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

and

PACIFIC GAS AND ELECTRIC COMPANY
CHILI BAR PROJECT
(FERC Project No. 2155)

WATER TEMPERATURE TECHNICAL REPORT

Prepared by:

Devine Tarbell & Associates, Inc.
Sacramento, California

Prepared for:

Sacramento Municipal Utility District
Sacramento, California

and

Pacific Gas and Electric Company
San Francisco, California

MAY 2005
Version 5

TABLE OF CONTENTS

Section & Description **Page**

TABLE OF CONTENTS

Section & Description **Page**

LIST OF TABLES

Table No. & Description **Page**

LIST OF TABLES

Table No. & Description **Page**

LIST OF TABLES

Table No. & Description **Page**

LIST OF TABLES

Table No. & Description **Page**

LIST OF FIGURES

Figure No. & Description **Page**

LIST OF FIGURES

Figure No. & Description **Page**

LIST OF APPENDICES

Appendix & Description

LIST OF APPLICABLE STUDY PLANS

Description

- Water Temperature Study Plan
- Water Quality Study Plan

3.7 Water Temperature Study Plan

This study is designed to provide information regarding water temperature in the Project stream reaches and reservoirs, and develop a water temperature model in those river reaches that warrant a model. The overall approach is to collect continuous water temperature readings in 2002/2003 in all Project reaches and determine if the temperatures protect the Basin Plan beneficial use of Cold Freshwater Habitat and other identified habitats/species needs. The extent to which modeling is needed for determining how beneficial uses can be protected will be determined in consultation with the Aquatics TWG, and model(s) will be developed in 2003 and/or 2004. Also note that additional river reach sampling (other than for a model, if needed) may occur in 2003 or 2004 if either of these years differs substantially from 2002 (e.g., if either is a dry water year which means that less flows would be released into bypass reaches) or if study results suggest that additional data is needed.

3.7.1 Pertinent Issue Questions

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

3. What are the effects of water temperatures on downstream Project diversions and reservoirs. What are the effects of Project operations on downstream water temperatures?
26. What are the temperatures available in the Project including potential modifications (e.g. cold water pools)?
49. What water temperature data already exists for the Project area and what are the gaps?
50. What mathematical models are available for evaluating Project-related water temperature impacts?

This study, in concert with the Water Quality (direct measurements of water quality parameters), Aquatic Bioassessment (assessment of overall water quality based on benthic macroinvertebrate indices), Channel Morphology (assessment of sediment in stream channels) and Project Sources of Sediment (assessment of Project sources of sediment that may enter the river and reservoirs) as well as amphibian and fish studies will be used to assess the condition of water quality in the area of the Project. In the case of the Water Quality Study Plan, water temperature data collected at all sampling sites will augment the database for this study. This includes temperature profiles that are collected at all reservoir-sampling stations each of the four sampling periods (first major rain, spring runoff, summer low flow, and reservoir turnover)

3.7.2 Background

The Basin Plan specifies that one of the designated beneficial uses of the river in the vicinity of the Project is Cold Freshwater Habitat (RWQCB 1998). In the reach downstream of Chili Bar Reservoir the freshwater habitat beneficial use is designated as both warm and cold (RWQCB 1998).

Historically, there has been some intermittent water temperature measurements collected in the Project stream reaches. These data have been presented to and discussed with the Aquatic TWG. To supplement these river temperature data and in anticipation of relicensings, SMUD deployed continuous water temperature recorders (one reading per hour) at 46 locations in the watershed, and SMUD routinely maintains meteorological and weather data gathering stations throughout the Project area. In general, the water temperature recorders are located immediately above and immediately below Project reservoirs. In some areas, recorders are placed near the middle of the reach between reservoirs, and some are deployed in tributaries upstream of Project reservoirs. The data from these recorders have been summarized and presented top the TWG to the extent data is available.

Recent water temperature information is available for all Project reservoirs except Rubicon, Buck Island, Robbs Peak, and Chili Bar. These data, including water temperature profiles, have been presented to the Aquatics TWG and are summarized below (profiles not included here to limit the length of this study plan).

.

- Rubicon Reservoir, Rockbound Lake, and Buck Island Reservoir – These three bodies of water in the upper watersheds of the UARP have not been historically monitored for water temperature. However, as described above, water temperature profile data will be collected at these water bodies as part of the Water Quality Study. Water temperature profile information will be collected at four time periods: first major rain, spring runoff, summer low flow, and fall turnover.

- Loon Lake Reservoir - Loon Lake Reservoir has a maximum gross storage capacity of 76,200 ac-ft at an elevation of 6,410 feet. Inflowing water to the reservoir includes outflow of the Buck Island–Loon Lake Tunnel and natural inflow of Ellis and Meadow creeks. *In situ* water temperature data were collected at the mouths of the feeder streams and near the terminus of the Buck Island–Loon Lake Tunnel. In June 2000, the temperature of inflowing water was 21° C from Ellis Creek (DO of 6.1 mg/l) and 11° C from the Buck Island-Loon Lake Tunnel (9 mg/l). Water Year 2000 was generally considered to be an above normal Water Year.

  Water temperature profiling has been conducted in Loon Lake Reservoir on four occasions: in October 1980 by Ecological Analysts, in June and September 1996 by USGS, and at seven locations in the reservoir in November 1999 and June 2000 by SMUD. The 1981, 1996, 1999 and 2000 Water Years were generally considered to be dry, wet, wet, and above normal Water Years, respectively. The reservoir elevations when sampling was conducted were 6390.37 feet (1980), 6409.36 feet (1996), 6382.73 feet (1999) and 6402.34 feet (2000). In general, this sampling consistently shows that Loon Lake Reservoir is a cold, clear, well-oxygenated waterbody. In the October 1980 and November 1999 profiling, separated by 19 years, water temperatures were between 11° and 12° C throughout the water column. The June 2000, profiling exhibited weak stratification at all seven sampling locations. Maximum surface temperatures were between 13° and 15° C, while minimum temperatures at the bottom of the reservoir were approximately 8° C (reservoir bottom ranged between 45 and 70 feet below the surface). Profiles at the deepest sampling locations (70 feet) showed a broad metalimnion gradually dropping to the low temperatures (8° C) and a poorly defined hypolimnion. Similar results were obtained in a limnological survey performed by the USGS in June of 1996 (USGS web site).

  Dissolved oxygen concentration in Loon Lake Reservoir was consistent between the November 1999 and June 2000 sampling period, ranging between 8 and 9 mg/l throughout the water column. These results are also consistent with the October 1980 study, which yielded fairly consistent DO levels between 8.4 and 8.9 mg/l across three sampling locations. These concentration levels reveal that Loon Lake is at or near 100 percent saturation. The limnological investigations performed by the USGS in 1996 confirm these findings.

  All Secchi disk transparency data that have been collected at Loon Lake Reservoir have revealed excellent water clarity. In 1980 Secchi disk observations noted transparency to a depth of 36 feet. The studies of 1999 and 2000 revealed little change in water clarity over 19 years, with Secchi disk transparency measured between 36 and 44 feet under calm conditions in November and between 25 and 32 feet in June under windy conditions. (SMUD 2001, Page E2-10 and 11.)

  As described above, water temperature profile data will be collected at Loon Lake as part of the Water Quality Study. Water temperature profile information will be collected at four time periods: first major rain, spring runoff, summer low flow, and fall turnover.

- Gerle Creek Reservoir - Gerle Creek Reservoir is a small and shallow reservoir with a total storage capacity of 1,260 ac-ft at an elevation of 5,231 feet. The reservoir serves primarily as an afterbay for the Loon Lake Powerhouse. Hence, retention time is short, and the majority of the water entering the reservoir is powerhouse tailrace inflow, which originates from the intake structure at the bottom of Loon Lake Reservoir. Other inflow sources include Gerle Creek and Angel Creek.

  SMUD performed water temperature profiling at four locations in Gerle Creek Reservoir in November 1999 and June 2000. As described above, 1999 and 2000 Water Years were generally considered to be wet and above normal Water Years, respectively. The reservoir elevations when sampling was conducted were 5224.0 feet (1999) and 5226.0 feet (2000). In November, inflowing water temperature from the Loon Lake Powerhouse tailrace was 11° C, reflecting the isothermal temperature of Loon Lake Reservoir. Water temperature profiles in the Gerle Creek Reservoir were isothermal, at approximately 10° C. This slightly cooler temperature of the reservoir was due, in part, to the 5° C temperature of the inflowing Gerle Creek (Angel Creek was dry). A similar, but opposite, trend was observed in June. Loon Lake Powerhouse tailrace water was cold, at 9° C, reflecting Loon Lake Reservoir water temperatures just off the reservoir bottom. Gerle Creek Reservoir water temperature profiles reflected slight surface warming in the shallow center of the reservoir, but the deeper section near the dam exhibited a constant temperature with depth (up to 33 feet deep) of 10.5° C. This warming above the tailrace water temperature was due in part to the contributions of Gerle Creek (13° C) and Angel Creek (11° C).

Dissolved oxygen was between 8.5 and 9.5 mg/l at all sites (reservoir profile and stream sites) in both November 1999 and June 2000. Secchi disk transparency in Gerle Reservoir was close to the maximum depth (35 to 36 feet). Turbidity ranged from 2.5 to 4 NTUs, while specific conductance was between 7 and 10 µS/cm. (SMUD 2001, Page E2-11 and 12.)

As described above, water temperature profile data will be collected at Gerle Creek Reservoir as part of the Water Quality Study. Water temperature profile information will be collected at four time periods: first major rain, spring runoff, summer low flow, and fall turnover.

- Ice House Reservoir - Ice House Reservoir has a maximum gross storage capacity of 45,960 ac-ft at an elevation of 5,450 feet. The primary source of inflow to the reservoir is the South Fork Silver Creek. Limited data have been collected in South Fork Silver Creek as it enters the reservoir. *In situ* measurements taken in November 1999 (3 cfs) reveal a temperature of 4.5° C, while similar measurements taken in June 2000 (123 cfs) show a temperature of 13° C.

  Limnological investigations of Ice House Reservoir were performed by the California Department of Fish and Game in 1961 (Nicola and Borgeson 1970) shortly after Ice House Dam construction, by Ecological Analysts in 1980, and by SMUD in 1999 and 2000. CDFG collected its data in 1961 during one-to-two-week intervals throughout the summer. The 1961, 1980, 1999 and 2000 Water Years were generally considered to be dry, above normal, wet and above normal Water Years. The reservoir elevations when sampling was conducted were 5450 feet (1961), 5448.0 feet (1980), 5407.84 feet (1999) and 5448.43 feet (2000). Nicola and Borgeson found that surface water temperature in Ice House Reservoir was highest in July and August. A thermocline, ranging from a depth of 15 to 60 feet, formed in June and persisted through early October. Mean monthly Secchi disk readings ranged from about 20 to 30 feet.

  Ecological Analysts conducted reservoir profiling in Ice House Reservoir at three locations in July and September 1980, and SMUD did profiling at four locations in November 1999 and June 2000. These data show that at over 110 feet maximum depth, Ice House Reservoir is a relatively deep reservoir, and strong stratification at the deeper sampling locations. A temperature profile in June 2000 was similar to that described above for Loon Lake Reservoir, although surface temperatures were warmer at Ice House Reservoir (17°-19° C vs. 14° C) and bottom temperatures colder (7° C vs. 8° C). The June 2000 data are nearly identical to those of July 1980, when surface water temperatures averaging 18.7° C across three sampling stations and bottom temperatures were 7° C. These data agree with the June data from the 1960s (Nicola and Borgeson 1970), which exhibited epilminetic water temperatures of approximately 20° C and bottom temperatures of 7° C.

  Water temperature data were collected at Ice House Reservoir as part of a 7-year monitoring study conducted shortly after construction of Ice House Dam (Livesay 1972). Between the years 1963-1969, weekly *in situ* temperature measurements were taken in the epilimnion of Ice House Reservoir (at surface, 3 feet, and 6 feet below surface) over a 14-week period from June-September. Temperature measurements were taken roughly between 9:00 am and noon throughout the study period. Recorded temperatures typically ranged from a low of 15°-16° C to a high of 20°-21° C, with the maximum temperatures occurring in August of most years. The warmest temperatures recorded occurred in 1964, reaching a maximum of 23° C in the first week of August.

  Dissolved oxygen concentrations measured at Ice House Reservoir in 1980 were high, ranging roughly between 8.5 to 10.5 mg/l during both the July and September sampling efforts. The lower DO concentrations observed in the epilimnion of Ice House Reservoir in July 1980 are likely due to the effects of a warmer and fully mixed upper layer. The colder, unmixed hypolimnion exhibited higher and uniform dissolved oxygen levels with depth. This orthograde oxygen profile is typical of moderately oligotrophic lakes at an early stage in summer stratification (Wetzel 1975).

Secchi depth readings in Ice House Reservoir were relatively deep, established at 20 feet in October 1982 and ranging from 23 to 26 feet in November 1999 and June 2000. These findings were nearly identical to those of Nicola and Borgeson (1970), who measured a range of values between 18 and 28 feet, depending on month. The highest Secchi disk values were recorded in July.

Specific conductance, measured only in November 1999 and June 2000, was low in the reservoir and feeder stream. In the reservoir, values were constant with depth at about 9.5 µS/cm. Incoming stream water conductivity varied between streams, from less than 5 to greater than 23 µS/cm. Total dissolved solids were also low, between 5 and 6 mg/l at all depths in the reservoir and 3-13 mg/l in the feeder streams. (SMUD 2001, Page E2-12 - 15.)

As described above, water temperature profile data will be collected at Ice House Reservoir as part of the Water Quality Study. Water temperature profile information will be collected at four time periods: first major rain, spring runoff, summer low flow, and fall turnover.

- Union Valley Reservoir - Union Valley Reservoir has a maximum gross storage capacity of 277,290 ac-ft at an elevation 4,870 feet. Inflowing water to the reservoir is composed of many sources, including tailrace outflow of the Robbs Peak and Jones Fork powerhouses, and natural inflow of Tells, Big Silver, Wolf, Yellow Jacket, and Jones Fork Silver creeks.

  In situ water quality data were collected at the mouths of the streams that feed Union Valley Reservoir in 1999 and 2000. While limited in scope (essentially only covering the days of November 5, 1999, when the reservoir elevation was 4815.1 feet, and June 5, 2000, when the reservoir elevation was 4867.89 feet), the data, nonetheless, demonstrated that surface water runoff into Union Valley Reservoir, such as at Wolf Creek, can rise as high as 20° C in June, while maintaining DO levels of 9.5 mg/l. The coldest water inflowing water temperatures were 10° C, recorded at two small (unnamed) streams entering the reservoir from the south with the DO concentrations of 9 mg/l. Specific conductance of the feeder streams ranged from 6.6 to 67.8 µS/cm.

  Water quality profile data were recorded at Union Valley Reservoir in July and September 1980, November 1999, and in June 2000. The reservoir elevations when sampling was conducted were 4826.23 feet (1980), 4816.00 feet (1999) and 4867.78 feet (2000). In each sampling effort, separate profiles were recorded at three or more sampling locations in the reservoir. The thermal profile data of June 2000 and July 1980 demonstrate strong summer stratification, with surface temperatures between 17-18° C and bottom temperature of 7° C, a range of temperatures that is nearly identical to that observed at Ice House Reservoir. Despite the separation of the sampling efforts by 20 years, the shapes of the temperature profiles were similar in June and July. In each case, the epilimnion was about 20 feet deep, followed by a distinct metalimnion where temperatures dropped approximately 10° C within 40 feet. The data of September 1980 indicated a warming of the reservoir, with a deeper epilimnion at 20° C. In November 1999, Union Valley Reservoir was isothermal at 14.5° C.

  Dissolved oxygen profiles were mildly orthograde in both June 2000 and July 1980, exhibiting concentrations of approximately 8 mg/l in the epilimnion and 9.5 mg/l in the metalimnion and hypolimnion. In November 1999, Union Valley Reservoir exhibited a constant DO profile, at 7-7.5 mg/l. Specific conductance was nearly uniform from the surface to the bottom at 10 µS/cm, and pH ranged from approximately 6.5 to 7. Turbidity in the reservoir was very low (less than instrument detection in 1999/2000), and Secchi disk depth was between 25 and 27 feet during June 2000 and 24 feet in 1980. (SMUD 2001, Page E2-16.)

  As described above, water temperature profile data will be collected at Union Valley Reservoir as part of the Water Quality Study. Water temperature profile information will be collected at four time periods: first major rain, spring runoff, summer low flow, and fall turnover.

- Junction Reservoir - Junction Reservoir serves as an afterbay to Union Valley Powerhouse and forebay for the Jaybird Powerhouse. As such, it is a small facility, capable of impounding 3,250 ac-ft at an elevation of 4,450 feet. As a result, retention time is short, estimated at 20 hours. The major sources of inflow to the reservoir are tailrace outflow of Union Valley Powerhouse and regulated inflow from South Fork Silver Creek (i.e., Ice House Dam release plus accretion).

  SMUD conducted water quality profiling at five locations in Junction Reservoir in November 1999 and June 2000 (reservoir elevation of 4429.43 and 4441.18 feet, respectively), and *in situ* measurements were taken at two inflow streams (South Fork Silver Creek and Little Silver Creek), and at a site below the dam. Stratification was evident during June 2000, but the epilimnion was very shallow and temperatures decreased sharply below approximately 15 feet. Surface temperatures approached 19° C, approximately 10° C warmer than observed in November 1999. Bottom temperatures (maximum depth of about 110 feet) were approximately 7° C. Temperatures measured for South Fork Silver Creek at this time in June (tributary to the southern arm of the reservoir) exceeded 19° C with an estimated flow of 47.3 cfs. Dissolved oxygen at Junction Reservoir ranged from approximately 8 to 10 mg/l in the reservoir, and between 8 and 8.5 mg/l in tributary streams. Specific conductance was between 11 and 18 µS/cm at all locations; pH between 6.4 and 6.8, and Secchi depth between 25 and 35 feet, in June 2000. In contrast, Secchi disk depth in November at Junction Reservoir was only 8 to 10 feet deep. (SMUD 2001, Page E2-17.)

