fish in the 25-49 mm size range. California roach were observed only in the 25-49 mm size range (Figure 4.2-2 of the *Reservoir Fisheries Technical Report).*

4.1.3 Union Valley Reservoir

4.1.3.1 Reservoir Fluctuation

The primary purpose of Union Valley Dam is to store water transported via the Jones Fork and Robbs Peak powerhouses as well as tributary inflows. The maximum gross (and usable) storage capacity of Union Valley Reservoir is 266,303 ac-ft of water at elevation 4,870 feet, which is the top of the spillway gates when closed. DSOD requires that the gates be open from November through April 1, at which time the maximum reservoir elevation is 5,855.0 feet.

As with Loon Lake and Ice House reservoir, storage levels at Union Valley Reservoir typically follow an annual cycle, with the reservoir elevations reaching their highest levels typically by June 1 each year. The reservoir levels gradually lower throughout the summer as the water is passed through the Union Valley Powerhouse generating electricity to meet SMUD's peak demand during this time period. This gradual lowering of the reservoir continues into the fall and winter months. In addition to providing water to generate electricity to meet SMUD's fall and winter peak energy needs, this operational regime also provides adequate space at Union Valley Reservoir for storage of rain and snowmelt runoff during the winter/spring months, thus minimizing spillage. The water elevation slowly rises during the spring and early summer as the rain and snowmelt runoff refill this reservoir.

Figure 4.1-7 shows the historical minimum, maximum and median reservoir elevations by month for the water years 1976 through 1998. Over this 23-year period, median high water elevation for June and July were near full pool, averaging 4,862 feet. Median low water elevation occurred in January, averaging 4,809 feet. This represents a median seasonal change in water elevation at Union Valley Reservoir of about 53 feet. Because the reservoir levels are managed, based in part on the estimated future runoff for the remainder of the water year, more significant seasonal fluctuation may occur in individual years. Average elevation change per day in Union Valley Reservoir is about 0.6 feet, as reported in Table 4.2-1 of the *Reservoir Shoreline Habitat Technical Report.*

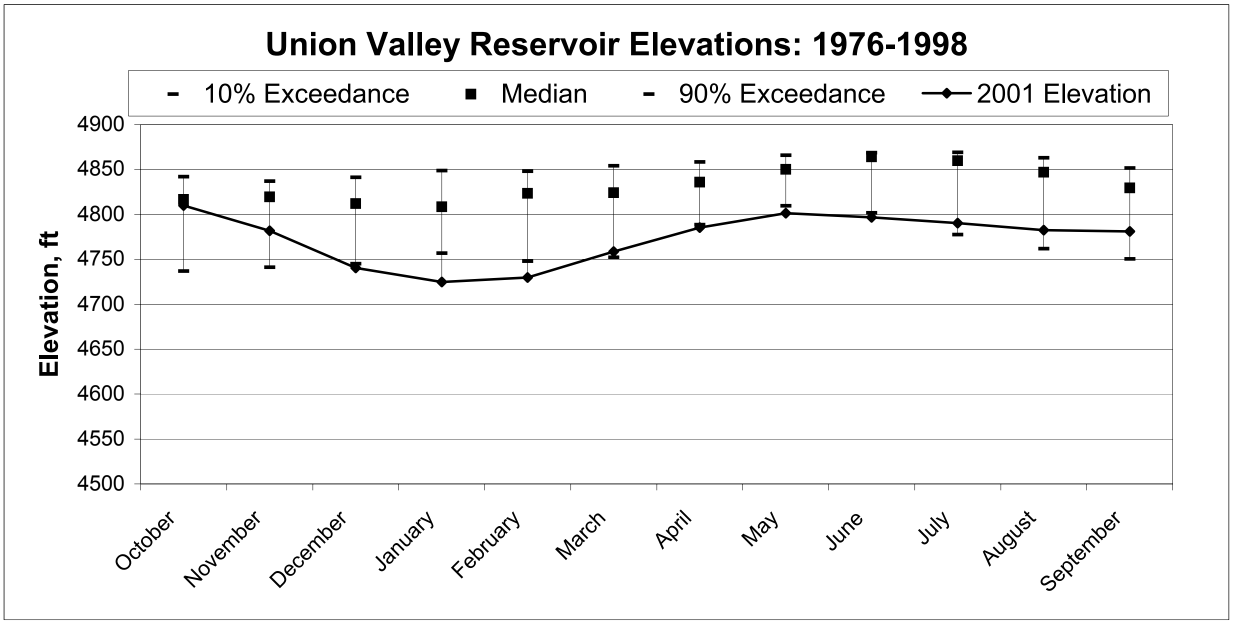

Figure 4.1-7. Union Valley Reservoir monthly median, 10 percent exceedance and 90 percent exceedance water surface elevations, based on data from 1976 through 1998 and 2001 elevations.

As requested by the Aquatic TWG on June 10, 2004, the above figure also shows Union Valley Reservoir water surface elevations in Water Year 2001. In that year, the reservoir was drawn down to lower than typical levels due to a state-wide electrical demand in California.

4.1.3.2 Flow Through Deepwater Intakes

Up to 1,577 cfs of water is released from Union Valley Reservoir though the Union Valley Powerhouse Penstock to the Union Valley Powerhouse located on Junction Reservoir, which is an afterbay for Union Valley Powerhouse. Union Valley Dam does not have a low-level outlet. The invert elevation, height, width and cross-sectional area of the Union Valley Powerhouse Penstock Intake are shown in Table 3.0-1.

As described above, the maximum amount of flow that can be passed through the Union Valley Powerhouse Penstock Intake is about 1,577 cfs. Based on historic records from 1976 through 1999, the median flow through the power tunnel is 415 cfs, with 10 and 90 percent exceedances of 1,150 cfs and 1 cfs. The maximum flow was 1,560 cfs (0.5% exceedance) (Figure 4.1-8).

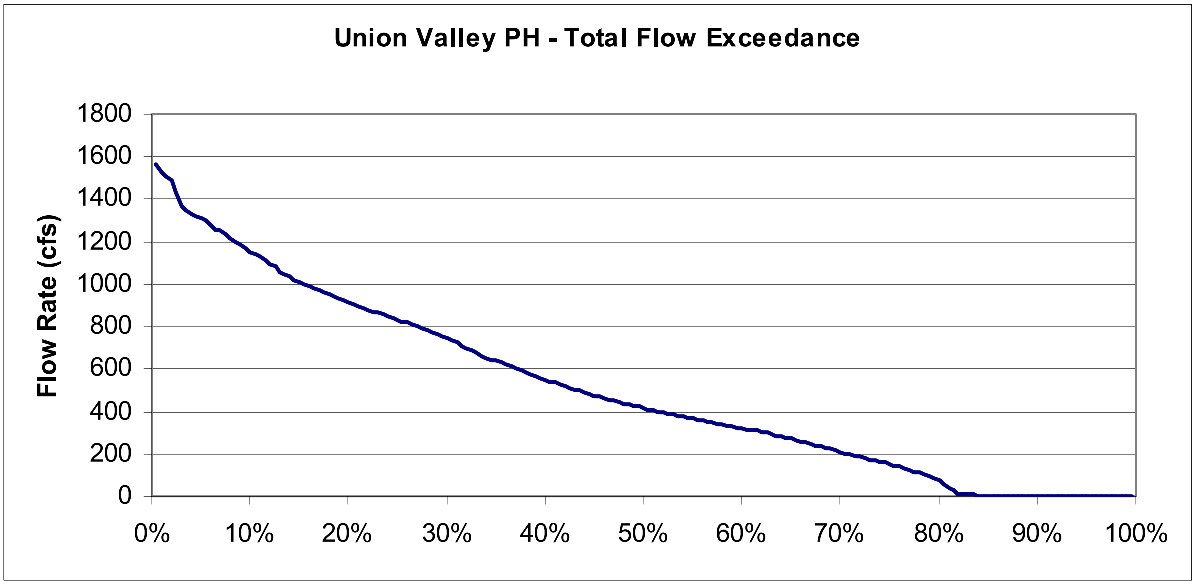

Figure 4.1-8. Union Valley Powerhouse Penstock withdrawal exceedance curve based on period from 1976 through 1999.

Therefore, one can assume that the median, 10 percent and 90 percent exceedance approach velocities at the Union Valley Powerhouse Penstock Intake associated with these flows are 0.41 fps (415 cfs divided by 1,010 sq-ft), 1.14 fps (1,150 divided by 1,010 sq-ft) and less than 0.01 fps (1 divided by 1,010 sq-ft), respectively.

4.1.3.3 Depth of Deepwater Intake

Figure 4.1-9 shows the historical reservoir elevations by month for the water years 1976 through 1998 relative to the elevations of the top and bottom of the submerged intake structure. Figure 4.1-9 also shows on the right-hand scale the mean monthly power diversion intake flows in cfs. These flows not only represent average monthly withdrawals of water, but also relate directly to average monthly approach velocities at the intake structure.

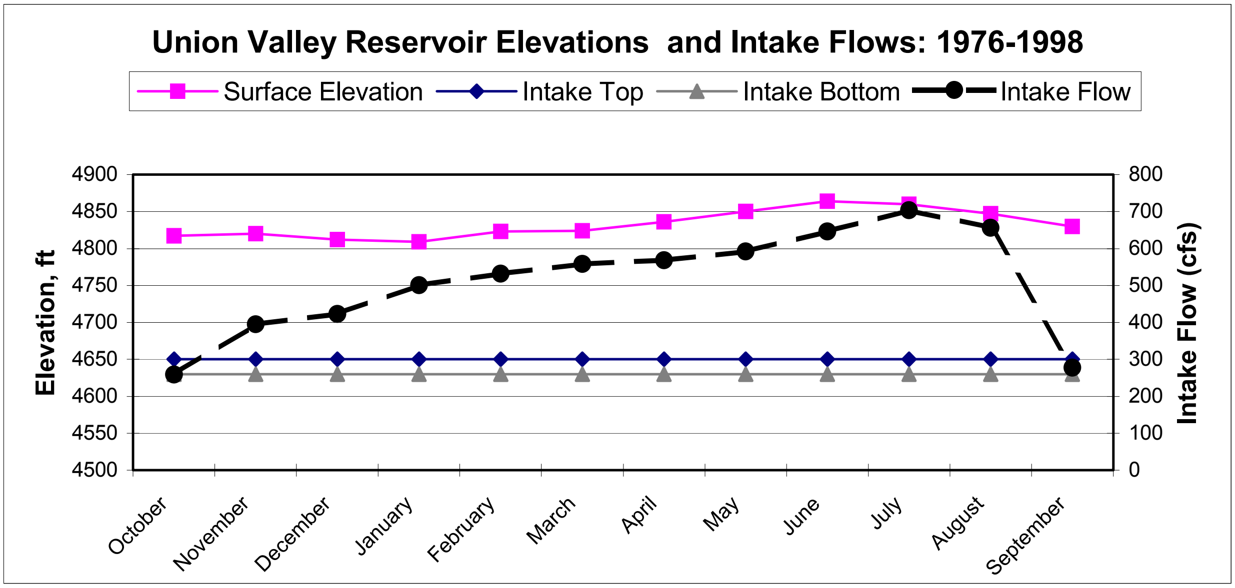

Figure 4.1-9. Union Valley Reservoir median monthly water surface elevation, depth of deepwater intake, and flow through the deepwater intake based on data from 1976 through 1998.