  Union Valley Powerhouse discharges directly into Junction Reservoir. Typical discharge flows during November and June range from 200 to 400 cfs in November and 300 to 700 cfs in June, depending on generation needs. Temperature data is not available within the short reach from the Union Valley powerhouse discharge point, however temperature data is available below Junction Dam. This water source is largely hypolimnetic flows from Union Valley powerhouse, and ranges from 1° to 5° in November, and 6° to 12° in June. This is consistent with profile temperatures taken in November 1999 and June 2000.

  As described above, water temperature profile data will be collected at Junction Reservoir as part of the Water Quality Study. Water temperature profile information will be collected at four time periods: first major rain, spring runoff, summer low flow, and fall turnover.

- Camino Reservoir - Camino Reservoir serves as an afterbay to Jaybird Powerhouse and forebay for Camino Powerhouse. As such, it is a small facility, capable of impounding 825 ac-ft of water at an elevation of 2,915 feet, with short retention time. The major sources of inflow to the reservoir are tailrace outflow of Jaybird Powerhouse and regulated inflow from Silver Creek (i.e., Jaybird Dam release plus accretion). SMUD conducted water temperature profiling in Camino Reservoir occurred on June 2000 when the reservoir elevation was 2905.57 feet. Water quality profiles were recorded at three locations in the reservoir, and *in situ* measurements were taken at the point of inflow to the reservoir of Silver and Jaybird creeks. Despite the short retention time, the temperature profile recorded nearest the dam, where the depth of water was nearly 50 feet, exhibited a weakly stratified water column. At this sampling station, there was 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, and specific conductance was low at the reservoir sampling sites (approximately 10 to 15 µS/cm). Turbidity was less than 2 NTUs. (SMUD 2001, Page E2-17.)

  As described above, water temperature profile data will be collected at Camino Reservoir as part of the Water Quality Study. Water temperature profile information will be collected at four time periods: first major rain, spring runoff, summer low flow, and fall turnover.

- Brush Creek Reservoir - Brush Creek Reservoir serves as a forebay to Camino Powerhouse, and is capable of impounding 1,530 ac-ft at an elevation of 2,915 feet. Inflows to the reservoir include natural inflow from Brush Creek and periodically tailrace water from Jaybird Powerhouse, when the reservoir is operated to provide spinning reserves. The tailrace water is routed to Brush Creek Reservoir via the Camino and Brush Creek tunnels (see Section B3.6). SMUD conducted water temperature profiling in Brush Creek

Reservoir in June 2000 when the reservoir elevation was 2909.44 feet. No metalimnion was evident in the temperature profile, although temperatures dropped steadily with depth from near 17° C at the surface to near 7° C at a maximum depth of approximately 100 feet. DO was between 7 and 9.5 mg/l, and pH ranged between approximately 6.4 and 7.2. Specific conductance was quite variable in contrast to other locations in the Project, with values increasing from approximately 20 µS/cm (nearly twice as high as most other sites monitored) to near 30 µS/cm at a depth of about 80 feet. Spring activity near the bottom of Brush Creek Reservoir is a possible explanation for these results. Turbidity was less than 2.5 NTUs and Secchi disk depth measured 29 feet. (SMUD 2001, Page E2-18.)

As described above, water temperature profile data will be collected at Brush Creek Reservoir as part of the Water Quality Study. Water temperature profile information will be collected at four time periods: first major rain, spring runoff, summer low flow, and fall turnover.

- Slab Creek Reservoir - Water inflow from the SFAR is the most important determinant of water quality in Slab Creek Reservoir, although Brush Creek, Slab Creek, and Long Canyon Creek also have an influence. SMUD's water quality studies in 1999 and 2000 included sites on Slab and Brush creeks on the north side of the reservoir, a site on the SFAR upstream of the reservoir, and a site in Long Canyon Creek on the south end of the reservoir. Temperatures of the inflow streams ranged from 12° C to 14° C, DO ranged from 9.5 to 11.5 mg/l, and pH ranged from 6.7 to 7.1 at sites upstream of the Project. Water quality studies were performed at Slab Creek Reservoir in November 1999 and June 2000, when reservoir elevations were 1829.83 and 1838.20 feet, respectively. Water quality data were collected at six locations along the 5-mile-long reservoir. 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. DO ranged from 8.8 to 10.2 mg/l, pH approximately 6.9, and specific conductance was typical of other Project reservoirs at approximately 20 µS/cm. Turbidity was not measurable, although Secchi disk depth of 11 to 15 feet suggests some particulate matter in the water column. (SMUD 2001, Page E2-18 and 19.)

  As described above, water temperature profile data will be collected at Slab Creek Reservoir as part of the Water Quality Study. Water temperature profile information will be collected at four time periods: first major rain, spring runoff, summer low flow, and fall turnover.

Water temperature has not been modeled anywhere in the system.

Select weather monitoring stations of SMUD's are listed in Table 1 below.

3.7.3 Study Objectives

The study objectives are to:

- gather and analyze data to determine if water temperatures in the Project area protect the Basin Plan beneficial use of Cold Freshwater Habitat and the needs of other identified habitats/species.
- Evaluate the cold water pool and seasonal availability of impounded waters within Project reservoirs

Table 1. Select Meteorological sites monitored by the Sacramento Municipal Utility District.

Nearest Project Reach	Designation	Parameters Monitored	Period of Record/Comments
Ice House Dam	Alpha	Air temperature, precipitation	System installed 1965
Ice House Dam	Mud Lake	Air temperature, precipitation	System installed 1971
Upstream of Union Valley Reservoir	Peninsula	Air temperature, precipitation	System installed 1994
Upstream of Union Valley Reservoir	Robbs Peak	Air temperature, humidity, barometric pressure, wind direction and speed	System installed 1968
Robbs Peak Dam	Robbs Saddle	Air temperature, humidity, barometric pressure, wind direction and speed	System installed 1971
Loon Lake Dam	Van Vleck	Air temperature, precipitation	System installed 1971
Silver Creek	Fresh Pond	Air temperature, humidity, barometric pressure, wind direction and speed	System installed 1971
Total	6		
Other meteorological sites	Folsom Dam (USBR	Air temperature, humidity, barometric pressure, wind direction and speed	Unknown
	Bald Mountain	Air temperature, humidity, barometric pressure, wind direction and speed	Unknown

3.7.4 Study Area

The study area includes all Project-affected stream reaches and reference reaches described below, and all Project reservoirs excluding Robbs Peak Reservoir due its small size. The PG&E facility at Chili Bar and the downstream reach will also be included in this study effort.

3.7.5 Information Needed From Other Studies

Information needed from other relicensing studies to complete the Water Temperature Study includes stream flows from the Hydrology Study and reservoir temperature and dissolved oxygen profiles from the water quality study. Water temperature models will be developed for specific reaches and it is expected that models will be used to estimate flow needs to comply with Basin Plan water temperature standards and to support other identified habitats/species needs, and be used as a tool in other studies to determine how the Project could be operated to provide desirable water temperatures. Data on the size of the cold water pools in the reservoirs of concern and the amount of topographic and vegetation shading in the reaches of concern may be needed. A rationale for model selection has been prepared as Attachment 1 of this document

3.7.6 Study Methods And Schedule

The study methods will include the following steps:

- In response to Aquatics Issue Question #50, a brief presentation will be made to the Aquatics TWG regarding various water temperature models that are available and discuss the data requirements and the limitations and benefits among the models. If upon review of initial data in 2002 it is determined by the TWG that modeling is needed, this study plan will be reviewed immediately to ensure that the appropriate data are being collected for the 2002 – 2003 seasons (see analysis section below)

- The continuous stream water temperature recorders described in Table 2 and the meteorological stations described in Table 1 will be maintained through June 2004, or until it is determined they are no longer needed. It is intended that these recorders are in-place year round, and SMUD has installed redundant recorders where theft or vandalism is a possibility. However, some recorders may be lost during high flow events. At the lower elevations, the recorders will be inspected quarterly to ensure proper working condition, and retrieval of data at routine intervals. At the higher elevations where access is difficult and the snow pack deep, the recorders will not be visited from mid-winter to early spring. Should it be determined that a water temperature model is appropriate in any reach, it is expected that the monitors will be maintained to gather additional data to develop the model and calibrate it. The monitors will be periodically checked for calibration.

Table 2. Water temperature sampling sites to be measured by the Sacramento Municipal Utility District for relicensing of the Upper American River Project in 2002.

Water Temperature Monitoring Site	Existing SMUD Water Temperature Monitoring Site	Proposed CDFG Monitoring Site[2] (1/8/02)	Water Temperature	
			Continuous	Profile[3]
RUBICON RIVER				
Inflow to Rubicon Reservoir	43 (installed 05/02)	1	1	
Outflow from Rubicon Reservoir	6 (installed 10/00)	3	1	
Rubicon Reservoir (mid-res.)		39		1
Upstream of Rubicon Springs	45 (installed 05/02)	5	1	
HIGHLAND CREEK/LITTLE RUBICON RIVER				
Buck Island Reservoir (mid-res.)		41		1
Outflow from Buck Island Reservoir	18 (installed 10/00)		1	
Upstream of Rubicon River	12 (installed 10/00)		1	
Rockbound Lake (mid-res.)				1
GERLE CREEK				
Outflow from Loon Lake Reservoir	5/47[1] (installed 10/00)	6	1	
Loon Lake Reservoir (Near Dam)				1
Loon Lake Reservoir (Mid-Reservoir)				1
Loon Lake Reservoir (Near Pleasant Lake arm)				1
Jerrett Creek Inflow to Gerle Creek (McKinstry Lake)	56 (installed and removed)	7	1	
Gerle Creek upstream of Gerle Creek Reservoir	44 (installed 05/02)		1	
At Wentworth Springs above Jerret Creek	42 (installed 10/00)	8	1	
Inflow to Gerle Creek Reservoir	3 (installed 10/00)	9	1	
Outflow from Gerle Creek Reservoir	33/40[1] (installed 4/01)	10	1	
Below Gerle Creek (above confl. with Rubicon River)	54 (installed 05/02)	12	1	
SOUTH FORK RUBICON RIVER				
Inflow to Robbs Peak Reservoir	13/38[1] (installed 7/01)		1	
Outflow from Robbs Peak Reservoir	34/50[1] (installed 5/01)		1	
Upstream of confluence with Gerle Creek	53 (installed 05/03)		1	
Upstream of Rubicon River	10 (installed 5/01)	13	1	
SOUTH FORK SILVER CREEK				
Inflow to Ice House Reservoir	22/41[1] (installed 7/01)	18	1	
Ice House Reservoir (Near Dam)				1
Ice House Reservoir (Mid-Reservoir)				1
Ice House Reservoir upper end				1
Outflow from Ice House Reservoir	28/29[1] (installed 11/00)	19	1	
Ice House minimum flow weir	32 (installed 03/01)		1	
Ice House Road Bridge	52 (installed 05/02)		1	
Midway Between Ice House & Junction Reservoirs	4 (installed 11/00)	20	1	
Inflow to Junction Reservoir	24 (installed 11/00)	21	1	
SILVER CREEK				
Tells Creek Inflow to Union Valley Reservoir	1/46[1] (installed 10/00)	14	1	
Big Silver Creek Inflow to Union Valley Reservoir	11/36[1] (installed 7/01)	15	1	
Jones Fork Inflow to Union Valley Reservoir	17/49[1] (installed 7/01)	17	1	
Union Valley Reservoir - near dam				1
Union Valley Reservoir - mid res.				1
Union Valley Reservoir - Robbs tailrace				1
Union Valley Reservoir - Jones Fork tailrace				1
Outflow from Junction Reservoir	19 (installed 10/00)	22	1	
Onion Creek Inflow to Silver Creek (inaccessible)		23		
Silver Creek upstream of Onion Creek (inaccessible)		24	1	
Silver Creek Inflow to Camino Reservoir	20 (installed 10/00)	25	1	
Outflow from Camino Reservoir	9 (installed 1/01)	27	1	
Midway Between Camino Reservoir and SFAR	23/25[1] (installed 1/01)	28	1	
BRUSH CREEK				
Inflow to Brush Creek Reservoir	58 (installed 05/02)	32	1	
Brush Creek Reservoir				1
Outflow from Brush Creek Reservoir	26 (installed 11/00)	33	1	
Brush Creek at mouth of Slab Ck Res.	59 (installed 05/02)			

Table 2 (continued)

Water Temperature Monitoring Site	Existing SMUD Water Temperature Monitoring Site	Proposed CDFG Monitoring Site[2] (1/8/02)	Water Temperature	
			Continuous	Profile[3]
SOUTH FORK AMERICAN RIVER				
Upstream of Silver Creek	37/48[1] (installed 7/01)	29	1	
Upstream of Camino Powerhouse (downstream of confl. with SFAR)	15/21[1] (installed 1/01)	30	1	
Downstream of Camino Powerhouse	27 (installed 1/01)	31	1	
Slab Creek Inflow to Slab Creek Reservoir		34	1	
Outflow from Slab Creek Reservoir	31 (installed 3/01)	35	1	
SFAR above WR PH	55 (installed 06/02			
Rock Creek Inflow to SFAR	57 (installed 06/03)	36	1	
Mosquito Road Bridge Crossing	14 (installed 3/01)	37	1	
Chili Bar Res				1
Inflow to Chili Bar Reservoir (at WR PH)	2 (installed 11/01)	38	1	
Outflow from Chili Bar Dam	64/65 (installed 07/02)	49	1	
Upstream of Dutch Creek	60/61 (installed 07/02)	49	1	
Downstream of Greenwood Creek	62/63 (installed 07/02)		1	
Upstream of Weber Creek	67 (installed 07/02)		1	

[1] Indicates Licensee's redundant water temperature gages at one location.

[2] CDFG proposed sampling locations not included in this table:

- #2: Did not include Highland Creek inflow to Rockbound Reservoir because it dries up. On 1/25/02, CDFG said OK to not monitor unless this site is needed for modeling in future.
- #11: Did not include inflow to Gerle Creek due to small size of watershed upstream of the reservoir. On 1/25/02, CDFG said OK to not monitor unless this site is needed for modeling in future.
- #16: Did not include since it was a repeat of CDFG location #15.
- #24: Added to above table on 1/25/02.
- #26: Did not include since unsure of the value of temperature of Jay Bird Creek. On 1/25/02, CDFG said OK to not monitor unless this site is needed for modeling in future.
- #40: Added to above table on 1/25/02.
- #42, 43, 44, 45, 46, 47 & 48: Did not include these reservoirs since historical information is adequate to describe water temperature conditions. Added deep locations sampled in 2000 at Loon Lake, Ice House and Union Valley on 1/25/02. CDFG said OK to not profile others unless needed for modeling.
- #49: Chili Bar Reservoir not included: not a UARP Project facility.

[3] During reservoir profiling, pH, DO, specific conductance and total dissolved solids will also be measured in profile.

- In addition to the water temperature profiling that will be performed as part of the Water Quality Study, profiling will also be conducted once in late August/early September (the period of strongest reservoir stratification) 2003 in the three storage reservoirs: Loon Lake, Ice House and Union Valley reservoirs. As for the water quality study methods, a multi-parameter water analyzer will be used *in situ* to measure water temperature (±0.1 °C), dissolved oxygen (±0.2 mg/l), pH (±0.2 unit), and total suspended solids (mg/l) at the locations described in Table 1. Note that the locations in Loon Lake, Ice House and Union Valley reservoirs will correspond to the deep-water locations profiled in 1999 and 2000. Instruments will be calibrated prior to each field visit according to manufacturer’s specifications. Measurements will be taken at vertical increments of one meter in water less than 20 meters, increments of 2 meters in water depths between 20 and 30 meters, increments of 3 meters in water depths between 30 and 40 meters, and 4-meter increments in water deeper than 40 meters. Should it be determined that a water temperature model is appropriate in any reach, it is expected that additional water temperature profiling in the reservoirs with stratification behavior may be done.

It was anticipated that the water temperature model presentation was to be made to the Aquatics TWG in January and March 2003. The actual presentations were made on January 9 and May 1, 2003. As described above, the continuous water temperature recorders will be maintained through June 2004, or until they are no longer needed. Data analysis will occur in November 2002/03, and the results of the first/second year of study will be presented to the Aquatic TWG in December 2002/03. Should the data indicate that additional investigation is warranted (such as development of a water temperature model in certain reaches), this study plan will be amended, in consultation with the Plenary Group, to include data gathering and analysis in the specific problem areas in 2004.

3.7.7 Analysis

For the continuous stream water temperature data, hourly means, minimums and maximums will be reported. Raw data will also be made available on a CD upon request. Daily mean, minimum and maximum values will be calculated and plotted (temperature verses time). Daily average stream flow and available corresponding dissolved oxygen points will also be shown on the plots, where these data are available, along with ambient daily air temperature maximums and minimums. It is expected that this analysis will also be used in analyzing whether water temperature is too cold. The extent to which modeling is needed for determining how beneficial uses can be protected will be determined in consultation with the Aquatics TWG, and the model(s) will be developed in 2003. A rationale for model selection appears as Attachment 1 of this document. For the reservoir temperature data (including historical data), water temperature, dissolved oxygen, pH and total suspended solids profiles will be prepared. The location and capacity of low level outlets and power tunnel outlets will be identified to determine the extent of the cold water pool and the ability to access this pool all reservoirs.

3.7.8 Study Output

It is anticipated that the water temperature model white paper will be presented to the TWG. A preferred model will be selected in 2003. Modifications to this study plan to assure that the appropriate data are being collected will occur immediately. A presentation on the study was made to the Aquatics TWG and the Plenary Group in January 2003. It is expected that water temperature recorders will be left in place through 2004 so that these data can be used to develop and calibrate the model. The ultimate study output will be a written report that includes the issues addressed, study objective, study area including sampling locations, methods, analysis, results, discussion and conclusions. The report will include a tabular data set for average hourly minimums, maximums and means. Graphs of daily maximum, minimum and mean temperatures at each station will be plotted with associated ambient air temperatures and flow (where available). The report will be prepared in a format that can easily be incorporated into the Licensee's draft environmental assessment report that will be submitted to FERC with the Licensee's application for a new license.