4.1.3.4 Reservoir Stratification and Fish Populations

Information in Section 4.1.8 of the *Water Temperature Technical Report* shows that Union Valley Reservoir strongly stratifies in summer with surface temperatures of 17°C to 18°C and bottom temperature of 7°C, a range of temperatures similar to those observed at Ice House Reservoir. In June and July, the epilimnion is approximately 20 feet deep, followed by a distinct metalimnion where temperatures drop approximately 10°C within 40 feet. In September, the reservoir is warmer with a deeper epilimnion at 20°C. In October 2002, temperatures of close to 18.0°C were found in the top 56 feet of the reservoir, followed by a metalimnion to around 213 feet, below which temperatures were stable around 5.9°C. The reservoir remains stratified in November with a thermocline in the 187 to 197 foot depth range. Epilimnion temperatures range from approximately 12.4°C at the surface to around 11.0°C at 187 feet, and the hypolimnion has water temperatures at about 6.0°C. In contrast to Ice House Reservoir, the DO profile in Union Valley Reservoir does not indicate obvious phytoplankton activity. Dissolved oxygen profiles are mildly orthograde in both June and July, exhibiting concentrations of approximately 7.0 mg/l. By November, Union Valley Reservoir exhibits a constant dissolved oxygen profile at 7.0 to 7.5 mg/l. Secchi disk depth ranged between 25 and 27 feet during June 2000, and was 24 feet in 1980.

As reported in Table 4.0-1 of the *Reservoir Fisheries Technical Report,* fish populations in Union Valley Reservoir include rainbow trout, lake trout, Sacramento suckers, smallmouth bass, cutthroat trout, kokanee salmon, lake trout (mackinaw), smallmouth bass, golden shiner, green sunfish and mosquitofish. In 2002, 64 smallmouth bass, 22 kokanee salmon, 16 Sacramento sucker, seven rainbow trout, and one lake trout were collected in gill nets (Table 4.0-2 of the

Reservoir Fisheries Technical Report). The length-frequency distribution for smallmouth bass found that the majority (35 fish) forms a peak in the 300-349 mm size range. Kokanee, with nearly 20 fish, were most common in the 300-349 mm size range. Rainbow trout were distributed in the 300-449 mm size range. Sacramento sucker were distributed from 350-499 mm, with a single Sacramento sucker in the 550-559 mm size range. A single lake trout was the largest fish sampled, observed in the 850-899 mm size class. (Figure 4.4-2 of the *Reservoir Fisheries Technical Report.)*

4.1.4 Junction Reservoir

4.1.4.1 Reservoir Fluctuation

The primary purpose of Junction Dam, which is located on Silver Creek, is to capture the local inflows from the South Fork Silver Creek and the Little Silver Creek, and function as an afterbay for the Union Valley Powerhouse and as a forebay to the Jaybird Powerhouse. The gross and usable storage capacity of Junction Dam at normal full pool (El. 4,450.0 feet) are 2,610 ac-ft and 2,104 ac-ft of water, respectively.

Figure 4.1-10 shows the average historical minimum, maximum and median reservoir elevations by month for the water years 1988 through 1998. Over this period, monthly median high water elevations varied only one foot, from 4,445 to 4,446 feet. This represents a negligible median seasonal change in water elevation at Junction Reservoir. Because the reservoir is operated as a re-regulating reservoir for daily peaking operation of the Jaybird Powerhouse, water level in the reservoir may fluctuate daily with changing volumes of inflows and powerhouse flow. Typical fluctuation is no more than 15 feet, ranging between the operating pool levels of 4,435 feet and 4,450 feet. Average elevation change per day in Junction Reservoir is about 20.7 feet, as reported in Table 4.2-1 of the *Reservoir Shoreline Habitat Technical Report.*

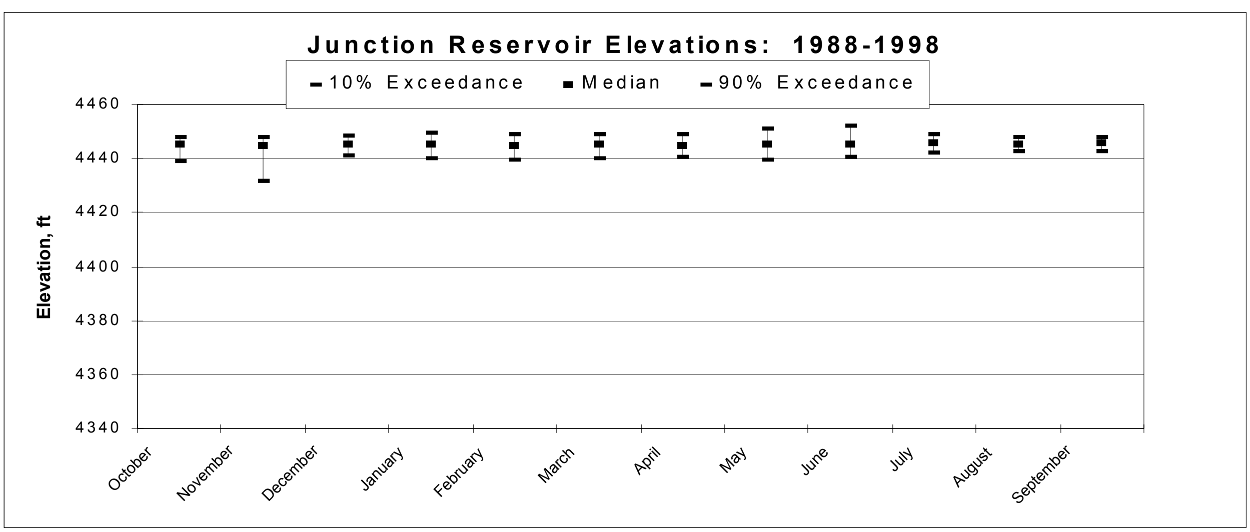

Figure 4.1-10. Junction Reservoir monthly median, 10 percent exceedance and 90 percent exceedance water surface elevations, based on data from 1988 through 1998.

4.1.4.2 Flow Through Deepwater Intakes

Water is released from Junction Reservoir by either passing over the Junction Dam spillway, passing through the Jaybird Power Tunnel or passing through the Junction Dam Low-Level outlet. At normal full pool (El. 4,450.0 feet), the maximum capacity of the Jaybird Power Tunnel is 1,345 cfs and the maximum capacity of the one 18-inch-diameter hollow cone valve low-level outlet is 138 cfs. The invert elevation, height, width and cross-sectional area of the Jaybird Power Tunnel intake and the Junction Dam Low-Level intake behind the trashracks are shown in Table 3.0-1.

To determine the range of typical flows through the Jaybird Power Tunnel, DTA calculated the average monthly flow through the power tunnel from 1988 through 1998 (Figure 4.1-11). This analysis indicated that the lowest average monthly flow through the Jaybird Power Tunnel intake occurs in November (328 cfs) while the highest average monthly flow occurs in March (901 cfs). Based on the these data and the 1,470 sq ft cross-section area of the Jaybird Power Tunnel Intake (Table 3.0-1), the range of approach velocities typical for the intake is from 0.22 fps (328 cfs divided by 1,470 sq-ft) to 0.61 fps (901 cfs divided by 1,470 sq-ft).

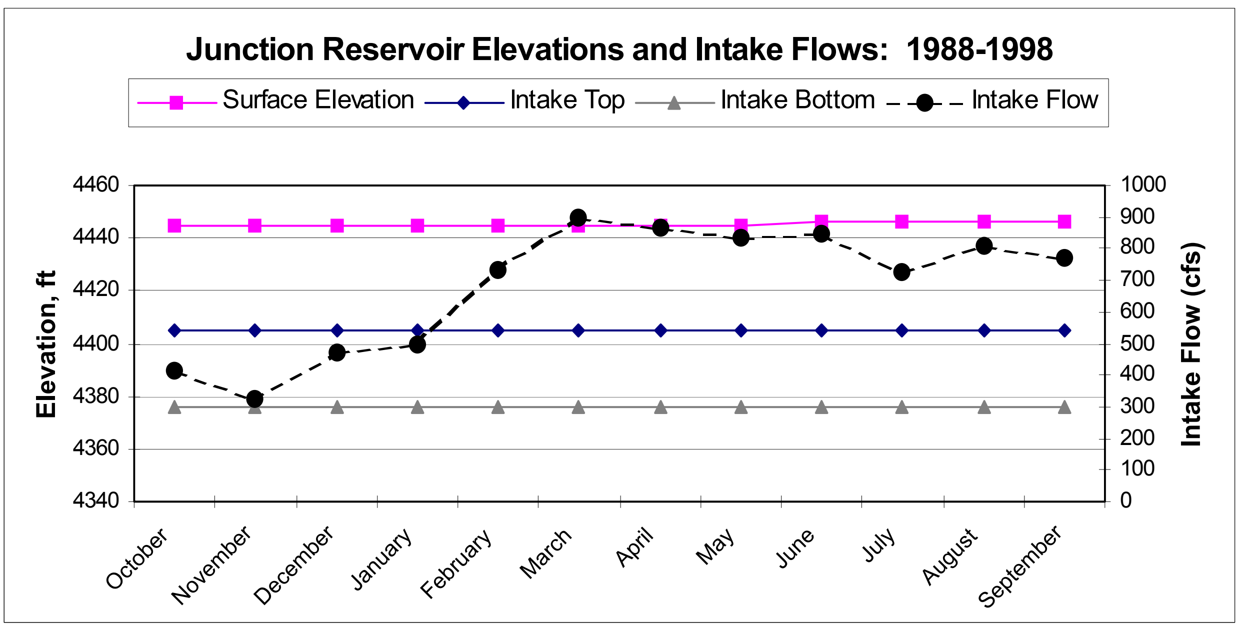

Figure 4.1-11. Junction Reservoir median monthly water surface elevation, depth of deepwater intake, and flow through the deepwater intake based on data from 1988 through 1998.

The maximum amount of flow that can be passed through the Junction Dam low-level intake is about 138 cfs. The minimum streamflow release requirement is from 5 to 20 cfs, depending on water year type. Based on the range of historic minimum streamflows and the 16 square foot cross-sectional area of the intake structure (Table 3.0-1), one can assume that the range of approach velocities at the Junction Dam Low-Level Intake is from 0.31 fps (5 cfs divided by 16 sq-ft) to 1.25 fps (20 cfs divided by 16 sq-ft).

4.1.4.3 Depth of Deepwater Intakes

Figure 4.1-11 shows the historical reservoir average elevations by month relative to the elevations of the top and bottom of the submerged intake structure. Figure 4.1-11 also shows on the right-hand scale, the mean monthly power diversion intake flows in cfs. These flows not only represent average monthly withdrawals of water, but also relate directly to average monthly approach velocities at the intake structure.

4.1.4.4 Reservoir Stratification and Fish Populations

Water temperature stratification in Junction Reservoir is evident in June, but the epilimnion is very shallow and temperatures decreased sharply below approximately 15 feet. Surface temperatures approach 19°C, approximately 10°C warmer than in November. Bottom temperatures (maximum depth of about 110 feet) are approximately 7°C. Dissolved oxygen ranges from approximately 8 to 10 mg/l in the reservoir. Secchi disk depth in November is about 8 to 10 feet deep. See Section 4.1.9 of the *Water Temperature Technical Report* for a more detailed discussion of water temperature in Junction Reservoir.

Fishes in Junction Reservoir include rainbow trout, brook trout, brown trout, Sacramento sucker and kokanee (Table 4.0-1 of the *Reservoir Fisheries Technical Report)*. In 2002, 47 Sacramento sucker and ten brown trout in the gill netting surveys were collected. No other species were caught (Table 4.0-2 of the *Reservoir Fisheries Technical Report).* Sacramento suckers ranged in size from 300 to 499 mm, with a peak at 400-499 mm. Brown trout were spread across several different size ranges, most from 300-449 mm and one fish at 550-599 mm and one fish at 700-749 mm. The highest concentration of brown trout occurred in the 300-349 mm size range. (Figure 4.5-2 of the *Reservoir Fisheries Technical Report.)*

4.1.5 <u>Camino Reservoir</u>

4.1.5.1 Reservoir Fluctuation

Camino Reservoir, located on Silver Creek, is a small reservoir capable of impounding a maximum of 541 ac-ft of water (usable storage of 489 ac-ft) at a normal maximum full pool elevation of 2,915 feet, which is the top of the Camino Dam spillway gates, which are normally closed. The gates are only opened if water might spill over the gates. This reservoir serves as an afterbay to Jaybird Powerhouse and as one of the two forebays to Camino Powerhouse. The dam also captures accretion flows that enter Silver Creek downstream of Junction Dam.

Figure 4.1-12 shows the historical minimum, maximum and median reservoir elevation by month for the water years 1988 through 1998. Over this period, monthly median high water elevations varied only one foot, from elevation 2,904 to 2,905 feet. This represents a negligible median seasonal change in water elevation at Camino Reservoir. Because the reservoir is operated as a re-regulating reservoir for daily peaking operation of both the Jaybird and Camino Powerhouses, water levels in the reservoir fluctuates daily with changing volumes of inflows and powerhouse flow. Typical daily fluctuation is no more than 20 feet, ranging between the operating pool levels of 2,890 feet and 2,910 feet.

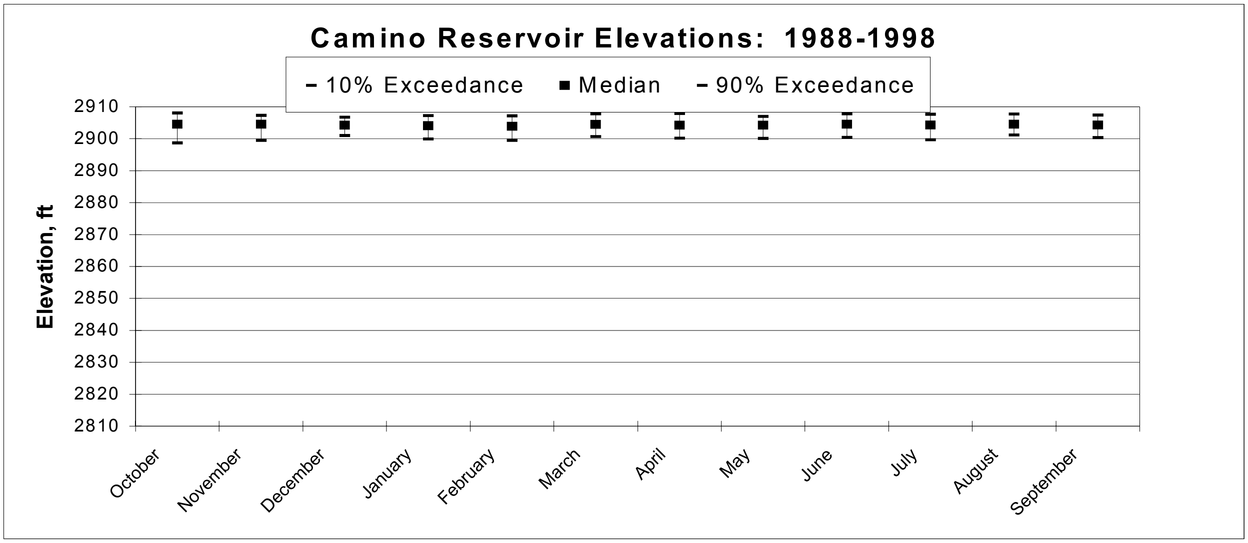

Figure 4.1-12. Camino Reservoir monthly median, 10 percent exceedance and 90 percent exceedance water surface elevations, based on data from 1988 through 1998.

4.1.5.2 Flow Though Deepwater Intakes

Water is released from Camino Reservoir by either passing over the Camino Dam spillway, passing through the Camino Tunnel or passing through the Camino Dam Low-Level outlet. At normal full pool (El. 2,915.0 feet), the maximum capacity of the Camino Tunnel is 1,200 cfs and the maximum capacity of the one 18-inch-diameter hollow cone valve low-level outlet is 112 cfs. The invert elevation, height, width and cross-sectional area of the Camino Tunnel intake and the Camino Dam Low-Level intake behind the trashracks are shown in Table 3.0-1.

To determine the range of typical flows through the Camino Tunnel, DTA calculated the average monthly flow from 1988 through 1999 (Figure 4.1-13). This analysis indicated that the lowest average monthly flow through the Camino Tunnel intake occurs in November (337 cfs) while the highest average monthly flow occurs in March (782 cfs). Based on the these data and the 1,330 square foot cross-section area of the Camino Tunnel Intake (Table 3.0-1), the range of approach velocities typical for the intake is from 0.25 fps (327 cfs divided by 1,330 sq-ft) to 0.59 fps (782 cfs divided by 1,330 sq-ft).

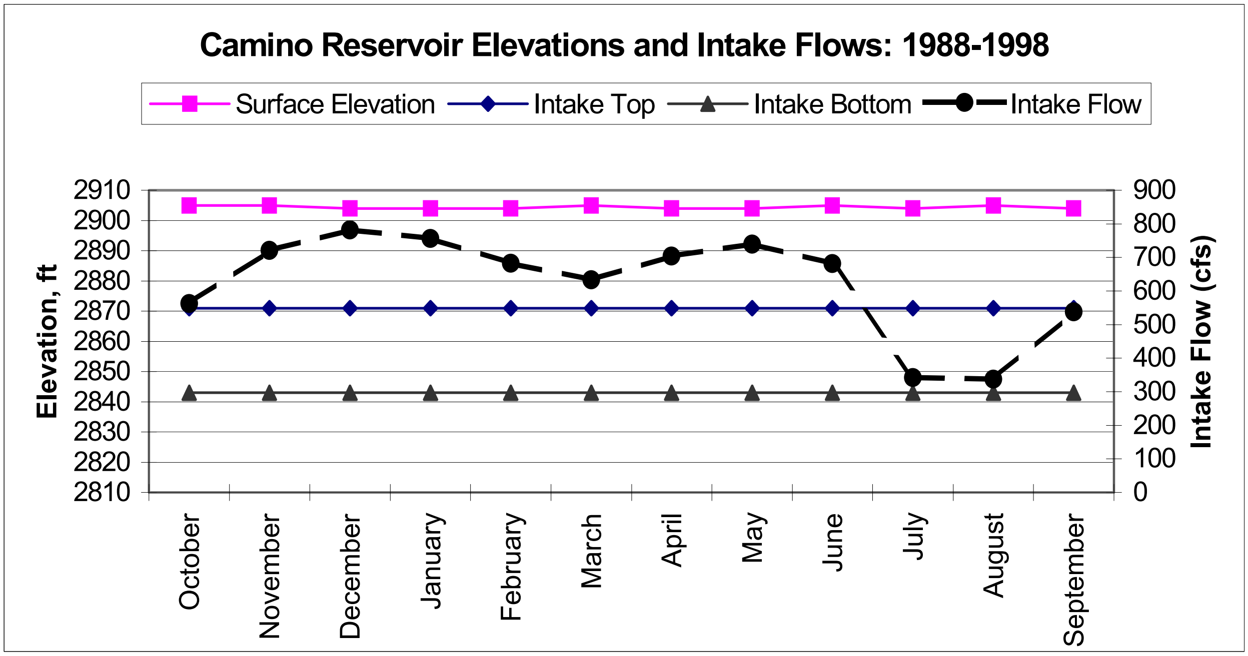

Figure 4.1-13. Camino Reservoir median monthly water surface elevation, depth of deepwater intake, and flow through the deepwater intake based on data from 1988 through 1998.

The maximum amount of flow that can be passed through the Camino Dam Low-Level intake is about 112 cfs. The minimum streamflow release requirement is from 5 to 20 cfs, depending on water year type. Based on the range of historic minimum streamflows and the 16 square foot cross-sectional area of the intake structure (Table 3.0-1), one can assume that the range of approach velocities at the Junction Dam Low-Level Intake is from 0.31 fps (5 cfs divided by 16 sq-ft) to 1.25 fps (20 cfs divided by 16 sq-ft).