3.7.9 Preliminary Estimated Study Cost

3.7.10 Plenary Group Endorsement

This study plan was approved on January 25, 2002 by the following entities of the Aquatic TWG: CDFG, USFS, PCWA, EDCWA, PG&E and SMUD. BLM will defer until studies below Chili Bar are agreed upon. This study plan will be sent out to other members of the Aquatic TWG for their electronic consideration.

On July 14, 2003 the Aquatic TWG again approved this study plan since not all agencies were present at the January 25, 2002 meeting. The following entities approved the plan: SWRCB, SMUD, CSPA, PG&E, USFS. BLM and CDFG. No participant said they could not "live with" the study plan.

The Plenary Group approved the plan on September 9, 2003. The participants a the meeting who said they could "live with" this study plan were USFS, SWRCB, NPS, CDFG, El Dorado County, Taxpayers Association of El Dorado County, Teichert Materials, ARRA/Camp Lotus, El Dorado Irrigation District, SMUD, PCWA, City of Sacramento, FOR, and PG&E. None of the participants at the meeting said they could not "live with" this study plan.

3.7.11 Literature Cited

RWQCB (Regional Water Quality Control Board). 1998. Water Quality Control Plan (Basin Plan) for the Central Valley Region – Sacramento River and San Joaquin River Basins (Fourth Edition). Published by the California Regional Water Quality Control Board, Central Valley Region and the State Water Resources Control Board, Sacramento.

SMUD (Sacramento Municipal Utility District). 2001. Initial Information Package for Relicensing of the Upper American River Project (FERC Project No. 2101). Sacramento, CA.

Attachment 1
Water Temperature Model Review

Prepared by Kent Doughty, Water Specialist, DTA; August 2003

Several water temperature models were reviewed at the January 9, 2003 Aquatic TWG meeting. These models can be grouped into categories of empirical (rely on statistical or algebraic relationships among data including mass balance analysis), zero dimensional (steady state), 1-dimensional hydrodynamics (considers either reservoir vertical stratification or longitudinal differences but not both) and 2-D or 3-dimensional models (fully hydrodynamic). Steady state models such as USFWS's SNTEMP and EPA's RBM10 do not analyze in-reservoir dynamics and river flow must be constant. That is, the stream flow conditions can vary with time, but must exist sufficiently long for the steady-state results to reach the lowest point in the stream network being modeled. This constraint usually affects the length of reach modeled or the minimum time-step used in a simulation. These models are often described as being 1-Dimensional since they account for longitudinal temperature differences between segments of the river reach being modeled. These models are technically 0-Dimensional for hydraulics and 1-Dimensional for water temperature since steady state hydraulic conditions apply. The climatic variables used as input to SNTEMP (and similar models) are dynamic (i.e., change as a function of time) but are generally limited to a minimum time-step of one day (due to the steady-flow constraints identified above). Maximum water temperatures are estimated by calculating the amount of heat flux occurring from solar noon to sunset (when maximum water temperatures are assumed to occur). Diurnal water temperature variation is then estimated using a sine curve; minimum temperatures being derived by difference using the maximum temperature estimates. These steady-flow, dynamic temperature models can be quite good ($\pm$ 0.5^{o}C or less) at predicting mean daily temperatures with steady state flow. Results are less accurate for maximum and minimum daily values; typically $\pm$1^{o}C. The Corp's of Engineers' CE-QUAL-W2 is probably the most widely applied public domain 2-D model. It is capable of modeling variable, non-steady flows as well as vertical and longitudinal stratification of a water body. Temperature predictions for a well-calibrated W2 model are typically, on average within 0.5^{o}C for hourly temperature data. It can be applied to both reservoir and riverine reaches; however, numeric instability can arise when modeling river hydraulics for moderate to steep gradients, especially when the flow is small relative to channel size. While meteorological and hydrological data requirements are similar for all the models, the input data requirements for 2-D models are more intensive (e.g., a relatively detailed bathymetry of the stream channel in the modeled reach is required). The predictive capability of all models is subject to the precision, resolution and completeness of input data.

Modeling non-stratified reservoirs can be accomplished with all of the 1-D temperature models widely available. Modeling water withdrawal from a single layer in a stratified reservoir can be accomplished using SNTEMP or other 1-D models. Modeling the in-reservoir dynamics of a stratified reservoir where vertical velocity gradients affect constituent distribution or influence the destratification process requires the application of a 2-D model such as CE-QUAL-W2.

A river basin can either be modeled as a series of individual models applied to distinctive reaches or the reach models can be linked in a network. If resource questions are specific to a reach, then one only needs to identify the upstream boundary conditions as input variables without the need to create a model network for the upstream portion of the basin. Similarly, if two or more reaches need to be linked; i.e., reservoir and downstream river reach, these can be treated as separate models with the output from the upstream reservoir model serving as input for the downstream river reach model. Structuring the model with sufficient complexity to be able to address the resource question is the objective. Unnecessary model complexity can contribute added model error or uncertainty as well as increase the computation time required to run the model.

Many of the diversion reaches within the UARP are high gradient, turbulent flow. Gradients range from about 2-12%. The steepness of these channels exceeds the capability to accurately apply a 2-D hydraulic model. To some extent, this modeling limitation can be overcome by reconfiguring the model bathymetry into a stair step channel where the vertical element of the gradient is aggregated into a series of vertical drops. The summer low flow levels in the diversion reaches of the UARP also make application of CE-QUAL-W2 difficult.

It is recommended that SNTEMP be selected for modeling UARP temperature issues identified to date. The ease of application, the accuracy and precision of this physical based model, the availability (as a public domain resource), and the ability for multiple users to understand the results are important considerations. SNTEMP can adequately model water temperatures (i.e., achieve industry standards for precision and accuracy) in the UARP. Travel times in project reaches are generally short and project operations fulfill the requirements of the steady-flow assumptions (with the notable exception of the reach downstream of Chili Bar dam that is subject to daily fluctuating flows).. SNTEMP has equal or better capability for modeling temperature regimes than RBM10; the latter is more applicable to reservoirs and tends to overestimate residence time for riverine reaches.

It is recommended that CE-QUAL-W2 be used to model temperature dynamics within stratified reservoirs where concern that changes in operation could deplete a cold water pool. Output from CE-QUAL-W2 can be reconfigured to provide input boundary condition data for linked SNTEMP models in downstream reaches. SNTEMP or an empirical based statistical analysis could be applied for modeling unstratified reservoirs.

Each of the project reaches is next reviewed. Candidate reaches for temperature modeling were identified at the May 1, 2003 Aquatic TWG meeting and are noted in this document. Empirical data will be reviewed in late summer (after additional data is downloaded) to determine if data are sufficient to use in an analysis that would obviate the need to model a particular reach. This would not necessarily rule out later including any reach for eventual inclusion in a modeling exercise.

Addendum to Attachment 1

Evaluation of Heat Source Temperature Model

Prepared by Kent Doughty, Water Specialist, DTA; August 2003

Heat Source is a 1-dimensional (longitudinal) model that was developed by Oregon State Department of Environmental Quality. The model is dynamic for heat flux and partially dynamic for hydraulics. The model uses a finite differences mathematical approach to approximating dynamic mass transfer within river segments. This explicit approximation is completely physically based and therefore highly sensitive to bathymetric data. Although flow needs to be steady state, the flow can vary between longitudinal model segments. Heat Source uses spatially distributed data commonly available from topographic map data (geographic position reference, elevation, topography, etc.) and process based equations for simulating stream temperatures; it is not a reservoir model. Hourly water temperatures are predicted at requested downstream end of channel segments in the watershed. In a past application on the Willamette River basin in Oregon, the absolute average deviation from the measured hourly temperature data was 0.7^{o}C and the standard error was 0.9 ^{o}C for large scale basin-wide model extending over a year period. The model uses GIS data, 1:5000 scale stream geometry and riparian vegetation data, measured hourly water temperature data and climate data (multiple climate stations can be specified.) and measured daily flow data (flow data required for boundary conditions and lateral inflow) to predict stream temperatures within fixed 100-ft length model segments. The model applies a detailed quantification of riparian canopy based on aerial photos or FLIR and has mostly been used for the development of TMDL loading capacities. The model provides for detailed analysis of the effect of vegetation and topographic shading on stream temperature. Model documentation is good. Model set up and calibration are facilitated by Ttools templates developed by Oregon Department of Environmental Quality. Model applications still require considerable effort to set up and calibrate. In fact, the model embraces analytical complexity and requires a richness of spatial data resolution. The approach to calculating the heat flux is considered to be state of the art (more sophisticated than SNTEMP). HeatSource uses a dynamic approach for solving the heat flux process whereas SNTEMP is essentially steady state for heat flux modeling. HeatSource model include mass transfers from tributaries, groundwater inflows, landscape thermal radiation, adiabatic cooling, robust radiation modeling, multiple evaporation methods and complex hydrodynamic routing with hyporheic exchange within the substrate. The HeatSource model uses a finite difference approximation of the one-dimensional heat transfer equation. Maintaining high spatial resolution for this approach minimizes error. The HeatSource model hydrodynamics are not as sophisticated as CEQUALW2; the latter is two-dimensional. Advantages of the Heat Source model are most applicable to a watershed level modeling approach through its interface capabilities with Geographic Information Systems. These interfaces allow for high spatial resolution over a large geographic area. This process based model utilizes spatial data sets that are readily available for large areas (GIS, DEM and aerial imagery). The treatment of shade is more detailed than many other models. Heat Source also has the capability to incorporate groundwater mixing when most, or a portion of river flow, goes subsurface. The model accounts for the heat flux in the hyporheic zone. The added computational time requirements for this model and potential for numeric instability are disadvantages relative to more simplistic steady state models like SNTEMP.

It is recommended that SNTEMP be used for individual river reach modeling for the UARP Project. Temperature modeling at a watershed level for the UARP has not been identified as a necessity and basin-wide modeling approaches inherently have the potential for introduction of added error uncertainty relative to a reach modeling approach. While Heat Source provides a more sophisticated approach to mass transfer analysis and the heat flux computation is dynamic, the additional computational time, model complexity and high sensitivity to bathymetric data are distinct disadvantages. The reduction in model error/uncertainty with Heat Source relative to SNTEMP likely does not offset these disadvantages when applying models to individual reaches. SNTEMP adequately addresses temperature modeling questions raised to date for the UARP project (with the possible exception of analysis of peaking operations downstream of Chili Bar. HeatSource requires very high resolution of spatial data, which makes it considerably more expensive to implement. SNTEMP is far easier to set up relative to the HeatSource model; SNTEMP's relative ease in application means that the model can be better understood and applied among a wider audience within the TWG.

3.6 Water Quality Study Plan

This study is designed to provide information regarding overall water quality in the vicinity of the Sacramento Municipal Utility District's Upper American River Project (UARP) and Pacific Gas and Electric Company's Chili Bar Project (projects), identify potential water quality problems related to the projects, and where the projects can control such factors, develop resource measures for the protection, mitigation and enhancement of water quality. Basic *in situ* water quality information will be gathered in projects reservoirs and in bypassed stream reaches to evaluate general aquatic ecosystem conditions. Under this study plan, water quality constituents will be sampled at times and in locations that may best identify water quality problems (Triage Sampling), and where problems are identified, follow-up investigations will proceed immediately and to the extent needed to clearly identify the problem and potential resource measures (Contingency Sampling). Some immediate Contingency Sampling activities are identified in this plan, but the full extent of Contingency Sampling cannot be identified until a specific problem is identified and an appropriate course of action determined by the Aquatics TWG. For instance, if warranted, Contingency Sampling may include multi-season or multi-year sampling. In addition to water column analysis, the potential for metals within projects waters to bioaccumulate through the aquatic food chain will be evaluated using fish tissue analysis in representative reservoirs. The Licensees recognize that the sampling program described in this Water Quality Study Plan could ultimately be as broad or broader in scope than the May 3, 2002 program discussed with the resource agencies, and are fully committed to implementing such a program if warranted.

3.6.1 Pertinent Issue Questions

The Water Quality Study Plan addresses the following Aquatic/Water Issue Questions:

Is operation of the Project protective of Basin Plan Designated beneficial uses?

39. How does the Project affect water quality (e.g. turbidity) and sedimentation, specifically at Slab Creek Reservoir, as operation of this reservoir affects sediment transport into Chili Bar Reservoir? How can we manage that impact if it exists? What are the historic events that have affected sedimentation?
41. Do the waters below the Project reservoirs meet the water quality objectives of the Basin Plan? How can the Project be managed to help meet them?
45 What type of long-term sediment and water quality strategies, operational practices and maintenance strategies exist?
46. Do the waters within the reservoirs and the diverted reaches adequately protect all designated beneficial uses?
47. Identify the Project-related pollution events that may have occurred in the watershed.
55. What are the (Project induced) effects of recreation (including on water and upslope activities) on water quality in the reservoirs and stream reaches (e.g. dispersed recreation and outhouses)?
60. What is the location of all spoil piles within the Project area and what are the effects on water quality?

Note that Issue Questions 39 and 45 as they relate to sediment are addressed in the Channel Morphology Study Plan, and Issue Questions 55 and 60 as they relate to upslope Project facilities, including spoil piles, are addressed in the Project Sources of Sediment Study Plan. Water temperature in both streams and reservoirs as well as pH, dissolved oxygen and conductivity in reservoirs are addressed in detail in the Water Temperature Study Plan and are included in this study to the extent that concurrent sampling will take place along with dependent constituents.

3.6.2 Background

Attachment 1 provides an overview of water quality constituents that are of primary interest in this study. Included in Attachment 1 for each constituent is a discussion of why it is important and sampling periods that may best represent seasons when the constituent would appear within the water column. Samples will be collected in those periods shown in Attachment 1 and described below. Initial water quality screening efforts will incorporate the concept of seasonality and will apply a general sampling approach that brackets projects-affected stream reaches and selectively samples impounded waters. However, because historical data collected on the South Fork Silver Creek below Ice House Reservoir and on Silver Creek below Union Valley Reservoir during dam construction (1959-

1961), and on the South Fork of the American River upstream of and just downstream of Slab Creek Reservoir (1992) during dredging of the reservoir may indicate that elevated levels of trace metals within the watershed (including Aluminum, Arsenic, Cadmium, Copper, Iron, Lead, Manganese, Mercury, Selenium, Silver, and Zinc) occurred during those periods, initial sampling efforts will include a focus on metals. To strengthen data collected in the initial triage approach to water column sampling and to determine potential bioaccumulation of metals within the aquatic food chain, fish tissues will be analyzed.

3.6.3 Study Objectives

The study objectives are to:

1. Characterize water quality under current Project operations by directly monitor water quality and using historical information as well as information from the Water Temperature, Channel Morphology, Project Sources of Sediment and Aquatic Bioassessment studies, among other studies.

2. Determine if Basin Plan water quality objectives (and other applicable water quality criteria) are met and assess whether Basin Plan designated beneficial uses are protected. Note that the SWRCB will ultimately determine if Basin Plan designated beneficial uses are protected during the 401 process.

3. Identify any project-controllable resource measures for the protection, mitigation and enhancement of water quality.

3.6.4 Study Area and Sampling Locations

The study area includes all reservoirs associated with the projects (Rubicon, Rockbound, Buck Island, Loon Lake, Gerle Creek, Ice House, Union Valley, Junction, Camino, Brush Creek, Slab Creek and Chili Bar) excluding Robbs Peak Forebay due to its small size (30 acre-feet), and all stream reaches identified by the Aquatic TWG and Plenary Group (Rubicon Dam, Rockbound Dam, Buck Island Dam, Rubicon Tunnel Outlet, Loon Lake Dam, Gerle Creek Dam, Robbs Peak Dam, Ice House Dam, Junction Dam, Camino Dam, South Fork American, Brush Creek Dam, Slab Creek Dam and the Reach below Chili Bar Dam). The study area also includes, to the extent necessary, tributary inflows into the reservoirs and reaches. Sampling locations are listed in Attachment 2.

3.6.5 Information Needed From Other Studies

Information needed from other UARP relicensing studies includes:

1. Location of Project-related recreation facilities from the UARP Relicensing recreation studies

2. Results of the Water Temperature Study to assess compliance with the Basin Plan water temperature standards

3. Results of the Channel Morphology and Project Sources of Sediment studies
4. Flow data from the Hydrology Study

5. Results of the Aquatic Bioassessment Study to corroborate the results of the Water Quality Study

6. Results from other resource studies to assess level of protection provided for Basin Plan Designated Beneficial Uses

The output of this Water Quality study may be used in other studies to assist in determining the overall health of the aquatic ecosystem.

3.6.6 Study Methods And Schedule

The study methods will include the following subtasks:

Gather Historic Information: Interviews will be done with SMUD Operations staff, ENF, SWRCB, RWQCB and CDFG staff and others to identify any Project-related historic pollution events, and any water quality data routinely collected by SMUD (such as turbidity levels upstream and downstream of Slab Creek Reservoir) or others. Also, these interviews will help determine if there are any historical water quality data available other than what is reported in SMUD's Initial Information Package (SMUD 2001) and what has been discussed with the Aquatic TWG to date. Documentation of pollution events (i.e. reports of events and follow-up actions), potential affects of the projects, as well as other historical water quality data will be collected. An inventory shall be prepared of all historic pollution events identified and any mitigation actions taken, including reference sources and a companion map that presents locations of documented events and geographic expanse of known effects.

Water Quality Data Collection

Laboratory Reporting: The laboratory will provide for each constituent sample, the laboratory's current method detection limit, reporting limit, practical quantitation limit, and J-value as appropriate. The lab will attempt to obtain, and report at detection limits at or below the adjusted maximum regulatory criteria. (See glossary of terms included as Attachment 4)

Sample *In situ* Field Parameters: Basic water quality parameters, including temperature, dissolved oxygen, conductivity, and pH will be measured at all general sampling locations and specified bypassed stream reach stations (identified in Attachment 2) once each during the spring runoff, the summer low-flow period, the fall season, and following the first major rain event. Reservoir stations will include *in situ* profiles and stream stations will be sampled from the shoreline in moving flow with the sampler upstream of the meter. Turbidity and TSS will be analyzed in the laboratory.

Sample Standard Water Quality Parameters: Attachment 1 lists seasonal sampling periods for each constituent to be analyzed in the water quality screening effort. For planning purposes, sampling for the fall turnover season is expected to be conducted in 2002, first major rain event sampling will be conducted in November/December 2002, and the spring runoff sampling period will occur in April/May 2003. The summer low-flow sampling period will occur in August/early September 2003. The Licensees will sample once in each specified sampling period beginning with the summer low flow period in 2002. The constituents that will be sampled in each seasonal period are those that behave in a manner most likely to be represented during the designated sampling period(s) and those constituents required for analyzing standard constituents (indicated by an "X" in Attachment 1). Sampling for these constituents can be divided into two phases: Triage and Contingency.

a) Triage Sampling: Triage sampling is designed to screen for water quality problems associated with the projects. Water quality samples will be collected once immediately downstream of each projects facility, in each projects reservoir and in the major inflows to each reservoir (Attachment 2). It is expected that many of the water quality sampling locations will correspond to water temperature monitoring locations. Interested Aquatic TWG and Plenary Group Participants will be invited into the field to confirm the sampling locations before sampling locations are finalized. One sample will be taken from the riverbank in flowing water (sampler upstream) downstream of each project facility and in major inflows to each reservoir (Attachment 2). During the summer low flow period when the reservoirs may be stratified, water quality samples will be collected in the upper epilimnion and in the hypolimnion a few feet above the reservoir bottom. During the fall turnover, spring runoff and first major storm critical periods when the reservoirs are not stratified, one sample will be collected at a point approximately one-third the total depth below the surface. Timing of reservoir turnover will be determined by thermographic profiles in Loon Lake Reservoir (representing Rubicon, Rockbound, Buck Island, Gerle and Loon Lake reservoirs), Union Valley Reservoir (Junction and Union Valley reservoirs), and Slab Creek Reservoir (Brush Creek, Camino, Chili Bar and Slab Creek reservoirs), conducted at intervals no greater than once weekly beginning October 1 and continuing through fall turnover. For this purpose, turnover will assume to occur when the thermocline has broken down (less than 1°C change in temperature per meter). The Licensees will determine whether Loon Lake or Union Valley reservoir profiling will act as a surrogate for commencing Ice House Reservoir fall turnover sampling after the September reservoir water temperature profiling is done per the Water Temperature Study Plan. Timing of the first major rain event will be assessed by the Licensees, who will provide the criteria for this event to the Aquatic TWG. When each sample is collected, a multi-parameter water analyzer will be used *in situ* to measure instantaneous water temperature, specific conductance, dissolved oxygen and pH At the same time, a grab sample will be collected in accordance with approved field sampling protocols. One Secchi depth measurement will be taken at each reservoir sampling location. Instruments will be calibrated prior to each field visit according to manufacturer's specifications. The date and time that the sample is collected, sampling site, jar number and other pertinent information will be recorded in the field for each sample, and the site will be located using a GPS unit. The grab sample jar will be labeled, preserved, stored and delivered to a State certified water quality laboratory and the contents analyzed using laboratory methods adequately sensitive to detect constituents at or below regulatory criteria levels. Where applicable, samples will be stored per laboratory standard operating procedures. Compliance with laboratory-approved storage procedures and with maximum holding periods allowed by lab method(s) used will be documented, and a chain-of-custody record will be maintained for each sample jar.

Triage sampling for MTBE and TPH will only be conducted on the epilimnion and hypolimnion stations of Loon Lake, Ice House, and Union Valley reservoirs where significant boat traffic occurs. Concurrent with the timing of seasonal grab samples, fecal coliform screening samples will be collected in surface waters at near-shore locations proximal to reservoir recreation facilities and in diverted stream reaches identified as high-use dispersed recreation areas by the Recreation TWG (Attachment 5 (a), Bacteria Screening Stations – to be drafted and approved by Aquatic TWG, in consultation with Recreation TWG). For the fecal coliform screening purposes (as compared to the detailed coliform program described below), the SWRCB and Licensees agree that EPA Method 9221 may be used and that the samples may be held for up to 24 hours before processing. For the screening analysis, the TWG agreed to use E. coli analyses instead of fecal coliform, as long as it was used consistently throughout the screening effort. Additionally, the SWRCB and Licensees agree that no chlorophyll-a sampling will be collected during initial triage efforts. Instead, the Aquatic TWG will review the Secchi disk and nutrient data for each reservoir for indications of excessive production (eutrophication). If such indications occur (low Secchi depth reading as compared to other reservoirs and high nutrient concentrations), the Licensees in consultation with the Aquatic TWG will develop a contingency Sampling Plan that may include chlorophyll-a sampling, and phytoplankton/zooplankton sampling.

For the grab samples, the lab will be instructed to immediately analyze the samples taken below the projects' facilities and in the reservoirs, including both epilimnion and hypolimnion samples collected during periods of reservoir stratification using the methods described in Attachment 3. The resulting data will be provided by email to the Aquatic TWG as soon as available from the lab. If SWRCB or other Aquatics TWG participants determine that data indicate that a problem might occur with one or more of the constituents (indicated by levels approaching regulatory numerical criteria thresholds, algae bloom noted in reservoirs or channel, or as otherwise identified by the Aquatic TWG), Contingency Sampling as described below will be initiated immediately.

b) Contingency Sampling: Contingency Sampling will focus on the specific water quality constituent(s) and areas where Triage Sampling data indicates a water quality problem might exist. It will include near-term and long-term activities to explore the problem. The near-term steps will include immediately directing the water quality lab to analyze the water quality samples taken from major inflows to the reservoirs for the constituent for which a problem is indicated. Because of the short laboratory holding times of certain constituents, SMUD and the laboratory will initiate special procedures to ensure that information is not lost due to expiration of the holding times. Constituents with short holding times include certain nutrients (e.g., Nitrate/Nitrite and Orthophosphate have 48 hour holding times) and TSS and TDS (7-day holding time). In these instances, the laboratory will be directed either to analyze for the specific constituents immediately upon arrival or to chemically preserve the samples for later analysis. Chemical preservation will only be performed in circumstances where the preservation does not influence the detection limit of the analytical technique. In addition, the Licensees will confer with the Aquatic TWG to identify any other locations (including downstream of the projects facilities and in tributaries to the reach) where additional samples should immediately be taken for the constituent. Some examples of where additional samples might be collected are listed in Attachment 2. The long-term activity will include developing a sampling program for the constituent at other times of the year or in multiple years, or in additional source or downstream locations if warranted based on the results of the near-term activities.

Fecal Coliform Sampling Program: A focused fecal coliform sampling effort will be conducted to demonstrate compliance with Basin Plan objectives requisite for protection of waters used for contact recreational activities. Samples will be taken at specified near-shore locations in the vicinity of reservoir recreation facilities and along diverted stream reaches known to be high dispersed-use areas (Attachment 5 (b), Fecal Coliform Program Sampling Stations – to be specified by Aquatics TWG, following consultation with the Recreation TWG). Samples will be collected no less than five times within a thirty-day period that includes either the Independence Day Holiday or the Labor Day Holiday.

Fish Tissue Analysis: Fish tissues will be sampled to assess potential bioaccumulation of metals in resident fish within specific reservoirs of the projects. Resident fish will be collected from locations within the Ice House, Union Valley, Slab Creek and Chili Bar Reservoirs, in accordance with CDFG Water Pollution Control Laboratory practices, and will be analyzed for Cadmium, Mercury, Arsenic, Nickel, Selenium, Chromium, Silver, Copper, Lead and Zinc, consistent with protocols of the SWRCB Toxic Substances Monitoring Program. Prior to initiating the tissue sampling effort, Licensees and their consultants shall provide to SWRCB staff and Aquatic TWG members a sampling plan that will meet the SWRCB and CDFG protocols.

QA/QC: All samples will be collected, handled and delivered to the lab consistent with specific EPA methods or other approved sampling/handling protocols including but not limited to Standard Methods for the Examination of Water and Wastewater. Appropriate QA/QC methods and documentation will be followed. Field QA/QC methods may somewhat vary by chemical constituents, but certain methods will be uniformly applied to all field sampling. Clean sampling techniques will be applied throughout the sampling effort. All sample bottles will be prepared by a California state-certified laboratory (ELAP). (Note that, due to the screening nature of the sampling, the Licensees and SWRCB agree that the single event fecal coliform/E. coli screening samples may be analyzed by a lab in Placerville, CA, if it is determined that the lab is reliable and even if it is not State certified.) The laboratory will prepare all sample bottles and, where necessary, place the appropriate amount and type of preservative in sample bottles. All field crew members collecting samples will be wearing gloves. All sample collection systems (e.g., Van dorn sampler) will be rinsed between sampling events with de-ionized water, and rinsed again with a portion of the sample water before filling of the sample jar. The labeled samples will be placed in closed, lightproof coolers filled with ice. Samples will delivered to the laboratory daily during sampling trips. The maximum holding times are indicated in Attachment 3. Iced samples are delivered to the laboratory within no more than 24 hours and typically within 12 hours of sample collection. In the case of mercury, EPA method 245.7 with a method detection limit of 10 parts per trillion (nanograms per liter) will be used as long as it is acceptable to the SWRCB. If this method is not acceptable to the SWRCB, a much more stringent field sampling regime will be followed in the future (EPA method 1631/1669). Quality control in the field will be assured by accurate and thoroughly completed sample labels, field sheets, chain of custody and sample log forms. Sample labels will include sample identification code, date, time, stream/lake name, sampling location, collector’s name, sample type and preservative if applicable. Calibration of field instrumentation for field measurements of dissolved oxygen, temperature, pH, and conductivity will be done daily according to the manufacturer’s instructions. Where appropriate, a two-point calibration will be applied. Hydrolabs deployed for continuous monitoring will be calibrated prior to initial deployment and at each data down loading interval (approximately every two weeks).

As discussed above, the result of the study will be presented to the Aquatic TWG as soon as available.

3.6.7 Analysis

All historical and newly gathered data will be summarized to characterize existing water quality conditions, and will be compared to regulatory criteria, standards and goals as identified by the SWRCB and members of the Aquatic TWG. As stated above, to assess compliance with Basin Plan water temperature and sediment objectives, the data from the Water Temperature, Channel Morphology, Project Sources of Sediment and Aquatic Bioassessment studies will be used. Further, the results of this study will be discussed with the results of the Hydrology Study.

3.6.8 Study Output

The Licensees and their consultants will provide data updates to the Aquatics TWG throughout the period of the water quality sampling program. A draft written water quality report will be presented to the Aquatics TWG for review and consideration no later than December of 2003. Based on one complete field season of data, and findings in the draft report, the SWRCB and members of the Aquatics TWG will determine the need for additional seasons of data collection and/or special constituent study. Final study output will be a written report that includes the issues addressed, objectives, study area including sampling locations, methods, laboratory reports and QA/QC, analysis, and results. A summary of results will be provided in tabloid format that shall include specific method detection limits for each constituent and analytical data reported. This report will include relevant graphs depicting the seasonal relationship between DO, temperature and pH at all locations. Additional graphs will be provided to more clearly demonstrate any changes in specific water quality parameters over time, depth, or longitudinal movement of flow through the system. Discussion appropriate to results and supportive of analyses and conclusions will be provided. All reports will be prepared in a format so that they can easily be incorporated into the SMUD's draft environmental assessment that will be submitted to FERC with Pacific Gas and Electric Company's Chili Bar license application.

3.6.9 Preliminary Estimated Study Cost

A cost estimate for this study will be developed after the Plenary Group has approved the study plan.

3.6.10 TWG/Plenary Endorsement

The Aquatic TWG approved this plan, as amended and with the understanding that the Licensees and SWRCB needed to resolve some items, on August 28, 2002 with the changes as noted. The participants at the meeting who said they could "live with" this study plan were USFS, CDFG, NMFS, PG&E and SMUD. None of the participants at the meeting said they could not "live with" this study plan. The Plenary Group approved this Study Plan on September 4, 2002, with the understanding that the Licensees and SWRCB would resolve their issues. The Plan was discussed again at the September 18, 2002 Aquatic TWG meeting and some modifications were made.

Since the SWRCB did not approve the study plan on August 28, 2002, the study plan was again discussed, revised and ultimately approved by the Aquatic TWG on December 2, 2002. The following TWG participants stated they could "live with" the study plan: USFS, PG&E, SWRCB, SMUD.

Given the changes in the text, the study plan was again presented to the Plenary Group on January 8, 2003 for final approval. The following participants stated they could "live with" the study plan: SWRCB, SMUD, USFS, PG&E, PCWA, GDPUD, Friends of El Dorado County, Camp Lotus, EID, and other participants. No one present at the meeting said they could not "live with" the study plan

3.6.11 Literature Cited

Regional Water Quality Control Board. 1998. Water Quality Control Plan (Basin Plan) for the Central Valley Region – Sacramento River and San Joaquin River Basins. Published by the California Regional Water Quality Control Board, Central Valley Region and the State Water Resources Control Board, Sacramento.

Sacramento Municipal Utility District. 2001. Initial Information Package for Relicensing of the Upper American River Project (FERC Project No. 2101). Sacramento, CA.

Code of Federal Regulations Title 40; 1999. Governmental Printing Office.

Standard Methods for the Examination of Water and Wastewater. 1992. American Public Health Association.

U.S. Environmental Protection Agency. 1961. STORET Water Quality Data Base.

Jordan, W.P. and Brown, R.J. 1993. American River Aquatic Sampling Report for November 1992. Prepared by Institute of Chemical Biology, University of San Francisco, for Sacramento Municipal Utility District.

Attachment 1 – Water Quality Sampling Periods
Attachment 2 – Water Quality Sampling Locations
Attachment 3 – Water Quality Analytical Methods
Attachment 4 – Glossary of Analytical Laboratory Terminology and Reporting Terms
Attachment 5 – Location of Fecal Coliform Sampling Stations (Developed by Aquatic TWG in consultation with the Recreation TWG)
Attachment 6 – Mercury in Tissue Sampling Protocol

ATTACHMENT 1

Water quality worksheet for the W Q Study Plan developed for relicensings of Sacramento Municipal Utility District's Upper American River Project and Pacific Gas and Electric Company's Chili Bar Project. (The column "What is it and why it is important" is provided as reference only.)

Constituent[4]	*What is It and Why is It Important?*	*SamplingPeriods*[1,2]			
		Spring Runoff[3]	*Summer Low Flow*	*Fall Turn-over*	*First Major Rain*
Water Temperature *	Temperature strongly influences aquatic biota. Increasing temperature results in lower dissolved oxygen concentrations. Temperature stratification in reservoirs can influence biological and chemical stratification in the reservoirs. Summer sampling is of most interest do to increased solar radiation and warmer water temperatures in riverine and reservoir reaches.	X	X	X	X
Dissolved Oxygen *	A measure of oxygen dissolved in water, measured as both ppm and saturation. In productive waters, large variation in dissolved oxygen can occur over a 24-hour period. Dissolved oxygen exhibits greatest fluctuations during periods of high photosynthetic activity (high DO) and high biotic activity and /or decomposition (low DO) in both riverine and reservoir reaches. Greatest fluctuations occur in late summer/early fall.	9.3-11.1 mg/L X	X	X	X
pH *	Logarithm of the reciprocal of the hydrogen ion concentration. This affects the solubility of metals in sediment and suspended material as well as toxicity of some compounds. A pH of 7 is neutral, a low pH is acidic, and a high pH is alkaline. Most aquatic biota require pH range of 6.5-8.5. 24-hour diurnal variations may exist most likely during late summer/early fall (similar to the dissolved oxygen diurnal patterns).	6.8-7.1 Units X	X	X	X
Turbidity	Measures inverse of water clarity, and affected by suspended and colloidal organic and inorganic matter. NTU scale is logarithmic. Elevated levels may cause gill abrasion in fish, reductions in incubation success, and impacts to benthic organisms.	<0.5-2 NTU's X	X	X	X
Hardness	Dependent primarily on amount of calcium and magnesium in water. Water with concentrations of 0 to 75 mg/l of calcium carbonate is considered "soft," and those between 150 and 300 are considered "hard." Good quality domestic water is usually less than 250 mg/l, and water above 500 mg/l encourages precipitation and scale. Often total alkalinity (see below) and hardness exhibit similar patterns. Regression models have been developed that have shown a positive linear relation between hardness and various trace metal concentrations.	4.5-7.2 mg/L X	X	X	X

ATTACHMENT 1 (continued)

Constituent[4]	*What is It and Why is It Important?*	*Sampling Periods*[1,2]			
		Spring Runoff[3]	*Summer Low Flow*	*Fall Turn-over*	*First Major Rain*
Specific Conductance *	Capacity to conduct an electric current and quick measure of ion concentration, and indicates total dissolved matter (metals and nutrients) and alkalinity. Streams with mixed fish populations usually have specific conductance between 150 and 500 µmhos/cm. Sierra streams usually have low specific conductance; hence the need to augment ion concentration by salt blocks when electrofishing.	12-24 µhmos/cm X	X	X	X
Total Suspended Solids (TSS)	A measure of solids in water which can be removed by filtration. The origin of suspended matter may be man-made wastes or natural sources such as silt. Elevated TSS concentrations generally occur during peak runoff. Over time, amounts of inert solids in excess of 90 mg/l can be lethal to fish.	<5-45 mg/L X	X	X	X
Total Dissolved Solids (TDS)	A measure of the amount of material dissolved in water mostly inorganic salts-carbonates, bicarbonates, chlorides, sulfates, phosphates, nitrates, calcium, magnesium, manganese, sodium, potassium, and other cations. Most major ions are conservative; calcium, magnesium, carbonate levels can be affected by pH extremes. TDS will vary seasonally, generally based on flow regimes.	<10-21 mg/L X	X	X	
TOC.	TOC requires less sample and can be more reliable than BOD tests. Also, BOD typically used in systems that receive waste effluent.		X	X	
Nitrate/Nitrite	Nitrate result from normal decomposition of organic mater, and is a common form in which nitrogen is added to fertilizer. In general, nitrogen enters a watershed that has little human activity as rain.. In rivers with little human activity, total nitrogen is around 0.12 mg/l with nitrate representing about 85% of the nitrogen.	<0.52 -0.63 mg/L X	X	X	X
Total Kjeldahl Nitrogen	The total concentration of nitrogen in a sample present as ammonia or bound in organic compounds.		X	X	
Ammonia	Ammonia occurs as a result of organic decomposition and is common in sewage, fertilizers. Form of nitrogen most readily taken up by plants. Can be toxic to fish at low concentrations. Ammonia will often be converted to nitrate in the presence of oxygen.	<0.05 -0.076 mg/L X	X	X	