4.1.5.3 Depth of Intakes

Figure 4.1-13 shows the historical reservoir elevations by month for the same period, not including 10 percent and 90 percent exceedance levels, but relative to the elevations of the top and bottom of the submerged intake structure. Figure 4.1-13 also shows on the right-hand scale, the mean monthly power diversion intake flows (including those which cannot be parsed out from Brush Creek Reservoir) in cfs. These flows not only represent average monthly withdrawals of water, but also relate directly to average monthly approach velocities at the intake structure.

4.1.5.4 Reservoir Stratification and Fish Populations

Water temperature profiles were recorded at three locations in Camino Reservoir in June 2000, which showed a weakly stratified water column and no distinct epilimnion, as water temperature gradually dropped from a surface value of 11.5°C to 7.5°C at a depth of 12 feet. Deeper water, down to 47 feet, exhibited an isothermal 7.5°C. Such temperature profiles are typical of water bodies with high through-flow volumes (Wetzel 1975). Dissolved oxygen was between 9 and 11 mg/l. See Section 4.1.10 of the *Water Temperature Technical Report* for a more detailed discussion of water temperature in Camino Reservoir.

Fishes in Camino Reservoir, based on historic reports, include rainbow trout, brook trout, brown trout, Sacramento sucker, "minnows," California roach, and riffle sculpin (Table 4.0-1 of the *Reservoir Fisheries Technical Report)*. Since Camino Reservoir is a restricted entry facility, fish were not collected.

4.1.6 Brush Creek Reservoir

4.1.6.1 Reservoir Fluctuations

Brush Creek Reservoir, located on Brush Creek, is capable of impounding up to 1,530 ac-ft of water at elevation 2,915 feet, of which only 374 ac-ft is usable. In addition to capturing the local inflow from Brush Creek, this reservoir serves as the second of the two forebays to Camino Powerhouse.

Unlike Camino Reservoir and the other reservoirs within the UARP, Brush Creek Reservoir is commonly not operated in a mode during which water is withdrawn through the power diversion intake. When operated, it is generally to provide spinning reserve for reliability purposes or to generate peak power during emergency and other limited situations when all available generating units are expected to operate at full load for short periods of time. Under this super-peaking operating mode, daily water levels may fluctuate up to 15 feet, ranging between the operating pool levels of 2,895 feet and 2,910 feet. Since the reservoir lies in a watershed with low natural inflow, over the appropriate nighttime periods of the next 2-3 days following this operating mode, the operation of the Camino Powerhouse typically ceases when operating the Jaybird Powerhouse. Water exiting the Jaybird Powerhouse via the Camino and the Brush Creek tunnels then refills Brush Creek Reservoir.

Figure 4.1-14 shows the historical minimum, maximum and median reservoir elevation by month for the water years 1988 through 1998. Over this period, monthly median high water elevations varied only four feet, from elevation 2,902 to 2,906 feet. This represents a small median seasonal change in water elevation at Brush Creek Reservoir.

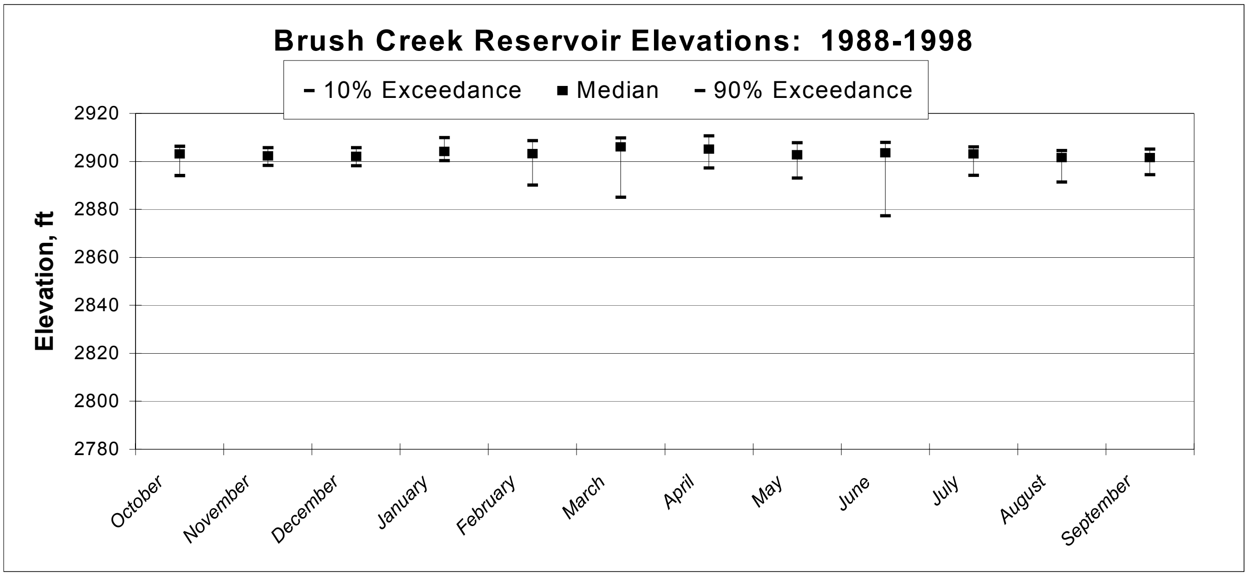

Figure 4.1-14. Brush Creek Reservoir monthly median, 10 percent exceedance and 90 percent exceedance water surface elevations, based on data from 1988 through 1998.

4.1.6.2 Flow Through Deepwater Intakes

Water is released from Brush Creek Reservoir by either passing over the Brush Creek Dam spillway, passing through the Brush Creek Tunnel or passing through the Brush Creek Dam Low-Level outlet. At normal full pool (El. 2,915.0 feet), the maximum capacity of the Brush Creek Tunnel is 1,900 cfs and the maximum capacity of the one 18-inch-diameter hollow cone valve is 145 cfs. The invert elevation, height, width and cross-sectional area of the Brush Creek Tunnel intake and the Brush Creek Dam Low-Level intake behind the trashracks are shown in Table 3.0-1.

Due to this varied mode of operation, inadequate data are available to characterize average approach velocities at the power diversion intake.

The maximum amount of flow that can be passed through the Brush Creek Dam Low-Level intake is about 145 cfs. The minimum streamflow release requirement is from 2 to 6 cfs, depending on water year type. Based on the range of minimum streamflows and the 42 square foot cross-sectional area of the intake structure (Table 3.0-1), one can assume that the range of approach velocities at the Brush Creek Dam Low-Level Intake is from 0.05 fps (2 cfs divided by 42 sq-ft) to 0.14 fps (6 cfs divided by 42 sq-ft).

4.1.6.3 Depth of Deepwater Intakes

Figure 4.1-15 shows the historical reservoir elevations by month for the same period, not including 10 percent and 90 percent exceedance levels, but relative to the elevations of the top and bottom of the submerged intake structure. As discussed above, it is not possible to characterize average monthly diversion intake flows.

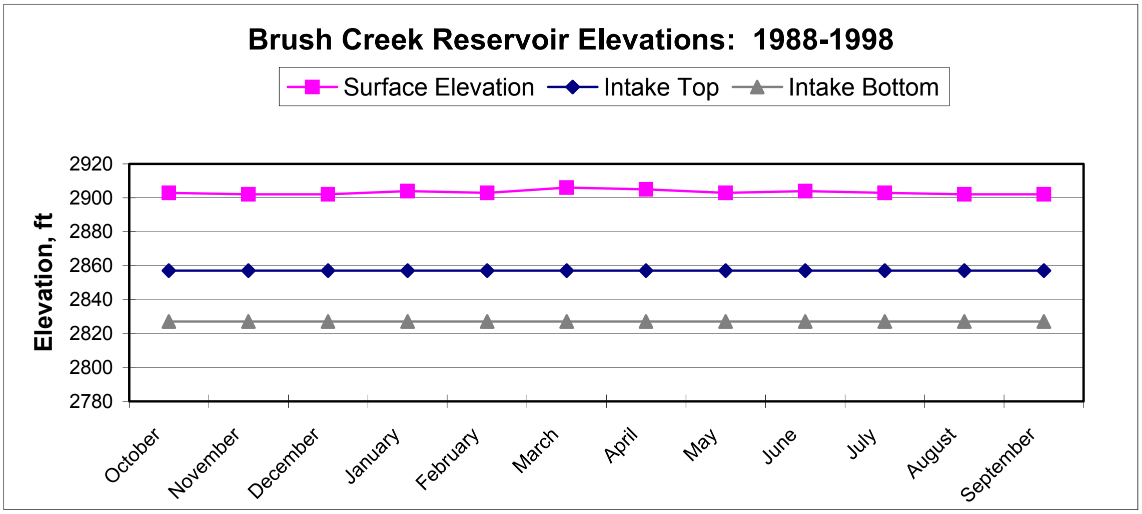

Figure 4.1-15. Monthly Brush Creek Reservoir elevations relative to intake elevations based on the period from 1988 through 1998.

4.1.6.4 Reservoir Stratification and Fish Populations

During the low-flow summer period, Brush Creek Reservoir exhibits a strong stratification at about 54 feet with surface water at about 20.1°C and the bottom temperature at about 8.9°C. Dissolved oxygen concentrations were about 9.33 mg/l on the surface to about 2 mg/l on the bottom. Secchi disk depth measured 29 feet. See Section 4.1.11 of the *Water Temperature Technical Report* for a more detailed discussion of water temperature in Brush Creek Reservoir.

CDFG stocking records report that brown trout, rainbow trout, and steelhead were previously planted in Brush Creek Reservoir. Rainbow trout have also been documented in a tributary to Brush Creek Reservoir. No additional fish sampling surveys have been performed.

4.1.7 Slab Creek Reservoir

4.1.7.1 Reservoir Fluctuation

Slab Creek Reservoir, located on the South Fork American River, is capable of impounding up to 13,335 ac-ft of gross storage (5,580 ac-ft of usable storage) at the normal maximum full pool elevation of 1,850.0 feet. In addition to capturing the local inflow from the SFAR, this reservoir serves as an afterbay to the 150 MW Camino Powerhouse.