ATTACHMENT 1 (continued)

Constituent[4]	*What is It and Why is It Important?*	*Sampling Periods*[1,2]			
		Spring Runoff[3]	*Summer Low Flow*	*Fall Turn-over*	*First Major Rain*
Total Phosphorous	Measure of the total amount of phosphorus – both biologically available and bound in organic compounds. Phosphorous results from normal decomposition of organic mater. In lakes, an N:P ratio greater than 16:1 indicates that phosphorous, rather than nitrogen, is limiting for production, which is typical in oligotrophic lakes in the Sierras.	<0.05 mg/L X	X	X	X
Dissolved Ortho-phosphate	Biologically available phosphorus – in the form of PO_4.	<0.2 mg/L	X	X	
Total Alkalinity (measured as $CaCO_3$)	Measures water's ability to neutralize acids (buffer capacity), and reduces toxicity of some metals. Levels above 400-600 mg/l may be harmful to crops and humans. Alkalinity of natural waters is due primarily to the presence of hydroxides, bicarbonates, carbonates and occasionally borates, silicates and phosphates.	<5-26 mg/L X	X	X	X
Calcium	Essential macronutrient, 5th most common element, and considered nontoxic. It is present in most natural systems introduced as water passes over calcium-rich formations. Contributes considerable to hardness (Sierra waters typically have low hardness) and may range from 0 to 200 mg/l naturally.	0.5-19 mg/L X	X	X	X
Chloride	Unlike free chlorine (which is toxic), the chloride ion is required by cells during photosynthesis.	0.32-0.92 mg/L X	X		
Magnesium	Essential macronutrient, primary component in photosynthetic pigments, 8th most common element. It is present in most natural systems, contributes considerable to hardness (Sierra waters typically have low hardness) and may range from 0 to several hundred mg/l naturally.	<0.5-0.63 mg/L X	X	X	
Potassium	Unlike terrestrial plants, K plays a minor role in plant growth. Needed in for enzyme activation.	<0.5 mg/L X	X		
Sodium	Sixth most abundant element and present in most waters naturally. Has low toxicity.	<0.5-2.1 mg/L X	X		
Sulfate		1.1-1.4 mg/L X	X	X	
Aluminum (Al)	Third most abundant metal in earth's crust. Not known to have a nutritional function in organisms. Enters system from leaching over aluminum-containing soils. Toxic in high concentrations and acidic (pH below 6.2) environments. In these cases, aluminum precipitates on fish gills, interfering with the transfer of calcium and sodium between blood and water. Also, in high concentrations may reduce primary productivity in lakes by combining with phosphates.	<0.05-0.130 mg/L as total Al X	X	X	X

ATTACHMENT 1 (continued)

Constituent[4]	***What is It and Why is It Important?***	***Sampling Periods***[1,2]			
		Spring Runoff[3]	***Summer Low Flow***	***Fall Turn-over***	***First Major Rain***
Arsenic (As)	Known carcinogen and a poison. Low levels occur naturally in surface water. Higher temperatures increase toxicity. Not affected by hardness.	<0.005 mg/L as total As X	X	X	
Barium (Ba)	16th most common element in nature, but only trace amounts usually found in surface waters.	<0.02 mg/L as total Ba X	X	X	
Cadmium (Cd)	Toxic metal and known human carcinogen, with bioaccumaltive properties carcinogen, with bioaccumaltive properties. Drinking water in the US has a mean of about 0.008 mg/l of total cadmium.	<0.0005 mg/L as total Cd X	X	X	
Copper (Cu)	Essential macronutrient for plants and animals. Generally considered to have low concentrations in oligotrophic aquatic systems of granitic alpine likes, which can limit photosynthesis. High concentrations of copper (usually as $CuSO_4$) are used to control algal blooms. Bradford et al (1968)[10] reported a mean concentration of 0.0012 mg/l of total Cu in 170 high Sierra lakes in CA. Exposure to levels less than 10 ppb (1μ/L) cause chronic toxicity symptoms in freshwater fish.	<0.001 mg/L as total Cu X	X	X	
Cyanide (CN)	Lethal toxin. Although not a metal, can combine to from alkali metal salts, and immobile metallocyanide. Often associated with gold extraction. At pH of 9.2 or less >90% occurs as free cyanide (CN^- or HCN). In general, cyanide has low persistance in surface waters (although may persist in groundwater). Cyanide has shown to adversely affect fish reproduction affecting the viability of the eggs. Not considered to be carcinogenic nor does it bioaccumulate.		X	X	
Iron (Fe)	Essential macronutrient for plants and animals. Enters watercourses from leaching of natural deposits in the form of relatively insoluble crystalines (i.e iron pyrite), particulates (organic matter or hydroxides) and soluble iron (ferric and ferrous iron). Hydrated ferric iron forms insoluable compounds and is deposited on sediments as a rust-colored layer called *ocher* ($Fe(OH)_3$). Bradford et al (1968)[5] reported a mean concentration of 0.0013 mg/l of total Fe in 170 high Sierra lakes in CA.	<0.1-0.120 mg/L as total Fe X	X	X	
Lead (Pb)	Toxic element that accumulates in animals, and toxicity is influenced by pH, alkalinity and hardness. Concentrations in natural waters usually less than 0.02 mg/l.	<0.0005-0.0028 mg/L as total Pb X	X	X	X

ATTACHMENT 1 (continued)

Constituent [4]	***What is It and Why is It Important?***	***Sampling Periods*** [1,2]			
		Spring Runoff [3]	***Summer Low Flow***	***Fall Turn-over***	***First Major Rain***
Manganese (Mn)	Necessary macronutrient for plants and animals (needed as a cofactor in several enzyme systems, including those involved in respiration and nitrogen metabolism), and normally present in surface waters in various oxidation states as soluble complexes or suspended particles. Rarely exceeds 1 mg/l in natural waters. Bradford et al(1968) [5] reported a mean concentration of 0.0003 mg/l of total Mn in 170 high Sierra lakes in CA.	<.0.01-0.016 mg/L as total Mn	X	X	
Mercury (Hg)	Organic and inorganic salts very toxic and mercury naturally associated with Sierra soils. Mercury bioaccumulation within the aquatic food chain has potential to cause risks to piscivorous wildlife and human health.	<0.0002 mg/L as total Hg	X	X	X
Nickel (Ni)	Seldom found in natural waters, but may enter due to leaching of nickel-bearing geologic formations, such as serpentine rock and soils, which are common in Sierras. Toxicity related to hardness and may be mobilized with low pH conditions.	<0.01 mg/L as total Ni X	X		
Selenium (Se)	Essential macronutrient but may affect normal embryo development and be toxic in higher concentrations.	<0.002 –0.004 mg/L as total Se	X	X	
Silver (Ag)	Considered one of the most toxic heavy metal ions, but because monovalent silver ion is easily reduced it is not readily accessible to living organisms in the natural environment. Toxicity increases with hardness.	<0.0005 mg/L as total Ag	X	X	X
Zinc (Zn)	Essential macronutrient element for human growth and many aquatic organisms. Bradford et al (1968) [5] reported a mean concentration of 0.0015 mg/l of total Zn in 170 high Sierra lakes in CA.	<0.02 mg/L as total Zn	X	X	
Total Coliform Bacteria	Non-pathogenic microorganisms used in testing water to indicate the presence of pathogenic bacteria. This test is not recommended, as it will not provide any additional information over the fecal coliform or E. coli bacterial tests.			X	X
Fecal Coliform/E. coli Bacteria	A group of bacteria normally present in large numbers in the intestinal tracts of humans and other warm-blooded animals. Bacteria levels are of interest primarily during high recreational periods at local beaches, or during high runoff in areas with potential for inputs of untreated animal wastes. (USEPA tests have now shown E. coli to have better correlation with water contact and sickness.)	X[1]	X	X	X
Oil & Grease	Enters system from man.		X	X	X

---

[1] Assuming data gathered is not duplicative of El Dorado County's sampling efforts for three sites below Chili Bar Reservoir

ATTACHMENT 1 (continued)

Constituent[4]	***What is It and Why is It Important?***	***Sampling Periods*** [1,2]			
		Spring Runoff [3]	***Summer Low Flow***	***Fall Turn-over***	***First Major Rain***
MTBE	Methyl-*ter*t-butyl ether used as a gas additive to make fuel burn more efficient. Is a possible carcinogen, and is being phased out in California.		X	X	
Total Petroleum Hydrocarbon	Enters system from man.	<0.050 mg/L	X	X	

1. Sampling Periods are defined as spring runoff (April/May), summer low flow (August/early September), fall turnover (October/ November), and first major rain (November/December).
2. Sampling strategies are defined by X's or numerically. "X" indicates those periods in which SMUD proposes to sample for this constituent.
3. The numerical ranges represent actual values obtained during the June 10, 2002 sampling event at 10 water sampling sites: Gerle Creek below Loon Lake, SF Rubicon below Gerle Creek, SF Silver Creek below Ice House, Silver Creek below Junction Dam, Silver Creek below Camino Dam, SFAR above Camino Powerhouse, SFAR above Camino Powerhouse, Brush Creek below Brush Creek Reservoir, SFAR below Slab Creek Dam, and SFAR & Whiterock Powerhouse Discharge.
4. All constituents designated with * are identified as *In situ* sampling parameters, and shall be included as standard sampling parameters at all triage sampling stations plus the designated bypass reach stations identified as WQ Monitoring Stations 9, 13, and 36 on Table 2.

ATTACHMENT 2

Water quality sampling locations for relicensing of Sacramento Municipal Utility District's Upper American River Project and Pacific Gas and Electric Company's Chili Bar Project.

Water Quality Monitoring Station	*Triage Sampling*	*Contingency Sampling*	
	Take & Analyze *	*Take with Triage Samples & Analyze if Problem*	*Take & Analyze if Problem*
1. Rubicon River inflow to Rubicon Resv.		X	
R-1. Rubicon Resv. mid-lake	1/3 depth / Epilimnion+hypolimnion		
2. Rubicon R. outflow from Rubicon Resv.	X		
3. Rubicon R. upstream of Rubicon Springs			X
3a. Fox Lake reach flow from Rubicon Resv		X	
4. Highland inflow to Rockbound Resv.		X	
R-2. Rockbound Lake mid-resv.	1/3 depth / Epilimnion+hypolimnion		
5. Rubicon outflow from Rockbound Lk.	X		
R-3. Buck Island Resv. mid-lake	1/3 depth / Epilimnion+hypolimnion		
6. Little Rubicon outflow from Buck Is. Lk.	X		
R-4a Loon Lake Resv. near dam	1/3 depth / Epilimnion+hypolimnion		
R-4b Loon Lk. mid-resv. in west body	1/3 depth / Epilimnion+hypolimnion		
R-4c Loon Lk. upper resv. N-E body	1/3 depth / Epilimnion+hypolimnion		
7. Gerle Ck. outflow from Loon Lake	X		
8. Jerrett Ck. upstream of Gerle Ck. con.			X
9. Gerle Ck. downstream of Jerret confl.	In situ *only*		X
10. Barts/Dellar Ck. upstream of Gerle Ck.			X
11. Gerle Ck. dwnstrm of Barts/Dellar conf.			X
12. Rocky Basin Ck. upstream of Gerle			X
13. Gerle Ck. dwnstrm of Rocky Basin conf	*In situ* only		X
14. Gerle Ck. inflow to Gerle Ck. Resv.	X		
R-5. Gerle Ck. Reservoir mid-resv.	1/3 depth / Epilimnion+hypolimnion		
15. Gerle Ck outflow from Gerle Ck Resv	X		
16. Gerle Ck Canal inflow to Robb's Frby	X		
17. S.F. Rubicon inflow to Robb's Foreb		X	
18. S.F. Rubicon upstream of Gerle Ck con.			X
19. S.F. Rubicon dwnstrm of Gerle Ck con.			X
20. S.F. Rubicon upstrm of Rubicon River	X		
21. Tells Ck. upstrm of Union Valley Resv.		X	
22. Big Silver Ck. upstrm of Union Valley		X	
23. Jones Fk Silver Ck inflow to Un.V. Res		X	
R-6a Union Valley Resv. near dam	1/3 depth / Epilimnion+hypolimnion		
R-6b Union Valley Resv. mid-resv.	1/3 depth / Epilimnion+hypolimnion		
R-6c Union Valley Resv. (Robb's Pk. PH tailrace zone)	1/3 depth / Epilimnion+hypolimnion		

ATTACHMENT 2 (continued)

Water Quality Monitoring Station	*Triage Sampling*	*Contingency Sampling*	
	*Take & Analyze **	*Take with Triage Samples & Analyze if Problem*	*Take & Analyze if Problem*
R-6d Union Valley Resv. Jones Fork arma	1/3 depth / Epilimnion+hypolimnion		
24. S.F. Silver Ck. upstrm of Ice House Res.		X	
R-7a Ice House Reservoir near dam	1/3 depth / Epilimnion+hypolimnion		
R-7b Ice House Reservoir mid-resv.	1/3 depth / Epilimnion+hypolimnion		
R-7c Ice House Reservoir upper lake body	1/3 depth / Epilimnion+hypolimnion		
25. S.F. Silver Ck. outflow from Ice House	X		
26a. S.F. Silver 3-4 mi. dwnstr of IH Resv	*In situ* only		X
26b. S.F. Silver upstrm of Big Hill Cnyn.			X
27. S.F. Silver Ck inflow to Junction Resv.	X		
28. Little Silver Ck. inflow to Junction Resv		X	
R-8 Junction Reservoir, mid-resv btwn arms	1/3 depth / Epilimnion+hypolimnion		
29. Silver Ck. outflow from Junction Resv.	X		
30. Onion Ck. upstream of Silver Creek			X
31. Silver Ck dwnstrm of Onion Ck confl.			X
32. Silver Ck. inflow to Camino Resv.	X		
33. Jay Bird Ck. inflow to Camino Resv.		X	
R-9. Camino Reservoir mid-resv.	1/3 depth / Epilimnion+hypolimnion		
34. Silver Ck. outflow from Camino Resv.	X		
36. Silver Ck. Immediately upstrm of SFAR	X		
37. SFAR upstream of Silver Ck confluence			X
38. SFAR upstream of Camino Powerhouse		X	
39. Brush Ck. inflow to Brush Ck. Resv.		X	
R-10. Brush Creek Resv. mid-resv. site	1/3 depth / Epilimnion+hypolimnion		
40. Brush Ck. outflow from Brush Ck Resv.	X		
41. SFAR dwnstrm of Camino Powerhouse	X		
R-11a Slab Creek Reservoir mid-resv. site	1/3 depth / Epilimnion+hypolimnion		
R-11b Slab Creek Resv. upper-resv. site	1/3 depth / Epilimnion+hypolimnion		
42. Slab Ck. inflow to Slab Ck. Reservoir		X	
43. SFAR outflow from Slab Ck Resv – upstream of Iowa- Brushy Cnyn Ck confl.	X		
44. SFAR between Slab Ck Res & Rock Ck			X
45. Rock Creek upstream of SFAR confl.			X
46. SFAR downstream of Rock Ck. confl.	X		
47. SFAR downstream of White Rock P.H.	X		
R-12a Chili Bar Reservoir near dam	1/3 depth / Epilimnion+hypolimnion		
R-12b Chili Bar Reservoir mid-resv. site	1/3 depth / Epilimnion+hypolimnion		
48. SFAR outflow from Chili Bar Resv.	X		
49. SFAR upstream of Dutch Creek			X
50. SFAR at Coloma gaging station			X

ATTACHMENT 2 (continued)

Water Quality Monitoring Station	***Triage Sampling***	***Contingency Sampling***	
	Take & Analyze *	***Take with Triage Samples & Analyze if Problem***	***Take & Analyze if Problem***
51. SFAR dwnstrm of Greenwood Creek, near ex-USGS 11445500	X		
52. SFAR upstream of Weber Creek			X
53. Weber Ck upstream of confl. w/ SFAR			X
54. SFAR below Weber Creek confluence in a riverine environment	X		

* During periods of reservoir stratification, samples will be collected within the upper epilimnion layer and also in the hypolimnion layer a few feet above the reservoir bottom. When reservoir profile is mixed, samples will be collected at a point below the water surface equivalent to approximately one-third the total water column depth.

ATTACHMENT 3

Water Quality Analytical Method and Maximum Lab Holding Times

Constituent	Method	Hold time
Al	EPA 200.8 and 245.7	180 d
As	EPA 200.8 and 245.7	180 d
Ba	EPA 200.8 and 245.7	180 d
Cd	EPA 200.8 and 245.7	180 d
Cu	EPA 200.8 and 245.7	180 d
Fe	EPA 200.8 and 245.7	180 d
Pb	EPA 200.8 and 245.7	180 d
Mn	EPA 200.8 and 245.7	180 d
Hg	EPA 245.7	28 d
Ni	EPA 200.8 and 245.7	180 d
Se	EPA 200.8 and 245.7	180 d
Ag	EPA 200.8 and 245.7	180 d
Zn	EPA 200.8 and 245.7	180 d
Oil and grease	EPA 1664	28 d
MTBE	SW 5030B/SW 83260B	14 d
TPH	SW 5030B/SW 8021B/9015	14 d
Nitrate-Nitrite	EPA 300.0	48 h
Ammonia as N	EPA 350.2	28 d
TKN as N	EPA 351.3	28 d
Total phosphorous	EPA 365.2	28 d
Orthophosphate	EPA 365.3	48 h
TOC	EPA 415.1	28 d
Hardness	EPA 130.2	180 d
Total Alkalinity	EPA 310.1	14 d
TSS	EPA 160.2	7 d
TDS	EPA 160.1	7 d
Cn	EPA 335.2	180 d
Ca	EPA 200.7	180 d
Mg	EPA 200.7	180 d
K	EPA 200.7	180 d
Na	EPA 200.7	180 d
chloride	EPA 200.7	28 d
sulfate	EPA 200.7	180 d
coliform/E. coli (screening)	9221/9222 D or as available	24 h
fecal coliform (regulatory)	9222	24 h

ATTACHMENT 4

Glossary of Analytical Laboratory Terminology and Reporting Terms

Method Detection Limit (MDL):

Is a measure of the method sensitivity. The MDL is the lowest concentration that can be detected by an instrument with correction for the effects of sample matrix and method-specific parameters such as sample preparation. It is the minimum concentration of a substance that can be measured and reported with 99 percent confidence that the analyte concentration is greater than zero, as defined in 40 CFR 136, Appendix B, revised as of May 14, 1999.

Criterion Quantitation Limit (CQL):

The level of analytical resolution needed to assess regulatory compliance. The CQL is the lowest amount of an analyte in a sample that can be quantitatively determined with suitable precision and accuracy. The desired criterion quantitation levels for the analysis of sampled constituents shall be set at 10% below the controlling (or lowest) applicable Basin Plan water quality objective, or California and National Toxics Rule criteria.

Practical Quantitation Limit (PQL):

The concentration that can be reliably measured within specified limits and accuracy during routine laboratory operating conditions. It is typically determined by a combination of the IDL (Instrument Detection Limit--the lowest the instrument is capable of seeing with specified confidence limits) and the lowest calibration standard used. The calibration level is selected (usually greater than the IDL) based upon the needs of the specific batch of samples being run (e.g. based on the levels set by the client, etc.)

Reporting Limit (RL):

The reporting limit for the laboratory. This is the lowest quantifiable (vs. estimated) concentration that the laboratory can determine, must be greater than or equal to the PQL, and is chosen based on client’s needs and/or quality control. Ideally, the RL should be equal to or lower than the desired minimum CQL to meet the purposes of this monitoring. Due to the low limits that are required for the water quality analysis, the reporting limit will be set as low as possible (i.e. the same as the practical quantitation limit). If it is not possible for the laboratory to reliably measure concentrations at the desired minimum CQL for a given constituent using the most sensitive commonly available methodology, estimated concentrations will be reported down to the MDL (even though these estimated concentrations are below the “reporting limit” – See *Procedures for Reporting Results*.)

Procedures for Reporting Results:

1. Sample results greater than or equal to the RL shall be reported as measured by the laboratory (i.e., the measured chemical concentration in the sample).
2. Sample results less than the RL, but greater than or equal to the laboratory’s MDL, shall be reported as “Detected, but Not Quantified” or DNQ. If the laboratory is unable to reliably measure concentrations at the desired minimum CQL for a given constituent (thus the RL is above the controlling applicable water quality objective or criteria), the estimated chemical concentration of the sample shall also be reported.
3. Sample results less than the laboratory’s MDL shall be reported as “Not Detected,” or ND.

ATTACHMENT 5

Location of Fecal Coliform / E. coli Sampling Stations

Attachment 5. Fecal/*E.coli* Sampling Sites For "5 in 30" and "Seasonal" sampling efforts

Site #	"5 in 30"	"Seasonal"	Location/Notes
UARP			
	X[2]		Buck Island reservoir near dam at dispersed camping site
		X	Buck Island reservoir north shore beach
		X	Loon Lake reservoir near-shore at northeast end at Pleasant campground
	X		Loon Lake reservoir at Ellis Creek inflow on west side of creek
		X	Loon Lake reservoir near-shore west of main dam
	X		Gerle Creek below Loon Lake gaging station at USFS property boundary (marked)
	X		Loon Lake reservoir near-shore near Northshore campground in dispersed recreation area between RV CG and main dam
		X	Loon Lake near-shore east of Loon Lake campground
		X	Gerle Creek below Ice House Road bridge below dispersed area
	X		Gerle Creek reservoir near-shore between dock and day use area
		X	Union Valley reservoir near-shore at Wench Creek campground
		X	Union Valley reservoir near-shore at Yellowjacket campground
	X		Union Valley reservoir near-shore at Camino Cove
	X	X	Union Valley reservoir near-shore at Fashoda beach (Peninsula)
	X		Union Valley reservoir near-shore at Jones Fork campground
		X	Union Valley reservoir near-shore at West Point boat ramp
	X		Jones Fork Silver Creek at Ice House road
	X		Big Silver Creek at bike bridge
		X	Ice House reservoir at inflow of South Fork Silver creek
	X		Ice House reservoir near-shore at east end near day use area
		X	Ice House reservoir near-shore at peninsula cove on north shore mid-length of reservoir ("Highland" area)
	X		Ice House reservoir near-shore near youth camp boat storage area
		X	Ice House reservoir near-shore west of boat launch area
	X		Ice House reservoir near-shore on west end of reservoir near day use area
		X	South Fork Silver Creek downstream of SMUD gaging station
		X	Junction reservoir near boat ramp dispersed camp area
		X	Camino reservoir near road
		X	Brush Creek boat ramp
	X		Brush Creek boat ramp
		X	Slab Creek reservoir boat ramp
	X		SFAR below bridge at Camino powerhouse
Chili Bar dam and reservoir			
		X	Chili Bar reservoir near shoreline (dam road)
	X	X	SFAR at gage station below dam

---

[2] "5 in 30" surveys will be performed to include Labor Day for upper elevation waterways; "5 in 30" surveys will be done during July 4 weekend for lower elevation waterways.

The downstream reach			
	X		SFAR downstream of Miner’s cabin (in coordination with BLM)
	X		SFAR at County Park parking lot
	X	X	SFAR downstream of Greenwood Creek
	X		SFAR upstream of Hastings Creek (in coordination with BLM)
	X		SFAR downstream of Weber Creek (in coordination with BLM)
		X	SFAR upstream of Salmon Falls (above inundation zone)

ATTACHMENT 6

SMUD UARP WATER QUALITY MONITORING PROJECT
FISH TISSUE STUDY

RESERVIORS SAMPLED	DAYS EFFORT
Slab Creek/Chili Bar	2
Union Valley/Ice House	1
Gerle/Loon Lake	2

TARGET SPECIES - Indigenous predator, either trout or bass.

Brown and Brook Trout are not hatchery raised and are good target species. Rainbows are often planted as catchables, but some occur as wild fish. The hatchery fish are identified by their fins. Wild fish have sharp edges on their fins, the rays are straight and the fins often have white tips. Hatchery raised fish have deformed fins, the rays are crooked and the edges are often fleshy. Hatchery trout that have survived several years after planting show regeneration of their fins. The new growth shows some characteristics of wild trout fins.

Bass (Largemouth or Smallmouth)
Probably only smallmouth bass will be found in these reservoirs and lakes.

Six fish of similar size (25% rule) will be collected from each reservoir and composited into one sample.

COLLECTION METHODS

The preferred method of collecting fish samples is electro fishing from a boat. This is effective along the shoreline and especially near the mouths of inflowing streams. To do this, there must be boat launching available and the water must have enough dissolved solids to carry an electric current. Alternatively, a gill net will be fished overnight.

Sampling should be completed by September 1, 2003.

SAMPLE PREPARATION

Fish will be dissected and homogenized using clean techniques according to DFG Fish and Wildlife Water Pollution Control Laboratory standard operating procedures. Liver and fillets will be composited and homogenized separately.

SAMPLE ANALYSIS - $386/sample or composite

Fish tissues will be analyzed for trace elements by ICP-MS at the DFG Marine Pollution Studies Laboratory at Moss Landing.

Tissue	Trace Elements Analyzed
Fillets	mercury, selenium, arsenic, cadmium, nickel
Liver	silver, chromium, copper, lead, zinc

ESTIMATED COMPLETION DATE – November 1, 2003

MERCURY IN TISSUE

1.0 SCOPE AND APPLICATION

This is an atomic spectroscopy method for the determination of mercury in fish tissue.

2.0 SUMMARY OF METHOD

2.1 Fish tissue is digested with concentrated nitric acid.

The mercury ions are reduced to elemental mercury with stannous chloride. The mercury vapor is analyzed by cold vapor atomic spectroscopy.

2.2 The detection limit for this method is approximately 0.02 µg/g wet weight for a 1.0 g sample.

3.0 INTERFERENCES

Certain volatile organic materials that absorb at this wavelength (253.7 nm) may cause interference. A preliminary run without reagents should determine if this type of interference is present. Chlorine causes severe interference.

4.0 APPARATUS AND MATERIALS

4.1 Digestion tubes: polypropylene digestion vessels - Cat. # SC499 or SC500 from Environmental Express

4.2 Ribbed watch glass - Cat. # SC505 from Environmental Express

4.3 50 ml Rohre/Tube - Cat. # 62.559 from Sarstedt (Aktiengesellschaft & Co)

4.4 15 ml Rohre/Tube - Cat. # 62.554.01 from Sarstedt (Aktiengesellschaft & Co)

4.5 Filter papers - Cat. # 1004 090 from Whatman, for use if filtration is needed for the sample

4.6 Hot block for metals digestions - Cat. # SC154 from Environmental Express

4.7 Teflon spatulas

4.8 Mercury lamp

4.9 Compressed argon

4.10 Atomic Spectroscopy Perkin Elmer equipped with: flow injection mercury system 400 (FIMS 400), data system, programmable autosampler (AS-90 series).

5.0 REAGENTS

5.1 Type II water

5.2 Stannous chloride dihydrate, crystal ("Baker Analyzed" JT3980-11), 25%$SnCl_2$*$2H_2O$ in 20% HCl. Dissolve 50g $SnCl_2$*$2H_2O$ in 40 ml HCl. Mix and allow to stand until $SnCl_2$*$2H_2O$ has dissolved and solution is clear. Bring to volume (200 ml) with type II water. PREPARE FRESH DAILY. (approximately 800 ml needed for the set of 32 tubes of sample, 5 tubes for standard curve and quality control)

5.3 Mercury Standard Solution (stock) – J.T. Baker, 1000 ppm

5.4 Mercury Standard Solution (intermediate) - 1.0 ppm in 1.0% nitric acid.
Partially fill a 1000 ml volumetric flask with Type II water. Add 1 ml of 1000 ppm $HgCl_2$. Bring to volume (1000 ml) with Type II water.

5.5 Mercury calibration standards: Partially fill each volumetric flask with Type II water, add the appropriate volume of 1.0 ppm $HgCl_2$ standard and 40 ml concentrated nitric acid and bring to volume with Type II water. As solution cools, it will be necessary to add water to keep level at 100 ml. Mix well.

0.0010 ppm: Add 0.10 ml of 1.0 ppm $HgCl_2$
0.0050 ppm: Add 0.50 ml of 1.0 ppm $HgCl_2$
0.0100 ppm: Add 1.00 ml of 1.0 ppm $HgCl_2$
0.0250 ppm: Add 2.50 ml of 1.0 ppm $HgCl_2$
0.0005 ppm: Add 5.00 ml of 0.01 ppm $HgCl_2$

5.6 Mercury Check Standard and Spike Standard: E.M. Science, 1000ppm.

5.7 Intermediate solution (A): 100.0 ppm in 1.0% nitric acid. Partially fill a 100 ml volumetric flask with Type II water. Add 10.0 ml of 1000 ppm $HgCl_2$. Bring to volume with Type II water.

5.8 Intermediate solution (B): 1.0 ppm in 1.0% nitric acid. Partially fill a 100 ml volumetric flask with Type II water. Add 1.0 ml of solution (A). Bring to volume with Type II water.

5.9 Check Standard: 0.010 ppm in 40% nitric acid. Partially fill a 100 ml volumetric flask with Type II water. Add 1.0 ml of solution (B). Bring to volume withType II water.

5.10 Hydrochloric acid (HCl), concentrated, reagent grade.

5.11 Nitric acid (HNO_3), concentrated, reagent grade.

6.0 SAMPLE COLLECTION, PRESERVATION, AND HANDLING

6.1 All samples must have been collected using a sampling plan that addresses the considerations discussed in this manual.

6.2 All sample containers must be prewashed with detergents, acids, and Type II water. Plastic and glass containers are both suitable.

6.3 Nonaqueous samples shall be frozen, when possible, and analyzed as soon as possible.

7.0 PROCEDURE FOR SAMPLE PREPARATION

Preparation of samples:

7.1 With each set of analyses, prepare 2 method blanks, 2 standard reference materials (~ 0.25 g dry tissue - Dorm 2 or NBS 1566a), 2 matrix spike, 2 laboratory control spike, and one duplicate for every 10 samples.

7.2 Samples with equal weight of water added: Place 2.0 ± 0.5 g into clean digestion tube.

7.3 Samples without added water: Place 1.0 ± 0.5 g into clean digestion tube.
7.4 Add 10 ml concentrated nitric acid and let stand overnight.

7.5 The next day, digest samples in a programmable hot block. The parameters for heating are as follows:

Ramp: 5^0 C / min.
Set temperature: 105-108^0 C.
Hold: 2 ½ hours

7.6 Allow the tubes to cool, then add Type II water to the calibration mark (25ml). Vortex tubes to mix well.

7.7 Moisture Determination, if required

1. Number an aluminum weighing dish to correspond to the sample beaker number.

2. Weigh the aluminum weighing dish and record its weight.

3. Tare the aluminum weighing dish.

4. Weigh ~ 3g (minimum 1g) tissue and record the weight.

5. Place moisture samples in a 70^{o}C oven for 48 hours.

6. After cooling samples, weigh and record the dry weights.

Percent Moisture Calculation

$$1 - \frac{(\text{Dry sample weight plus aluminum dish}) - (\text{Aluminum dish weight})}{(\text{Wet sample weight}) \ \text{X} \ (F)} \times 100$$

F = the added water factor = 0.6666 when added water equals one half of the sample weight (i.e. flesh samples - Selenium Verification Program)

0.5 when added water equals the sample weight (i.e. flesh samples - Toxic Substance Monitoring Program) 1 when water was not added to the sample (i.e. liver and sediment samples)

8.0 ANALYTICAL PROCEDURE

8.1 Prepare reagents:

8.1.1 25% $SnCl_2$ (see Section 5.2)
8.1.2 Rinse water -3.0% HCl (Prepare 1000 ml: 30 ml HCl add to 970 ml Type II water)
8.1.3 Reagent blank solution - 40% HNO_3 (Prepare 500 ml: 200 ml HNO_3 add to 300 ml Type II water)

8.1.4 Calibration standards (see Section 5.5)
8.1.5 Check standard (see Section 5.9)

8.2 Transfer calibration standards and check standard to 50 ml Rohre/Tube, samples to 15 ml Rohre/Tube. The tubes should be numbered to correspond to sample number.

8.3 Operation of FIMS 400 and auto sampler

8.3.1 Switch on the fume ventilation system, then the carrier gas supply (argon), adjust the pressure to 52 psig and finally switch on FIMS 400.

8.3.2 Switch on the computer, printer and start Windows.

8.3.3 In the Program Manager, double-click on AA 2.50.

8.3.4 When "AA WinLab" appears, proceed as follows:

- From the Tools menu, choose Open Workspace, or on the Toolbar, click on WkSpace.
- Select **hgtissue.fms**, then click on OK. The window appears.
- On the Toolbar, click on MethEd. Select **Tissue Hg Test**. All of the desired parameters have been entered for

Inst – Instrument parameters
Calib – Calibration parameters
FIAS – FIAS program instructions
Checks – Analytical checks for sample and calibration solutions
QC – Locations of quality control solutions and instructions for performing quality control procedures
Options – Remarks about the Method and options for saving and printing data

  - Saving a method: From the File menu, choose Save As Method. A dialog appears. If you want to save the Method under a new name, type a name for the file, then press Enter or click on OK. To save the Method with the original name, press Enter or click on OK.
  - Click on SampInfo on the Toolbar to enter the pertinent information (e.g. description, batch ID, analyst, the first sample ID should be at auto sampler location # 9).
  - Saving a sample information file: From the File menu, choose Save As ► Sample Infor File. A dialog appears. If you want to save the Sample Infor File under a new name, type a name for the file, then press Enter or click on OK.
  - Printing the Autosampler Loading List: From the File menu, choose Print ► Autosampler Loading List.
  - Select the name of the Results Data Set where you will save the results. If the data set exists, new data will be added to it.
  - Select the Save Data check box if you want the results saved in the data set specified.
  - Select the Print Log check if you want the results to be printed.

- Select the Off After Analysis: Lamp, Pumps check boxes to switch these items off at the end of the analysis.
- On the Automated Analysis window, check on "use Entire Sample Infor File" column.

- Click on the tab containing "Analyze": click on "Analyze all"after the reagents have been prepared, the signal has been optimized, the FIMS 400 flows have been set, the autosampler has been turn on, and the samples have been loaded.

8.3.5 To optimize the signal

- The absorbance values for each replicate should be similar. If the absorbance for the first replicate is higher than that for the subsequent ones, lengthen the Fill step on the FIAS page of the Method. If the absorbance of the first is replicate is lower, Lengthen the Prefill step.

- Ensure that the Read Delay (0 s) and Read Time (15 s) values are set correctly on the Inst page of the Method.

- Slight adjustments to the gas flow may improve sensitivity. If the peak maximum appears too early, slightly decrease the carrier gas flow. If the peak maximum appears too late, slightly increase the carrier gas flow.

  Note: If the carrier gas flow is too high, the mercury vapor is dispersed too rapidly. If the flow is too low, mercury vaporflows into the cell too slowly. In both situations the signal and sensitivity are low. A flow in the range 40-70 ml/min is generally suitable.

- A slight decrease in the outflow from the gas/liquid separator may improve sensitivity.