Figure 4.1-16 shows the historical minimum, maximum and median reservoir elevations by month for the water years 1976 through 1998. Over this period, monthly median high water elevations varied only two feet, from an elevation of 1,842 feet to 1,844 feet. This represents a negligible median seasonal change in water elevation at Slab Creek Reservoir. Because Slab Creek Reservoir is operated as a re-regulating afterbay/forebay, water level in the reservoir may fluctuate daily with changing volumes of local inflow and powerhouse flow. Typical weekly fluctuation is no more than 30 feet, ranging between the operating pool levels of 1,820 feet and 1,850 feet. Average elevation change per day in Slab Creek Reservoir is about 3.3 feet, as reported in Table 4.2-1 of the *Reservoir Shoreline Habitat Technical Report.*

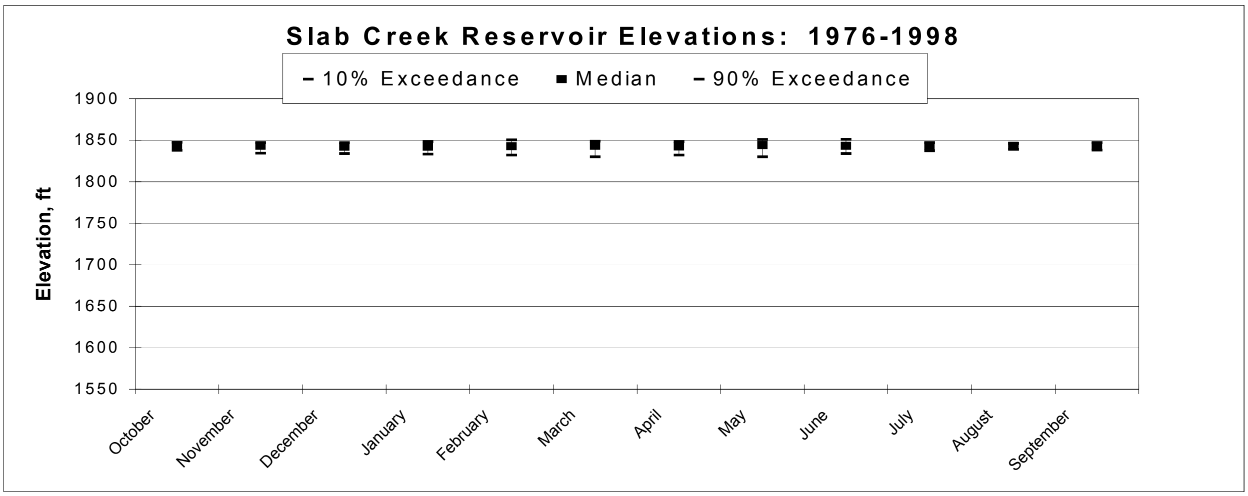

Figure 4.1-16. Slab Creek Reservoir elevations, including 10% and 90% exceedance levels by month, based on the period from 1976 through 1998.

4.1.7.2 Flow Through Deepwater Intakes

Water is released from Slab Creek Reservoir by either passing over the Slab Creek Dam spillway, through the White Rock Power Tunnel or through the Slab Creek Dam Low-Level outlet. The White Rock Power Tunnel has a maximum capacity of 3,950 cfs. The Slab Creek Dam low-level is comprised of one 24-inch-diameter Howell Bunger valve, which has a capacity of about 263 cfs at full pool. The invert elevation, height, width and cross-sectional area of the White Rock Power Tunnel intake and the Slab Creek Dam low-level intake behind the trashracks are shown in Table 3.0-1.

As described above, the maximum amount of flow that can be passed through the White Rock Power Tunnel is 3,950 cfs. Based on historic records from 1976 through 1999, the median flow through the power tunnel is 939 cfs, with 10 and 90 percent exceedances of 2,341 cfs and 284 cfs. The maximum flow was 3,433 cfs (0.5% exceedance). (Figure 4.1-17)

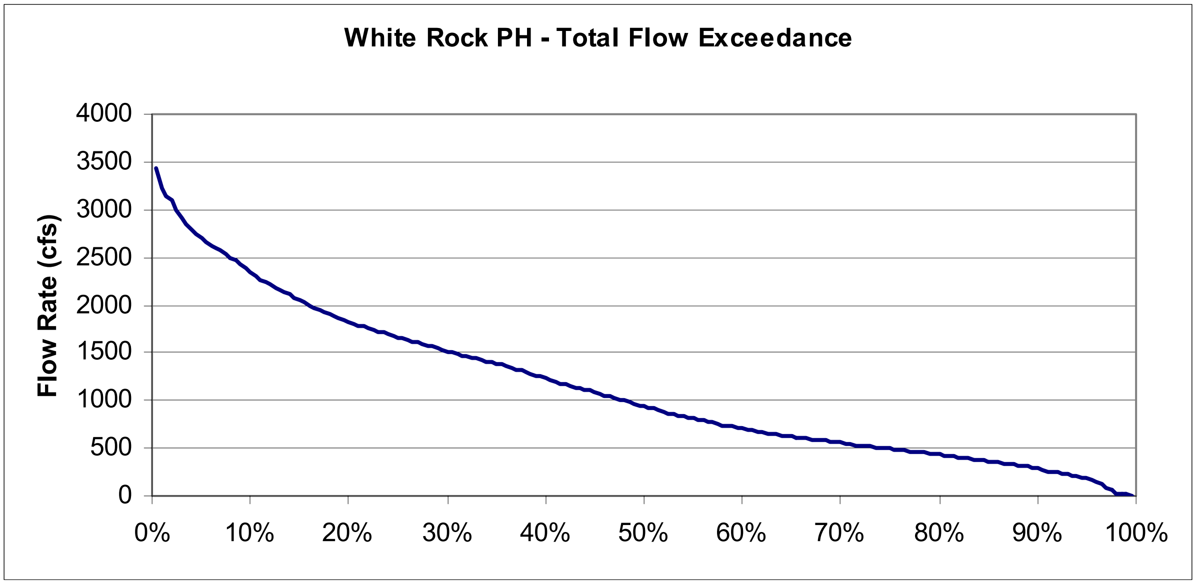

Figure 4.1-17. White Rock Power Tunnel withdrawal exceedance curve based on the period from 1976 through 1999.

Based on these flows and the 2,370 square foot cross-sectional area of the intake structure (Table 3.0-1), one can assume that the approach velocities associated with the median, 10 percent and 90 percent exceedance flows through the White Rock Power Tunnel Intake are 0.40 fps (939 cfs divided by 2,370 sq-ft), 0.99 fps (2,341 cfs divided by 2,370 sq-ft) and 0.12 fps (284 cfs divided by 2,370 sq-ft), respectively.

The maximum amount of flow that can be passed through the Slab Creek Dam low-level intake is about 263 cfs. However, this valve is not operated at this level except for periodic tests required by FERC or DSOD, or for specific studies, such as the recent Slab Creek Dam Reach Whitewater Boating Test Flow Study performed for the UARP relicensing. The minimum streamflow release requirement is from 10 to 26 cfs, depending on water year type, which is released through the low-level outlet. Based on the range of these minimum streamflows and the 16 square foot cross-sectional area of the intake structure (Table 3.0-1), one can assume that approach velocities at the Slab Creek Dam Low-Level Intake range from 0.63 fps (10 cfs divided by 16 sq-ft) to 2.25 fps (36 cfs divided by 16 sq-ft).

4.1.7.3 Depth of Deepwater Intakes

Figure 4.1-18 shows the historical reservoir elevations by month relative to the elevations of the top and bottom of the submerged intake structure. Figure 4.1-18 also shows on the right-hand scale, the mean monthly power diversion intake flows in cfs. These flows not only represent average monthly withdrawals of water, but also relate directly to average monthly approach velocities at the intake structure.

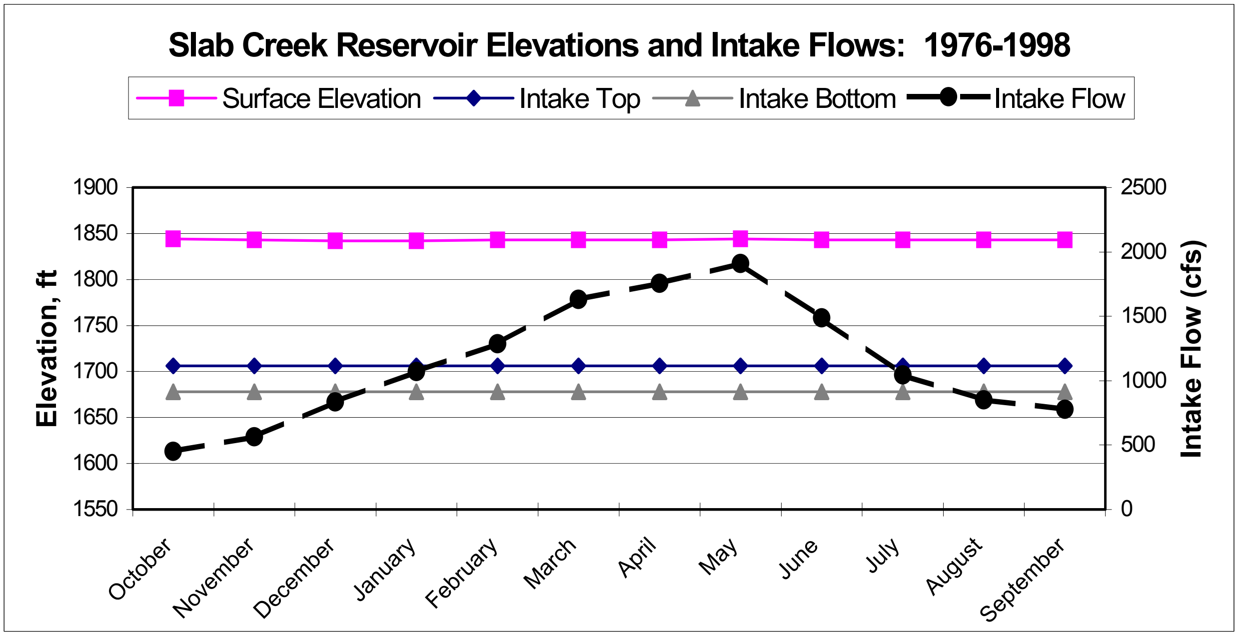

Figure 4.1-18. Monthly Slab Creek Reservoir elevations and intake flows, based on a period from 1976 through 1998.

4.1.7.4 Reservoir Stratification and Fish Populations

Water temperature profiling was conducted along the length of Slab Creek Reservoir in November 1999, June 2000, and October and November 2002. Vertical profiles of temperature during June 2000 at the deepest location (140 feet) showed a relatively narrow metalimnion at approximately 20 feet, with surface temperatures near 15°C and near-bottom temperatures of approximately 11°C. The October 1, 2002 temperature profile showed temperatures around 13.3°C above around 13 feet deep, dropping to 10.5°C to 11.5°C from around 23 to 164 feet. The November 12, 2002 temperature profile showed temperatures around 11.0°C at the surface, quickly dropping to a range of 10.2°C to 9.5°C below around 10 feet deep, down to 92 feet. In 1999 and 2000, DO levels ranged from 8.8 to 10.2 mg/l. The October 1 and November 12, 2002 DO profiles showed virtually no stratification with levels in the 9.3 to 10.3 mg/l range, with an equivalent range of 94% to 103% saturation, down to approximately 164 feet. Secchi disk depths of 11 to 15 feet suggest some particulate matter in the water column. See Section 4.1.12 of the *Water Temperature Technical Report* for a more detailed discussion of water temperature in Slab Creek Reservoir. Additional profiling data has been collected in 2003 for use in modeling temperature effects of the proposed Iowa Hill Pumped Storage Project.