  Note: If the outflow from the gas/liquid separator is too high, mercury vapor may escape through the waste outlet. If the out-flow is too low, the fluid level may rise so high that moisture escapes into the sample transfer tube and the FIMS-cell. If liquid does enter the FIMS-cell, you must clean the cell as described in FIMS: Installation, Maintenance, System Description.

- Slight adjustments to the carrier and reductant flows may improve sensitivity.

- If the FIMS-cell is contaminated, e.g. because liquid has entered the cell, you must clean the cell as described in FIMS: Installation, Maintenance, System Description.

8.3.6 To set up the FIMS – 400

- The carrier gas stream has a large influence on sensitivity. If he flow is too high, the atom or hydride cloud is dispersed too

- rapidly. If the flow is too low, the resulting signal and sensitivity are lower. A flow of 50-100 mL/min for the carrier stream is suitable. If there is no gas flow, the automatic gas valve may be closed. To start the flow, in the FIAS Control window, click on Valve Fill/Inject.

- Place the inlets of the carrier pump tube (yellow/blue), reductant pump tube (red/red) and sampling tube (leading to the FIAS valve) in containers of deionized water.

- Swing the pump pressure levers over to press the pump tube magazines against the rollers.

- On the Toolbar, click on FIAS. Then, in the FIAS Control window:

- Click on Valve Fill/Inject to set the valve to the Fill position. Type 100 for Pump # 1 Speed, and type 120 for Pump # 2 Speed. Click on Pump # 1 and Pump # 2 to start the pumps.

- The flows should be checked before every run. When checking flows, only use P-2. P-1 is dry except when sample is being pumped. The carrier pump tube (yellow/blue) should have a flow of 9-11 ml/min; the reductant pump tube (red/red) should have a flow of 5-7 ml/min. It is recommended that the tubes be replaced after two runs and that they are reversed when they are run the 2 nd time.

- After setting the flows, position the reagents.

- For gas/liquid separator, put filter paper's shiny side up

8.3.7 Sample Changer

- Load the sample carousel with standards, reagent blank solution and samples. Set in place the rinse solution (MQ H_2O) at location 0.

8.3.8 Initiate the run

- On the Toolbar, click on Analyses, select Autozero signal to zero the instrument.

- To analyze all the solutions: In the Automated Analysis Control window, click on Analyze All. All the solutions will be analyzed. The calibration solutions will be analyzed first, immediately followed by the samples and any other solutions (QC, reslope etc.).

PRECAUTIONS:

Check that the drain tube is connected to the gas / liquid separator and freely drains into collection vessel. The end of the drain tube must not be submerged in liquid. The exhaust hood over the FIMS should be left on at all times.

8.3.9 Post run: Rinsing procedure after automatic analyses

- Place the inlets of the carrier and reagent (e.g. reductant, buffer) tubes in a container of deionized water.

- On the Toolbar, click on Auto.

- In the Automated Analysis Control window, click on Analyze page tab.

  - Click on Select Location. In the dialog box, select the Go to wash option, then click on OK.

  - In the Automated Analysis Control window, click on Move Probe Up/Down to raise the sampling probe.
  - Place a beaker with the first rinse solution in the wash location (usually location 0).
  - Click on Move Probe Up/Down to lower the probe into the rinse solution.

- On the Toolbar, click on FIAS.

- In the FIAS Control window:

- Click on Valve Fill/Inject to turn the valve to the Fill position. (The position is shown in the Status display of the window.)

- In the FIAS Control window:

- Click on the Pump 1 and Pump 2 buttons to start the pump.

- In the FIAS Control window, click on Valve Fill/Inject a number of times while the pumps are running. This ensures that sample channel and the inside of the FIAS-valve are rinsed effectively. Rinse the tubing with the de-ionized water for as long as necessary to remove all traces of the previous reagent.

8.3.10 Quality Control

- All quality control data should be maintained and available for easy reference or inspection.

- Calibration curves must be composed of a minimum of blank and three standards. After running the calibration curve, analyze an initial calibration blank and an initial calibration check standard (ICB, ICV). A continuing calibration blank (CCB) and a continuing calibration check standard (CCV) should be analyzed. This check standard is used to check the validity of the calibration curve standard and therefore should be obtained different vendor. The CCV result must be within 85-115% of the expected concentration. After the last sample in the run, a final FCB and FCV should be analyzed.

- Dilute samples if they are more concentrated than the highest standard.

- Analyze a minimum of two blanks per sample batch to determine if contamination or any memory effects occur.

- Analyze two standard reference material (SRMs) of a comparable matrix with each set of samples.

- Analyze on duplicate sample for every ten samples.

- Analyze a matrix spike (MS) and matrix spike duplicate (MSD) with each run.

- Analyze a laboratory control spike (LCS) and laboratory control spike duplicate with each run.

9.0 REFERENCES

9.1 Evans, S.J., Johnson, M.S., Leah, R.T. 1986. Determination of Mercury in Fish Tissue, a Rapid, Automated Technique for Routine Analysis. Varian Publication Number AA-60.

9.2 Perkin Elmer, Publication B3118.20. FIMS Flow Injection Mercury System. Setting Up and Performing Analyses. Atomic Spectroscopy.

Analyst:_________________ Date:__________

Reviewed by:_________________ Date:__________

Laboratory Director:_________________ Date:__________

WATER TEMPERATURE TECHNICAL REPORT

SUMMARY

From Water Year 2001 through 2004, the Sacramento Municipal Utility District (SMUD) and Pacific Gas and Electric Company (jointly referred to as the Licensees) conducted water temperature studies to support the relicensings of SMUD's Upper American River Project (UARP) and Pacific Gas and Electric Company's Chili Bar Project. The studies were conducted in the 11 UARP reservoirs, Rockbound Lake, Chili Bar Reservoir and in river reaches that could be affected by operations of the two projects, including the Reach Downstream of Chili Bar. In addition, the Licensees measured dissolved oxygen, pH, specific conductance and water clarity in reservoirs; and SMUD developed water temperature models for three selected river reaches. The studies were conducted in conformance with study plans developed by the UARP Relicensing Aquatic Technical Working Group and approved by the UARP Relicensing Plenary Group.

The studies demonstrated that the 13 reservoirs are generally cold with summertime surface water temperatures less than 20°C and bottom temperatures around 7°C to 8°C in the deeper, stratified reservoirs. Rubicon, Buck Island and Loon Lake reservoirs and Rockbound Lake are dimitic: they generally have winter ice cover and fully mix twice a year - in fall before ice cover and in spring after the ice thaws. Since they are relatively shallow, Rubicon and Buck Island reservoirs do not thermally stratify, however Loon Lake Reservoir and Rockbound Lake each thermally stratify in summer with cold hypolimnia in the deepest portion or the reservoir. Ice House, Union Valley, Junction, Brush Creek, and Slab Creek reservoirs are monomitic: that is, they are never completely ice-covered, circulate freely in the winter, and stratify in the summer. Ice House and Union Valley reservoirs develop strong stratification during summer months, while Junction and Slab Creek Reservoir develop weak stratification or limited surface warming. Gerle Creek, Robbs Peak, Camino and Chili Bar reservoirs are polymictic: they normally do not have ice cover, do not stratify, and mix freely.

All of the 13 reservoirs are generally well oxygenated. Oxygen concentrations in the upper portions of the reservoir in summer are typically greater than 85 percent saturation and 8.0 milligrams per liter (mg/l). None of the reservoirs showed bottom anoxic conditions, although lower DO concentrations (less than about 7 mg/l and 50% saturation) were found at the bottom of Ice House, Union Valley and Brush Creek reservoirs. The reservoir waters are slightly acidic to slightly alkaline with pH readings generally ranging from about 6.0 to 8.0 (where 7.0 is considered neutral). Specific conductance showed an increasing trend from upstream reservoirs (readings ranging from about 6 to 13 µS/cm) to the downstream reservoirs (20 to 37 µS/cm), indicating increasing ion concentration from the upper to lower elevation reservoirs. The reservoir waters are relatively clear, with Secchi disc readings ranging from about 10 to 30 feet in the deeper reservoirs.

About 62 percent of the river reaches potentially affected by the two projects have water temperatures that do not exceed a mean daily value of 20°C and a maximum value of 25°C. These reaches include:

- All of Loon Lake Dam Reach (8.5 miles)
- All of Gerle Creek Dam Reach (1.2 miles)
- Downstream portion of Robbs Peak Dam Reach (about 4 miles)
- Upstream portion of Ice House Dam Reach (about 7 miles)
- All of Junction Dam Reach (8.3 miles)
- Upstream portion of Camino Dam Reach (about 3 miles)
- All of Brush Creek Dam Reach (2.2 miles)
- Upstream portion of Slab Creek Dam Reach (about 4 miles)
- Upstream portion of Reach Downstream of Chili Bar (11.5 miles)

In the remaining 38 percent of the reaches potentially affected by the two projects, water temperatures exceed one or both of the temperature criteria described above. These are:

- All of Rubicon Dam Reach (4.2 miles): mean daily water temperature exceeds 20.0°C about 7-12% of the time, but maximum daily water temperature always less than 25°C
- All of Buck Island Dam Reach (2.5 miles): 11-13% and 26.4°C in the downstream portion
- Upstream portion of Robbs Peak Dam Reach (about 2 miles): 4%, but maximum daily water temperature always less than 25°C
- Lower middle and downstream portions of Ice House Dam Reach (about 4 miles): 0.6-2% and 26.0°C
- Downstream portion of Camino Dam Reach (about 3 miles): 10% and 25.6°C
- All of the SFAR Reach (2.8 miles): 13% and 25.8°C
- Downstream portion of Slab Creek Dam Reach (about 4 miles): 28% and 26.7°C
- Downstream portion of Reach Downstream of Chili Bar (1.6%, and maximum daily water temperature of 23.6°C) (about 7.6 miles)

The ambient air temperatures that occurred during the stream water temperature monitoring period reflect a wide range of conditions. Mean monthly air temperatures for June-September at a nearby long-term weather station show that ambient conditions in the period 2001 through 2004 were generally between normal (50 percent exceedance) or hot (10 percent exceedance). The month of July in both 2002 and 2003 was extremely hot, with July 2003 representing the maximum mean monthly air temperature experienced over the 1944-2003 period of record.

1.0 INTRODUCTION

This technical report is one in a series of reports prepared by Devine Tarbell and Associates, Inc. (DTA) for the Sacramento Municipal Utility District (SMUD) and Pacific Gas and Electric Company (jointly referred to as the Licensees) to support the relicensings of SMUD's Upper American River Project (UARP) and Pacific Gas and Electric Company's Chili Bar Project. The Licensees intend to append this technical report to their respective applications to the Federal Energy Regulatory Commission (FERC) for new licenses. The report addresses water temperature in reservoirs and in streams effected by the twp projects, and includes the following sections:

- **BACKGROUND** – Includes when the applicable study plan(s) was 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; and the study area. In addition, requests by Resource Agencies for additions to and modifications of 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 by request in a separate compact disc (CD) for additional data analysis and review by interested parties.
- **LITERATURE CITED** – A listing of all literature cited in the report.

This technical report does not include a discussion regarding the affects of the two projects on water temperature and related environmental resources, nor does the report include a discussion of appropriate protection, mitigation and enhancement (PM&E) measures. A discussion regarding the effects of the two projects will take place within collaborative settlement group dialogues. An impacts discussion regarding the UARP is included in the applicant-prepared preliminary draft environmental assessment (PDEA) document, which is part of SMUD's application for a new license. Development of resource measures will occur in settlement discussions by the UARP Settlement Negotiations Group (SNG), which will occur in 2005, and will be reported on in SMUD's PDEA and Pacific Gas and Electric Company's Chili Bar Project license application.

2.0 BACKGROUND

The UARP Aquatic Technical Working Group (TWG) developed two study plans that pertain specifically to water temperature (the Water Temperature Study Plan and the Iowa Hill Water Temperature Study Plan) and a third study plan (Water Quality Study Plan) that required extensive water quality and temperature monitoring in reservoirs. This technical report addresses the Water Temperature Study Plan and these portions of the Water Quality Study Plan that pertains to water temperature. The Iowa Hill Water Temperature Study Plans will be addressed in a separate technical report, to be issued in early 2005.

2.1 Water Temperature Study Plan

On January 8, 2003, the UARP Relicensing Plenary Group approved a Water Temperature Study Plan that was developed and initially approved by the relicensing Aquatic TWG on January 25, 2002, revised and again approved on July 14, 2003. The study plan was designed to address, in part, the following issues questions developed by the Plenary Group:

Issue Question 3.	What are the effects of water temperatures on downstream Project diversions and reservoirs? What are the effects of Project operations on downstream water temperatures?
Issue Question 26.	What are the temperatures available in the Project including potential modifications (e.g. cold water pools)?
Issue Question 49.	What water temperature data already exists for the Project area and what are the gaps?
Issue Question 50.	What mathematical models are available for evaluating Project-related water temperature impacts?

Specifically, the objectives of the study plan were:

- Gather and analyze data to determine how the UARP and Chili Bar Project features and operations might affect water temperature, and if water temperatures in the vicinity of the Projects meet the goals of the State Water Resources Control Board's (SWRCB) Basin Plan (RWQCB 2001) beneficial use of Cold Freshwater Habitat and the needs of other identified habitats/species.

- Evaluate the coldwater pool and seasonal availability of impounded waters within UARP reservoirs and the Chili Bar Reservoir.

The study area included all UARP and Chili Bar Project affected stream reaches, including the Reach Downstream of Chili Bar, all reference reaches, and all UARP and Chili Bar Project reservoirs excluding Robbs Peak Reservoir due its small size.

2.2 Water Quality Study Plan

On January 8, 2003, the UARP Relicensing Plenary Group approved a Water Quality Study Plan that was developed and initially approved by the relicensing Aquatic TWG on August 28, 2002, revised and again approved on December 2, 2002. With regards to water temperature, the study plan was designed to address, in part, the following issues questions developed by the Plenary Group:

Issue Question 41.	Do the waters below the Project reservoirs meet the water quality objectives of the Basin Plan? How can the Project be managed to help meet them?
Issue Question 45.	What type of long-term sediment and water quality strategies, operational practices and maintenance strategies exist?
Issue Question 46.	Do the waters within the reservoirs and the diverted reaches adequately protect all designated beneficial uses?

Specifically, the objectives of the study plan were:

- Characterize water quality under current UARP and Chili Bar Project operations by directly monitor water quality and using historical information as well as information from the Water Temperature, Channel Morphology, Project Sources of Sediment and Aquatic Bioassessment studies, among other studies.
- Determine if Basin Plan water quality objectives (and other applicable water quality criteria) are met and assess whether Basin Plan designated beneficial uses are protected.

The study area was the same as that for the Water Temperature Study Plan. The temperature data gained from the water quality fieldwork is included in this report.

2.3 Agency Requested Information

In a May 13, 2004, letter, the resource agencies stated:

> We are still reviewing this report [Licensees' January 8, 2004, Water Temperature Technical Report] and will provide comments once our review is complete. At this time Agency staff request that all thermographic monitoring continue through the 2004 field season.

The Licensees have not received any additional comments from the Resource Agencies regarding the January 8, 2004, Water Temperature Technical Report, and have maintained all water temperature monitoring loggers up to October 1, 2004. The Resource Agencies' comments on the January 8, 2004 Water Quality Technical Report and in their May 13 letter did not include any specific comments or recommendations regarding water temperature.

In addition, in a July 6, 2004 meeting, the Aquatic TWG requested that SMUD include in the revised Water Temperature Technical Report:

1. Quality control editing. Some of the numbers in the tables are switched around.
2. Check thermographs for time drift.
3. Description of placement of thermographs.
4. Import the Secchi disk depth data with profile data.
5. Time of day of sampling is missing from profile data.
6. Union Valley May 2003: Not clear why the probe took 78 readings at one depth. Explain what happened to depth readings.
7. Provide explanations for anomalies.
8. Tables summarizing temperature conditions needed for different species.
9. Check on low DO levels at various reservoirs; compared % saturation to raw data.

Also resulting from subsequent Agency requests in 2003-2004, additional stream temperature sensors were placed in the following locations in 2004:

- Gerle Creek – 0.5 mile downstream of Loon Lake dam
- Gerle Creek – 1.5 miles downstream of Loon Lake dam
- South Fork Rubicon River – 2.0 miles downstream of confluence with Gerle Creek
- Silver Creek – 0.5 mile downstream of Junction dam
- Rock Creek – just upstream of confluence with South Fork American River

Lastly, During a September 9, 2004 conference call, the Resource agencies requested that SMUD make some modifications to the water temperature models presented in Version 1 of this Water Temperature Technical Report.

2.4 Water Year Type

The UARP Relicensing Water Balance Model Subcommittee established five water year types to be applied to all preliminary analysis with the understanding that the UARP Relicensing Plenary Group, with cause, may modify the current water year types in the future. The five current water year types are triggered by the February 1, March 1, April 1 and May 1 California Department of Water Resources (CDWR) forecast for total water year unimpaired inflow into Folsom Reservoir. An additional trigger is CDWR's annual October 1 calculation of the actual total water year unimpaired inflow into Folsom Reservoir. The February 1 forecast determines the water year type applied for the period from February 10 through March 9: the March 1 forecast the period from March 10 through April 9; the April 1 forecast the period from April 10 through

May 9; the May 1 forecast the period from May 10 through October 9; and the October 1 estimate the period from October 10 through February 9. The inflow levels area:

• Critically Dry (CD) Water Year:	Less than 900,000 acre-feet
• Dry (D) Water Year:	From 900,001 to 1,700,000 acre-feet
• Below Normal (BN) Water Year:	From 1,700,000 to 2,600,000 acre-feet
• Above Normal (AN) Water Year:	From 2,600,000 to 3,500,000 acre-feet
• Wet (W) Water Year:	More Than 3,500,000 acre-feet

The study described in this Technical Report covers the period from October 2001 though September 2004. For this period, the CDWR Folsom Reservoir inflow forecasts and estimate are provided in Table 2.4-1.

Table 2.4-1. CDWR forecast of total yearly inflow to Folsom Reservoir (acre-feet), 2001-2004.