Fish surveys conducted in Slab Creek Reservoir in 2002 found 39 Sacramento sucker, 29 hardhead, five brown trout, and one Sacramento pikeminnow (Table 4.0-2 of the *Reservoir Fisheries Technical Report)*. The length-frequency distribution found Sacramento sucker between the size ranges of 300-549 mm with a peak in the 400-449 size range. One Sacramento sucker was observed in the 200-249 mm size range. Hardhead length distribution was similar to the Sacramento sucker, ranging between 250-499 mm in size. Brown trout were captured in the 350-449 mm size ranges, with one outlier in the 700-749 mm size range. (Figure 4.6-2 of the *Reservoir Fisheries Technical Report.)*

4.2 Habits of Dominant Fish Species

4.2.1 Rainbow Trout

A review of the literature indicates that when water temperatures are suitable, rainbow trout are normally found near the surface of large reservoirs due to preferences for temperature, DO, food and cover. Fast (1973), May (1973), and Hess (1974) state that adult rainbow trout normally are found at depths less than or equal to the 18ºC isotherm in reservoirs where dissolved oxygen levels are greater than 3 mg/l. Moyle (2002) reports that optimal temperatures for growth of rainbow trout are 15ºC to 18ºC, but they can tolerate temperatures from near 0ºC to near 27ºC, and they can tolerate DO levels as low as 1.5 mg/l to 2.0 mg/l at low temperatures.

Warner and Quinn (1995) tracked six adult rainbow trout in Lake Washington during the summer and fall of 1989 with ultrasonic transmitters for 349 hours. The lake thermocline ranged from 49 to 66 feet during the tracking periods. They found that fish movements were slow and close to shore, and that rainbow trout were surface oriented, spending over 90 percent of their time in the top 10 feet of the lake and occasionally made brief dives to depths of 16 to 33 feet for about 2 to 3 minutes. Baldwin *et al.* (2000) found that rainbow trout in Strawberry Reservoir, Utah, were rarely caught offshore, and usually caught at depths between 3 and 53 feet. Strawberry Reservoir, at an elevation of 7,546 feet, has an average depth of 46 feet and a maximum depth of 230 feet, and the majority of the limnetic zone is less than 92 feet deep.

In two deep-water lakes that ranged between 263 and 295 feet deep on North Island, New Zealand, Rowe and Chisnall (1995) used hydroacoustics to look at distributions of adult rainbow trout. They found that when oxygen is not limiting, water temperature was the factor that determined depth distribution of trout. Most trout were found in or close to the thermocline. McAfee (1966) suggests that rainbow trout tend to be limnetic in their distribution in fluctuating reservoirs and deep oligotrophic lakes where most food is available in the open water or on the surface. Butler and Borgeson (1965) found that hatchery rainbow trout planted in Huntington Lake in Fresno County dispersed throughout the lake. Cordone and Nicola (1970) found that downstream movement of hatchery rainbow trout out of Beardsley Reservoir tended to be associated with the discharge of surface water over the spillway. This movement also varied with the strain of trout planted. Cordone and Nicola found Kamloops strain rainbow trout were more likely to emigrate from the reservoir than the domestic strains tested.

Younger rainbow trout are typically found in shallower water, closer to cover, in order to escape predation, and fry are rarely found in areas that are greater than three feet from cover (Raleigh *et al.* 1984). Natural production of rainbow trout in reservoirs occurs in tributaries. Northcote (1969) reviewed patterns of lakeward migration from inlet streams, and found that the age at lake entry typically ranged from age 0 to age 2. In the Finger Lakes in New York, Northcote reported that rainbow trout tended to migrate at age 1 and age 2 from tributaries with relatively cool stable summer flows, while age 0 migrants were most common in streams with low, warm summer flow.

Food availability is also a very important factor in determining where trout are located. Beauchamp (1990) determined that fishes constitute 90 percent of the diet biomass of large trout (greater than 14 inches) and that *Daphnia spp*. was the second most important food item. Nicola and Borgeson (1970) found that zooplankton (principally *Daphnia*) comprised almost the total volume of food consumed by all sizes of rainbow trout in Beardsley Reservoir. Warner and Quinn (1995) found that in Lake Washington, *Daphnia spp.* were densest in the top 33 feet of the water column, where the trout spent most of their time.

4.2.2 Brown Trout

The literature supports that brown trout prefer the upper portions of large reservoirs. This fish is classified by Moyle (2002) as being part of the shallow water assemblage in Lake Tahoe. Various studies have been conducted in large reservoirs in Norway looking at brown trout behavior as it relates to their distributions. In a large reservoir in Aursjoeen, Norway, Haugen and Rygg (1996) found that brown trout larger than eight inches were caught in the pelagic zone. Brown trout preferred benthic habitats in the upper 26 feet of the water column. Linlokken (1988) found that brown trout in acidified Lake Gjerstadvann in Norway lived in the top 53 feet of the water column. The thermocline in this lake was between 26 and 33 feet deep. Halvorsen *et al.* (1997) observed juvenile brown trout in two lakes in northern Norway and found that they were mainly caught at the surface to depths of 20 feet in the littoral and sublittoral zones. They determined that access to shelter was the most important factor in their horizontal distribution, which consisted of stony or vegetated habitats. Moyle (2002) reports that brown trout prefer temperatures of 12ºC to 20ºC, but they can survive to temperatures of 29ºC.

Hesthagen *et al.* (1995) looked at native and native-stocked brown trout in Lake Tesse, Norway. This is a regulated hydroelectric reservoir that is 210 feet at its deepest and at an altitude of about 2,800 feet. They found that the brown trout were spatially segregated according to size. The larger brown trout were found mainly in the pelagic zone feeding almost exclusively on surface insects and planktonic crustaceans. The smaller trout were mainly found in the epibenthic habitat despite having a better food availability in the pelagic habitat. This was interpreted as a stronger need by the smaller individuals for shelter to avoid encounters with larger individuals and consequently predation. Other researchers (Hegge *et al.* 1989) also saw this predation avoidance behavior.

Like rainbow trout, younger brown trout would be expected to be typically found in shallower water, closer to cover, in order to escape predation. This behavior limits exposure of smaller, weaker trout to predation. Natural production of brown trout in reservoirs occurs in tributaries.

4.2.3 Sacramento Sucker

Sacramento sucker primarily migrates out of reservoirs into tributaries to spawn, although some shoreline spawning has been observed in Pine Flat Reservoir, California, where spring freshets were flowing into the lake (Moyle 2002). Like other small fishes, juvenile suckers prefer shallow water, and so are at limited risk of being entrained in a deep intake. In lakes, Moyle (2002) reports that adult suckers spend the daylight hours in relatively deep water but move into shallow water at night to feed. Suckers associate with bottom substrates where these bottom dwellers feed on bottom associated food resources, rather than utilizing open water habitat. They can be found over a wide temperature range, but have a preferred temperature range of 20ºC to 25ºC (Moyle 2002).

4.2.4 Smallmouth Bass

Smallmouth bass are both stream dwelling and lake/reservoir dwelling, and have become established in a number of reservoirs. They tend to concentrate at depths of around 3 to 33 feet in the upper reaches, in narrow bays, or areas along shore with gravel bottoms and where rocky shelves and other structures exist under water. They prefer clear waters in lakes and reservoirs with abundant cover and summer temperatures in the range of 20ºC to 27ºC (Moyle 2002). Their young prefer shallow water habitats with cover from cannibalistic adults and where prey food is abundant. Dissolved oxygen levels in excess of 6 mg/l are needed for growth, and 1 mg/l to 3 mg/l is needed for survival (Moyle 2002). Spawning takes place in May and June in northern California reservoirs, where the mature adults move into water less than five feet deep to spawn.

4.2.5 Hardhead

The following life history description of hardhead is taken directly from the CDFG's Web site at: http://www.dfg.ca.gov/hcpb/cgi-bin/read_one.asp?specy=fish&idNum=31

Description: Hardhead is a large cyprinid, reaching lengths in excess of 60 cm SL. Body shape is similar to that of Sacramento squawfish, with which they co-occur, but the body is deeper and heavier and the head is less pointed. Hardhead also differ from squawfish in that their maxilla do not extend beyond the anterior margin of the eye and they possess a frenum connecting the premaxilla to the head. Hardhead have 8 dorsal rays, 8-9 anal rays, and 69-81 lateral line scales. Adults have large molariform pharyngeal teeth, but juvenile teeth are hooklike. Juveniles are silver; adults are brown-bronze dorsally. During the spawning season adult males develop fine nuptial tubercles in the head region (Moyle 1976).

Taxonomic Relationships: *Mylopharodon conocephalus* was first described as Gila conocephala by Baird and Girard (Girard 1854b) from one specimen collected from the "Rio San Joaquin." Ayres (1854a) redescribed the species as *Mylopharodon robustus*. Girard (1856a) recognized the generic designation and reclassified *G. conocephala* as *Mylopharodon conocephalus* and recognized *M. robustus* as a closely allied species. Jordan (1879), however, considered the genus monotypic and united both forms as *Mylopharodon conocephalus* (Jordan and Gilbert 1882) and attributed the generic nomenclature to Ayres and the specific nomenclature to Girard and Baird. Electrophoretic studies by Avise and Ayala (1976) and morphometric analysis by Mayden et al. (1991) indicate it to be closely allied to Sacramento squawfish in the California fauna but different enough to be retained in a separate genus.

Life History: Hardhead is a bottom feeder that forages for benthic invertebrates and aquatic plant material in quiet water. Occasionally they will also feed on plankton and surface insects, and in Shasta Reservoir they were known to feed on cladocerans (Wales 1946). Smaller fish (<20 cm SL) feed primarily on mayfly larvae, caddisfly larvae, and small snails (Reeves 1964), whereas the larger fish feed more on aquatic plants (especially filamentous algae), as well as crayfish and other large invertebrates (Moyle, unpubl. data). The ontogenetic changes in teeth structure seem to fit this dietary switch. Reeves (1964) stressed that no fish remains have been found in the stomachs of large hardhead.

In Britton Reservoir, Shasta County, adult hardhead concentrated in the surface waters (<1 m) and could often be seen motionless close to the surface (Vondracek et al. 1988). This behavior made them an important prey for bald eagles that nested in the area.

Hardhead reach 7-8 cm by their first year, but growth slows in subsequent years. In the American River, hardhead reach 30 cm SL in 4 years; in the Pit and Feather rivers, it typically takes six years to reach that length (Moyle et al. 1983, PG&E 1985). The Feather River fish in the 44-46 cm SL range were aged at 9-10 years, but older and larger fish probably exist in the Sacramento River.

Hardhead mature following their second year and presumably spawn in the spring (Reeves 1964), judging by the upstream migrations of adults into smaller tributary streams during this time of the year (Wales 1946, Murphy 1947, Bell and Kimsey 1955, Rowley 1955). Shapovalov (1932) reported the presence of mature eggs in females during March, but gonads of males and females caught in July and August were spent (Reeves 1964). Estimates based on juvenile recruitment suggest that hardhead spawn by May-June in Central Valley streams and that the spawning season may extend into August in the foothill streams of the Sacramento-San Joaquin drainage (Wang 1986).

Spawning activity has not been documented, but reproductive behavior presumably involves mass spawning in upstream gravel riffles (Moyle 1976). Females are highly fecund, producing over 20,000 eggs (Burns 1966) although Reeves (1964) reported fewer (9,500-10,700) eggs.

Habitat Requirements: Hardhead are typically found in undisturbed areas of larger middle- and low- elevation streams (Moyle and Nichols 1973, Daniels and Moyle 1982). Elevational range of hardhead is 10-1,450 m (Reeves 1964). Most streams in which they occur have summer temperatures in excess of 20ºC, and optimal temperatures for hardhead (as determined by laboratory choice experiments) appear to be 24-28ºC (Knight 1985). However, in a natural thermal plume, hardhead generally selected temperatures of 17-21ºC (cooler, but usually not warmer, temperatures were available). Cech et al. (1990) demonstrated that hardhead are relatively intolerant of low oxygen levels, especially at higher temperatures, a factor which may limit their distribution to well oxygenated streams and the surface water of reservoirs. Hardhead prefer clear, deep (>1 m) pools with sand-gravel-boulder substrates and slow water velocities (<25 cm sec-1) (Moyle and Nichols 1973, Knight 1985, Moyle and Baltz 1985). In streams, adult hardhead tend to remain in the lower half of the water column, rarely moving into the upper water column (Knight 1985), while juveniles concentrate in shallow water close to the stream edges (Moyle and Baltz 1985). However, in Britton Reservoir (Vondracek et al. 1988) and in large pools of the Pit River downstream from the reservoir (Hunt et al. 1988), they were found close to the surface. Hardhead are always found in association with Sacramento squawfish and usually with Sacramento suckers. They tend to be absent from streams where introduced species, especially centrarchids, predominate (Moyle and Nichols 1973, Moyle and Daniels 1982) or streams that have been severely altered by human activity (Baltz and Moyle 1993). Hardhead populations are well established in mid-elevation reservoirs used exclusively for hydroelectric power generation, such as the Redinger and Kerkhoff Reservoirs on the San Joaquin River, Fresno County, and Britton Reservoir on the Pit River, Shasta County. In the Pit River, hardhead are most abundant in Upper Lake Britton where habitat is more riverine and less abundant in the lacustrine habitat of Lower Lake Britton, where centrarchids are more abundant (PG&E 1985). The initial establishment of hardhead in recently impounded reservoirs is probably the result of residual populations of juvenile fish growing to large sizes before populations of predatory centrarchid basses are established.

Distribution: Hardhead are widely distributed in low to mid-elevation streams in the main Sacramento-San Joaquin drainage as well as in the Russian River drainage. Their range extends from the Kern River, Kern County, in the south to the Pit River (south of the Goose Lake drainage), Modoc County, in the north. In the San Joaquin drainage, populations are scattered in the tributary streams, but are absent from the valley reaches of the San Joaquin River (Moyle and Nichols 1973, Saiki 1984, Brown and Moyle 1987). In the Sacramento River drainage, hardhead are present in most of the larger tributary streams as well as in the Sacramento River. They are present in the Russian River and in the Napa River, although the Napa River population is very restricted in its distribution (R. Leidy, pers. comm.). They are widely, if spottily, distributed in the Pit River drainage (Cooper 1983, Moyle and Daniels 1982), including the main Pit River and its series of hydroelectric reservoirs.

Abundance: Historically, hardhead have been regarded as a widespread and locally abundant species (Ayres 1854b, Jordan and Evermann 1896, Evermann 1905, Rutter 1908, Follett 1937, Murphy 1947, Soule 1951, Reeves 1964). Hardhead are still widespread in the foothill streams, but their specialized habitat requirements, combined with widespread alteration of downstream habitats, have resulted in localized, isolated populations. This makes them vulnerable to localized extinctions. Consequently, hardhead are much less abundant than they once were, especially in the southern half of their range. Reeves (1964) summarized the historical records and noted they were found in most streams in the San Joaquin drainage, but Moyle and Nichols (1973) found them in only 9% of the streams they sampled. Brown and Moyle (1987, 1993) resampled most of the sites of Moyle and Nichols (1973) and found that a number of hardhead populations had disappeared during the 15-year period.

Hardhead have been abundant enough in reservoirs in the past to be regarded as a problem species, under the assumption they competed with trout and other gamefishes for food. However, most of these reservoir populations proved to be temporary, presumably the result of colonization of the reservoir by juvenile hardhead before introduced predators became established. Populations in Shasta Reservoir, Shasta County, declined dramatically within two years (Reeves 1964), although hardhead are still present there in small numbers (J. Hayes, pers. comm.). Similar crashes of large reservoir populations have been reported from: Pardee Reservoir on the Mokelumne River, Amador/Calaveras County (Kimsey et al. 1956); Millerton

Reservoir on the San Joaquin River, Fresno County (Bell and Kimsey 1955); Berryessa Reservoir, Napa County (Moyle 1976); Don Pedro Reservoir, Tuolumne County; and Folsom Reservoir, El Dorado County (Kimsey et al. 1956).

Nature and Degree of Threat: Hardhead require large to medium-sized, cool to warm-water streams with natural flow regimes for their long-term survival. Because such streams are increasingly dammed and diverted, thus eliminating habitat, isolating upstream areas, or creating temperature and flow regimes unsuitable for hardhead, populations are declining or disappearing gradually throughout its range. A particular problem seems to be predation by smallmouth bass. Brown and Moyle (1993) observed that hardhead disappeared from the upper Kings River when the bass invaded the reach; a similar situation exists in the South Fork Yuba River (Gard 1994). Hardhead can colonize reservoirs but will persist only if exotic species, especially centrarchid basses, are not abundant. The few reservoirs in which they are abundant today are those in which water-level fluctuations (such as for power-generating flows) prevent exotic species from reproducing. However, either stabilization of water levels or increasing the amount of seasonal fluctuation of these reservoirs can result in increased populations of centrarchid basses and decreased hardhead populations.

Management: In absolute terms, hardhead still are abundant, but their recent downward population trend matches the declines shown by other California native fishes. It would be prudent to stabilize hardhead populations while they still are at moderate levels. The best way to protect hardhead is to have a number Aquatic Diversity Management Areas established in mid-elevation canyon areas in which normal flow regimes and high water quality are maintained (Moyle and Yoshiyama 1992, Baltz and Moyle 1993). Because hardhead are good indicator species of relatively undisturbed conditions, a system of such preserves would protect not only the species, but their entire biotic community. In the meantime, stream populations should be monitored to ascertain species' status. Particular attention should be paid to the Russian River population, which may have declined in recent years, and to populations in the San Joaquin drainage, which seem to be disappearing rapidly.

5.0 ANALYSIS AND DISCUSSION

Two recent papers show a consideration of similar factors in evaluating potential entrainment at hydroelectric reservoir intakes to those factors considered in this evaluation. Morsell (2002) states:

> Among the factors that may influence entrainment rates are:
>
> - Location of the intake relative to the shoreline and littoral zone;
> - Behavior and distribution of fish species in the reservoir;
> - Depth of the intake;
> - Winter draw-down of the reservoir;
> - Hydraulic capacity of the intake;
> - Approach velocity at the intake; and
> - Water quality (e.g., temperature and dissolved oxygen) with depth in the reservoir

Similarly, Normandeau Associates, Inc. (2002) state that:

> Among factors that can influence entrainment rates, this assessment examined the following:
>
> - Intake adjacent to shoreline – Nearshore intakes typically entrain fishes at higher rates than offshore intakes;
> - Intake location in littoral zone – The littoral zone is the most productive region of a reservoir and most fish rear in the shallower littoral areas;
> - Abundant clupeids – Entrainment rates trend highest at projects with clupeids such as gizzard shad and threadfin shad;
> - Intake depth – Fish are usually more abundant in shallower portions of a lake throughout most of the year;
> - Winter draw-down – Draw-down of a reservoir to provide storage of winter and spring runoff may place fish in a closer proximity to water intakes;
> - Hydraulic capacity – More water passed through intakes will entrain more fish for a given entrainment rate;
> - Water quality factor – Poor water quality (e.g., low dissolved oxygen in the hypolimnion) in a reservoir may form a barrier and reduce fish susceptibility to entrainment; and
> - Approach velocity – Approach velocities may positively correlate with entrainment rates, although FERC (1995) was unable to find a significant trend between entrainment rate and intake velocity. Other factors related to intake siting may be more important.

For fish to be entrained, they must be found in the vicinity of the intakes. As previously discussed, the concentration of trout in the vicinities of the UARP reservoir intakes is expected to be low because they tend to be somewhat randomly distributed throughout the upper elevations of the reservoirs or associated with bottom or nearshore structure. Kokanee salmon show a similar pattern, occupying near surface and open waters. Because of their spawning and rearing habitats, trout fry and juveniles are not expected to be found in the vicinity of deepwater intakes. Based on the literature, rainbow and brown trout are rarely found near the bottom of deep reservoirs. Adult trout are usually in the top one-third of the water column and are rarely found below the thermocline even when conditions in the hypolimnion are optimal. The literature suggests that where water temperature and DO are not limiting, as in the case of these reservoirs, adult rainbow trout mostly occur in the epilimnetic portions of reservoirs, primarily since their food prey is located there. There is site-specific evidence that, at least in Beardsley Reservoir in the Stanislaus drainage to the south of the UARP, the primary prey item of adult rainbow trout is *Daphnia*, which occurs in the upper portions of reservoirs. Young trout prefer the shallow portions of the reservoirs near shore where cover is abundant.

Water quality sampling in the reservoirs indicates that temperature and dissolved oxygen conditions are suitable for fish in each reservoir, and where thermoclines develop, they are relatively shallow and above the levels of the intakes. During winter and early spring, when the three principal UARP storage reservoirs are drawn down to their lowest levels of the year, water temperatures are generally cold and the potential for entrainment should still be limited because fish are less active when temperatures are low and less likely to encounter the intakes.

Trout are not only less active and less likely to encounter the intakes during the lower reservoir elevation periods; the densities of trout potentially vulnerable to entrainment are also much lower then. Of the UARP reservoirs, fish are only presently planted in the three storage reservoirs. Plants of catchable trout are generally made by CDFG every other week in Loon Lake from May through August, and every other week in Ice House and Union Valley reservoirs from May through September. Principally as a result of angler harvest, and other sources of mortality, very few of these fish would be expected to remain in the respective reservoirs into the winter period. It is the policy of the California Fish and Game Commission that "Catchable-sized trout shall be stocked only when it is reasonable to expect at least 50 percent by number or weight will be taken by anglers."

Likewise, concentrations of smallmouth bass and Sacramento suckers are expected to be low in the vicinity of the intakes because they tend to be distributed throughout the upper elevations of reservoirs and associated with bottom and/or nearshore structure, particularly the smaller life stages that would otherwise be potentially most vulnerable to entrainment. Hardhead, only found in Slab Creek Reservoir of all the UARP reservoirs, has similar habits but even more likely to be in the shallower waters of the reservoir as well as the more upstream ends of a reservoir (Moyle 2002). Juvenile suckers prefer shallow water, and so are at limited risk of being entrained in a deep intake. While adult suckers may spend the daylight hours in relatively deep water, during this period they are relatively inactive, avoiding currents. Most adult suckers active feeding occurs in shallow water; this should limit the chance of adult suckers encountering a deep intake. Of the UARP reservoirs with deepwater intakes, smallmouth bass are principally found in Union Valley Reservoir, which, even in its lowest median elevation month of January, has a water depth of 158.5 feet above the top of the intake structure. Therefore, smallmouth bass are unlikely to even encounter the intake structure.

Table 5.0-1 summarizes approach velocity and median depth of intakes information presented in Section 4.1. It is important to note that the period of highest average approach velocities is normally the period of the greatest water depths over the tops of the intakes for the storage reservoirs, and the re-regulating reservoirs show negligible monthly differences in their respective water depths over the tops of their intakes.

Table 5.0-1. Summary of approach velocities and depth of deepwater intakes.

	Estimated Approach Velocity (fps)					Depth at Top of Intake (ft)	
	% Exceedance			Range		Greatest	Least
Intake	Median	10%	90%	Min	Max		
LOON LAKE RESERVOIR							
Loon Lake Powerhouse Penstock Intake/ Loon Lake Dam Low-Level Intake	0.14	0.96	0.02	-----	-----	71.1 (Jun)	35.8 (Mar)
ICE HOUSE RESERVOIR							
Jones Fork Power Tunnel Intake	0.24	1.18	0.00	-----	-----	105.9 (Jun)	67.3 (Mar)
Ice House Dam Low-Level Intake	-----	-----	-----	0.71	2.14		
UNION VALLEY RESERVOIR							
Union Valley Powerhouse Penstock Intake	0.41	1.14	0.00	-----	-----	214.2 (Jun)	158.5 (Jan)
SLAB CREEK RESERVOIR							

Table 5.0-1. Summary of approach velocities and depth of deepwater intakes.

Intake	Estimated Approach Velocity (fps)					Depth at Top of Intake (ft)	
	% Exceedance			Range		Greatest	Least
	Median	10%	90%	Min	Max		
White Rock Power Tunnel Intake	0.40	0.99	0.12	-----	-----	138.2 (May)	136.2 (Dec)
Slab Creek Dam Low-Level Intake	-----	-----	-----	0.63	2.25		
JUNCTION RESERVOIR							
Jaybird Power Tunnel	-----	-----	-----	0.22	0.61	41.1 (Jul)	39.6 (Feb)
Junction Dam Low-Level Outlet Intake	-----	-----	-----	0.31	1.25		
CAMINO RESERVOIR							
Camino Tunnel Intake	-----	-----	-----	0.25	0.31	33.8 (Nov)	33.1 (Feb)
Camino Dam Low-Level Intake	-----	-----	-----	0.59	1.25		
BRUSH CREEK RESERVOIR							
Brush Creek Tunnel Intake	-----	-----	-----	No Data	No Data	49.6 (Mar)	45.5 (Dec)
Brush Creek Dam Low-Level Intake	-----	-----	-----	0.05	0.14		

In addition to the low densities of fish expected in the vicinities of the deep intakes in these reservoirs, any fish (whether trout or other species) that does encounter the deep intakes would usually be large enough to avoid involuntary entrainment. The intakes are relatively small structures in the reservoirs, and fish in winter (when the storage reservoirs are normally drawn down) are less active than in summer, so move around the reservoir less. Also, the fish that do come within the influence of the intakes should easily be able to escape the velocities that could potentially entrain them. A fish's ability to avoid entrainment is related to its swimming ability, which is a function of its size. A general "rule-of-thumb" is that a fish is able to maintain a cruising speed equal to about four fish-lengths per second for long periods, and speeds of about ten fish-lengths per second for short bursts (Alexander 1967, Clay 1961). For example, a 3-inch long trout would be capable of a cruising speed of about 1 fps and a burst speed of about 2.5 fps, while a 6-inch trout could maintain a cruising speed of 2 fps and a burst speed of 5 fps. Available swimming speeds reported for the principal species considered here, or their close relatives, as reported in FishBase (Froese and Pauly 2003), are given in Table 5.0-2. They support this general "rule-of-thumb."

Table 5.0-2. Sustained and burst swimming speeds of fish reported in FishBase.

Species	Number	Mode	Size Range	Mean Lengths/Second
Rainbow Trout	32	Sustained	100 mm – 640 mm	4.9
Rainbow Trout	6	Burst	40 mm – 280 mm	13.4
Brown Trout (sea run)	1	Sustained	340 mm	2.7
Brown Trout (sea run)	2	Burst	240 mm – 380 mm	9.2
Sockeye Salmon	10	Sustained	60 mm – 630 mm	2.9
Sacramento Sucker	3	Sustained	191 mm – 209 mm	2.4
Largemouth Bass	1	Sustained	210 mm	4.1

As noted earlier in the discussions of the length frequencies of the fish captured in the 2002 UARP reservoir fisheries study, most rainbow and brown trout caught were in the 200 mm – 500 mm length range, most kokanee peaked in the 300 mm – 350 mm length range, most smallmouth bass also peaked in the 300 mm – 350 mm length range, and most suckers were in the 250 mm – 500 mm length range. Using the general "rule-of-thumb" for a 200 mm (7.9 inch) fish results in a sustained swimming speed of 2.6 fps, and a burst speed of 6.6 fps. Using the general "rule-of-thumb" for a 500 mm (19.7 inch) fish results in a sustained swimming speed of 16.4 fps and a burst speed of 41.1 fps. The fish populations in the reservoirs are primarily composed of individuals large enough to avoid involuntary entrainment.

6.0 POTENTIAL APPROACH TO DEVELOP MITIGATION MEASURES

At the June 10, 2004 Aquatic TWG meeting, the TWG asked SMUD to include in the revised Deepwater Entrainment Technical Report one approach to a potential resource measure to mitigate for fish that might be entrained at the deepwater intakes at Loon Lake and Ice House reservoirs. It was understood that this approach was only an example and would be provided for consideration by the UARP Relicensing Settlement Negotiation Group (SNG) should the SNG determine that mitigation was appropriate. The Aquatic TWG asked that the approach be similar to one used by PG&E for the Mokelumne River Project.

The approach PG&E used to estimate entrainment in some of the Mokelumne Project reservoirs considered stocked fish and resident fish. However, a similar analysis for Loon Lake and Ice House reservoirs must focus on stocked fish only because population data on resident fish in these reservoirs are unavailable.

The first step of PG&E's analysis for stocked fish consisted of developing a range of entrainment rates for adult fish and for juvenile fish. For the lower end of adult fish entrainment rate range, PG&E applied a rate that was double the 0.2 percent of reservoir population estimated to be entrained from an actual entrainment study conducted at Southern California Edison's Balsam Meadows Project. For the upper end of the adult fish entrainment rate range, PG&E applied an estimated rate of ten percent entrainment, as determined by CDFG for PG&E's Crane Valley Project.

In developing a range of entrainment rates for juvenile fish, PG&E tripled the values for the low and high ends of the adult fish entrainment rate range, based on the assumption that juvenile fish were three times more susceptible to entrainment due to lower swimming speeds.

The second step of PG&E's analysis consisted of multiplying the low and high entrainment rate range values by the yearly number of stocked fish. In the case of the adult fish, this amounts to a simple multiplication of stocked catchable fish by the two estimated entrainment rates. For the juvenile fish (or stocked fingerlings) PG&E multiplied the number of juvenile fish by the two estimated entrainment rates, and then converted the estimated number of entrained juveniles to adult equivalents using a 17 percent natural survival rate between the juvenile life stage and adulthood.

Applying the above analytical approach used by PG&E to the number of fish stocked in Loon Lake and Ice House Reservoir in 2004 yields entrainment levels that range from 720 to 1,800 adult fish at Loon Lake Reservoir, and 924 to 2,310 adult fish at Ice House Reservoir (Table 6.0-1).

Table 6.0-1. Range of potentially entrained stocked fish at Loon Lake and Ice House reservoirs based on CDFG 2004 stocking records and an approach to estimate entrainment used by Pacific Gas and Electric Company for the Mokelumne Project.

Reservoir	Fish Stocked by CDFG in 2004	Potential Annual Entrainment Loss in Number of Adults	
		Low End Estimate[1]	High End Estimate[2]
Loon Lake	18,000 Catchable Rainbow Trout	720	1,800
Subtotal for Loon lake Reservoir		720	1,800
Ice House	19,000 Catchable Rainbow Trout	760	1,900
	2,400 Catchable Brown Trout	96	240
	10,000 Fingerling Rainbow Trout	68	170
Subtotal for Ice House Reservoir		924	2,310
	TOTAL	1,644	4,110

1 Number of catchable trout multiplied by 0.04 percent. Number of fingerling trout multiplied by 0.04 percent and then by 0.17 percent survivorship to determine catchable trout equivalents.
2 Number of catchable trout multiplied by 0.10 percent. Number of fingerling trout multiplied by 0.10 percent and then by 0.17 percent survivorship to determine catchable trout equivalents.

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