Year	Feb	Mar	Apr	May	Oct
2001	1,400,000	1,440,000	1,100,000	1,200,000	1,022,000
2002	2,380,000	2,070,000	2,170,000	2,070,000	2,019,000
2003	2,120,000	1,760,000	1,600,000	2,190,000	2,287,000
2004	2,120,000	2,210,000	1,925,000	1,725,000	1,616,000

Applying the water year type definitions to the CDWR forecasts and estimate results in the a dry water year type applied to 2001 and 2004, and below normal water year types applied to water year types 2002 and 2003 (Table 2.4-2).

Table 2.4-2. Water year types applied to individual months of the years 2001-2004.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
2001	AN	D	D	D	D	D	D	D	D	D	D	D
2002	D	BN	BN	BN	BN	BN	BN	BN	BN	BN	BN	BN
2003	BN	BN	BN	D	BN	BN	BN	BN	BN	BN	BN	BN
2004	BN	BN	BN	BN	BN	BN	BN	BN	BN	_D_	D	D

For the purposes of estimating streamflow at the water temperature monitoring sites, the four water year types in the existing UARP FERC license were used, and then adding accretion estimates to the 2001-2004 dam release data. See Section 4.2 for a complete discussion of how streamflows were estimated at the water temperature monitoring sites.

2.5 Weather Conditions

The water temperature monitoring data from 2001 through 2004 reflect conditions in the study area under a variety of ambient conditions. A review of air temperature data from a weather station located at Blue Canyon, California was conducted to aid in analysis of the water temperature data. Air temperature is a significant determinant of water temperatures in streams, along with other meteorological conditions such as solar radiation, relative humidity, and wind speed (Theurer et al. 1984). The Blue Canyon weather station was selected because of its long-term record (1944-2004) and similarities between its location and elevation (El. 5,200 ft) relative to the overall UARP/Chili Bar Project geographic area.

From the 1944-2004 daily record of air temperatures, mean monthly values were computed for June-September, one monthly value for each year. Mean values were computed rather than maximum values because of their more significant influence on thermal conditions; maximum monthly values provide more of a sense of extremes conditions, which don't necessarily influence the overall thermal regime for the month. The individual mean monthly temperature values were ranked and percentage exceedance values were developed, ranging from 50 percent exceedance (normal) to maximum (worst case). Mean monthly air temperatures for the years of the UARP water temperature monitoring program were compared to the historical record as a reference point for the ambient conditions that existed during the monitoring period (Table 2.5-1).

Table 2.5-1. Mean monthly air temperatures (°F) for June-September at Blue Canyon, California, expressed as percent values for 1944-2004 period of record, with a comparison to years of the UARP water temperature monitoring program (2001-2004).

	June		July		August		September	
Percent Exceedance	1944-2004 Temp	UARP Monitoring Year	1944-2004 Temp	Monitoring Year	1944-2004 Temp	Monitoring Year	1944-2004 Temp	Monitoring Year
50 (normal)	60.1		68.3	68.1 (2001)	67.6	67.2 (2003)	63.6	63.0 (2004)
40	61.9	62.2 (2001)	69.6	69.8 (2004)	68.7		64.0	
30 (warm)	63.4	63.4 (2004)	70.0		69.3	69.3 (2002) 69.2 (2004)	65.1	64.7 (2002)
25	63.6		70.4		69.6		65.3	
20	63.9	64.1 (2002)	70.6		70.1		65.8	
10 (hot)	65.1	65.1 (2003)	72.1		70.9	71.0 (2001)	66.8	66.2 (2001)
5	66.1		72.6	72.3 (2002)	71.7		67.9	69.1 (2003)
0 (max)	67.3		73.2	73.2 (2003)	72.9		70.4	

The information in Table 2.5-1 demonstrates that variability in ambient conditions that have occurred during the course of the 2001-2004 monitoring period. The year of 2001 exhibited normal air temperatures in June and July, and hot air temperatures in August and September. The year of 2002 exhibited generally normal air temperatures throughout the summer, except in July, when air temperatures were extremely hot, or near the 5 percent exceedance level. The year of 2003 exhibited the warmest air temperature conditions of the three years. In 2003, June and September were hot, while July air temperatures exceeded all other years in the 1944-2004 period of record. The year of 2004 was the most normal of the four years, with all summer months falling between the 30 percent exceedance (warm) and 50 percent exceedance (normal) temperatures.

3.0 METHODS

3.1 Reservoir Water Temperature Profiling

The study methods conformed to those developed by the Aquatic TWG and subsequently approved by the UARP Plenary Group. The Water Temperature Study Plan specified that the Licensees conduct water temperature profiling once in late August/early September (the period of strongest reservoir stratification) 2003 in the three UARP storage reservoirs: Loon Lake, Ice House and Union Valley reservoirs. The locations in Loon Lake, Ice House and Union Valley reservoirs generally corresponded to the deep-water locations profiled in 1999 and 2000 by Tetra Tech (Tetra Tech 2000a, 2000b). The Water Quality Study Plan required that the Licensees perform water temperature profiles in each UARP reservoir and in Chili Bar Reservoir once during the fall turnover, first major rain event, the spring runoff, and the summer low-flow period. These sampling events generally occurred in early September, mid-October, early November, and early May, respectively, for the two full seasons of sampling (2002-2004). There are times when the fall turnover event coincided with the first major rain event. In those cases, one sampling event for both was conducted.

The Licensees collected a number of profiles in the fall of 2002 to determine the specific timing of the fall turnover. Profiling was conducted in Loon Lake Reservoir (agreed by the Aquatic TWG to be representative of Rubicon, Rockbound Lake, Buck Island, Gerle and Loon Lake reservoirs), Union Valley Reservoir (representing Junction and Union Valley reservoirs), and Slab Creek Reservoir (representing Brush Creek, Camino, Slab Creek and Chili Bar reservoirs). Ice House Reservoir does not conform to the seasonal turnover of other reservoirs. It typically turns over on December 1 of each year. For this purpose, reservoir turnover was assumed to occur when the thermocline (less than 1 degree Centigrade, or °C, change in temperature per meter) had broken down. Timing of the first major rain event was linked to the first major (more than 1 inch in precipitation) storm of the year.

For reservoir profiling, a multi-parameter water analyzer (Hydrolab - 2002 and YSI – 2003/2004) was used *in situ* to measure water temperature (±0.15 °C), dissolved oxygen (±0.2 milligrams per liter, or mg/l), pH (±0.2 Units), specific conductivity (± 0.001microSeimens per centimeter, or µS/cm), and in some surveys, electric conductivity (± 0.001µS/cm). Instruments were calibrated prior to each season's survey effort according to manufacturer's specifications. Measurements were generally taken at vertical increments of at least one meter in water less than 20 meters, increments of two meters in water depths between 20 and 30 meters, increments of three meters in water depths between 30 and 40 meters, and four-meter increments in water deeper than 40 meters. Reporting of data for the purposes of this report is in 2-meter increments. In addition, one Secchi depth measurement (in feet) was taken at each reservoir sampling location to measure water clarity. Secchi disk depth was taken on the shaded side of the boat to facilitate visual tracking of the disk.

The specific sampling locations and the dates when profiles were taken (as well as reservoir elevation) are shown in Table 3.1-1. All profiles were done between 9 AM and 4 PM, with most between the hours of 10 AM to 3 PM.

Table 3.1-1. Locations for water temperature profiling in UARP reservoirs and in Chili Bar Reservoir.

Water Temperature Continuous Monitoring Site	Site Number	Profile Date(s)	Reservoir elevation (in feet, msl)
RUBICON RIVER			
Rubicon Reservoir (middle of reservoir)[1]	R-1	10/07/02	6,536
		09/17/03	6,538
		05/12/04	6,537
		09/21/04	6,535
HIGHLAND CREEK/LITTLE RUBICON RIVER			
Rockbound Lake (middle of reservoir)	R-2	10/07/02	Not available[2]
		06/11/03	-
		09/17/03	-
		05/12/04	-
		09/21/04	-
		11/02/04	-
Buck Island Reservoir (middle of reservoir)	R-3	10/07/02	6,429
		06/26/03[2]	6,429
		09/17/03	6,431
		05/12/04	6,429
		09/21/04	6,430
		11/02/04	6,428
GERLE CREEK			
Loon Lake Reservoir (near dam)	R-4a	10/08/02	6,399
		11/11/02	6,396
		05/14/03	6,371
		09/18/03	6,386
		05/06/04	6,402
		09/22/04	6,388
		11/10/04	6,385
Loon Lake Reservoir (middle of reservoir)	R-4b	10/08/02	6,399
		11/11/02	6,396
		05/14/03	6,371
		09/18/03	6,386
		05/06/04	6,402
		09/22/04	6,388
		11/10/04	6,385
Loon Lake Reservoir (upstream near Pleasant Lake arm)	R-4c	10/08/02	6,399
		11/11/02	6,396
		05/14/03	6,371
		09/18/03	6,386
		05/06/04	6,402
		09/22/04	6,388
		11/10/04	6,385
Gerle Creek Reservoir (middle of reservoir)	R-5	10/08/02	5,227

[1] Rubicon and Buck Island reservoirs are typically frozen in early November, hence no first major rain sampling was conducted on these two reservoirs. Rockbound is not typically frozen this time of year. Additionally, equipment malfunction in the field precluded profile data for 2003 Spring Runoff data

[2] Not a Project reservoir

[2] Buck Island was accessed by carrying in testing equipment and an inflatable raft on this date. It was not possible, however, to access Rockbound Lake and Rubicon Reservoir.

Table 3.1-1. Locations for water temperature profiling in UARP reservoirs and in Chili Bar Reservoir.

Water Temperature Continuous Monitoring Site	Site Number	Profile Date(s)	Reservoir elevation (in feet, msl)
		11/11/02	5,225
		05/14/03	5,227
		09/18/03	5,229
		05/06/04	5,224
		09/15/04	5,228
		11/10/04	5,224
SOUTH FORK SILVER CREEK			
Ice House Reservoir (near dam)	R-7a	11/14/02	5,427
		11/26/02	5,426
		06/12/03	5,445
		09/18/03	5,432
		05/11/04	5,440
		09/20/04	5,423
		11/01/04	5,419
		12/01/04	5,418
Ice House Reservoir (middle of reservoir)	R-7b	11/14/02	5,427
		11/26/02	5,410
		06/12/03	5,445
		09/18/03	5,432
		05/11/04	5,440
		09/20/04	5,423
		11/01/04	5,419
		12/01/04	5,418
Ice House Reservoir (upstream end)	R-7c	11/14/02	5,416
		11/26/02	5,410
		05/13/03	5,423
		06/12/03	5,444
		09/18/03	5,432
		05/11/04	5,440
		09/20/04	5,423
		11/01/04	5,419
		12/01/04	5,418
SILVER CREEK			
Union Valley Reservoir (near dam)	R-6a	11/14/02	4,816
		05/07/03	4,854
		09/18/03	4,842
		05/05/04	4,859
		09/14/04	4,833
		11/08/04	4,816
Union Valley Reservoir (middle of reservoir)	R-6b	11/14/03	4,816
		05/07/03	4,854
		09/18/03	4,842
		05/05/04	4,859
		09/14/04	4,833
		11/08/04	4,816
Union Valley Reservoir Robbs tailrace	R-6c	11/14/03	4,816
		05/07/03	4,854
		09/18/03	4,842
		05/05/04	4,859
		09/14/04	4,833

Table 3.1-1. Locations for water temperature profiling in UARP reservoirs and in Chili Bar Reservoir.

Water Temperature Continuous Monitoring Site	Site Number	Profile Date(s)	Reservoir elevation (in feet, msl)
		11/08/04	4,816
Union Valley Reservoir Jones Fork tailrace	R-6d	11/14/02 05/07/03 09/18/03 05/05/04 09/14/04 11/08/04	4,816 4,854 4,842 4,859 4,833 4,816
Junction Reservoir (middle of reservoir)	R-8a	11/14/02 05/13/03 09/16/03 05/05/04 09/14/04 11/08/04	4,434 4,443 4,439 4,438 4,440 4,448
Camino Reservoir (edge of reservoir)	R-9a	11/13/02 05/06/03 09/16/03 05/04/04 09/12/04 10/24/04	2,901 2,905 2,898 2,898 2,905 2,897
BRUSH CREEK			
Brush Creek Reservoir	R-10a	11/13/02 05/06/03 09/16/03 05/04/04 09/20/04 11/01/04	2,905 2,909 2,900 2,903 2,900 2,900
	R-10b	05/06/03	2,909
SOUTH FORK AMERICAN RIVER			
Slab Creek Reservoir (middle of reservoir)	R-11a	10/09/02 11/12/02 05/05/03 09/15/03 05/03/04 09/13/04 10/25/04	1,838 1,844 1,841 1,837 1,839 1,841 1,840
Slab Creek Reservoir (upper reservoir)	R-11b	10/09/02 11/12/02 05/05/03 09/15/03 05/03/04 09/13/04 10/25/04	1,838 1,844 1,841 1,837 1,839 1,841 1,840
Chili Bar Reservoir (middle of reservoir)	R-12b	10/09/02 11/12/02 05/05/03 09/15/03 05/03/04 09/13/04 10/25/04	Not available

Table 3.1-1. Locations for water temperature profiling in UARP reservoirs and in Chili Bar Reservoir.

Water Temperature Continuous Monitoring Site	Site Number	Profile Date(s)	Reservoir elevation (in feet, msl)
Chili Bar Reservoir (near dam)	R-12a	10/09/02 11/12/02 05/05/03 09/15/03 05/03/04 09/13/04 10/25/04	Not available

3.2 Stream Water Temperature

The study methods conformed to those developed by the Aquatic TWG and subsequently approved by the UARP Plenary Group. The Licensees tested and installed Tidbit® water temperature loggers (Onset Corporation) at 51 locations in the study area (Table 3.2-1). Most sensors were secured to either a large rock or 4x4 wooden post and then located in the deepest accessible location of the stream in flowing water. Given the lack of water in some streams in summer months (e.g., Jerrett Creek), loggers may have been discontinued. The loggers recorded water temperature (±0.2º C) every 15 minutes and then calculated and stored a mean hourly water temperature reading. The loggers were also inspected periodically to ensure proper working condition, and replaced as necessary. The mean hourly water temperature data were downloaded to a laptop computer as access and weather conditions permitted. When the data were downloaded, the computer resets the clock on the logger. Time and temperature recordings were checked in the office for any indications of time drift. A map showing the location of the logger sites is provided in Appendix B.

Table 3.2-1. Locations of continuous water temperature loggers for relicensing studies of the UARP and Chili Bar Project.

Water Temperature Continuous Monitoring Site	Site Number	Month and year Installed	GPS Coordinates
RUBICON RIVER			
Upstream of Rubicon Reservoir	RR4	May 2002	N 38º 58.783′ W 120º 13.008′
Rubicon Dam Reach, at Rubicon Dam	RR3	October 2000	N 38º 59.321′ W 120º 13.322′
Rubicon Dam Reach, above Rubicon Springs	RR2	May 2002	N 39º 00.347′ W 120º 13.685′
Downstream of Little Rubicon River Confluence	RR1	October 2000	N 39º 01.919′ W 120º 16.000′
HIGHLAND CREEK/LITTLE RUBICON RIVER			
Rockbound Dam Reach, Upstream of Rubicon River Confluence	LRR1	July 2002	N.39º 00.702′ W 120º 15.624′
Buck Island Dam Reach, at Buck Island Dam	LRR2	October 2000	N 39º 00.294′ W 120º 15.399′
GERLE CREEK			
Loon Lake Dam Reach, 0.5 miles downstream of Loon Lake Dam	GC5.9	June 2004	N 39º 00.399′ W 120º 18.915′

Table 3.2-1. Locations of continuous water temperature loggers for relicensing studies of the UARP and Chili Bar Project.

Water Temperature Continuous Monitoring Site	Site Number	Month and year Installed	GPS Coordinates
Loon Lake Dam Reach, 1.5 miles downstream of Loon Lake Dam	GC5.8	June 2004	N 39º 00.785′ W 120º 20.257′
Loon Lake Dam Reach, at Loon Lake Dam	GC6[3]	October 2000	N 38º 59.881′ W 120º 18.477′
Loon lake Dam Reach, Upstream of confluence with Gerle Creek	JC1	Installed and removed	N 39º 00.800′ W 120º 20.916′
Loon lake Dam Reach, Upstream of Jerrett Creek	GC5	October 2000	N 39º 00.748′ W 120º 20.827′
Loon lake Dam Reach, Downstream of Barts Creek	GC4	May 2002	N 38º 00.252′ W 120º 13.011′
Loon lake Dam Reach, Upstream of Gerle Creek Reservoir	GC3	October 2000	N 38º 59.071′ W 120º 22.766′
Gerle Creek dam Reach, at Gerle Creek Dam	GC2[3]	April 2001	N 38º 57.952′ W 120º 23.661′
Gerle Creek Dam Reach, Upstream of South Fork Rubicon River Confluence	GC1	May 2002	N 38º 57.255′ W 120º 23.905′
SOUTH FORK RUBICON RIVER			
Upstream of Robbs Forebay	SFRR4[3]	July 2001	N 38º 56.739′ W 120º 23.212′
Robbs Peak Dam Reach, at Robbs Forebay Dam	SFRR3[3]	May 2001	N 38 56.853′ W 120º 23.304′
Robbs Peak Dam Reach, Upstream of Gerle Creek Confluence	SFRR2	May 2002	N 38º 57.241′ W 120º 23.917′
Robbs Peak Dam Reach, Downstream of Gerle Creek Confluence	SFRR1	October 2000	N 38º 57.252′ W 120º 24.035′
Robbs Peak Dam Reach, upstream of confluence with Rubicon River	SFRR 0.5	July 2004	N 38º 57.577′ W 120º 24.808′
SOUTH FORK SILVER CREEK			
Upstream of Ice House Reservoir	SFSC6[4]	July 2001	N 38º 49.195′ W 120º 18.839′
Ice House Dam Reach, at Ice House Dam	SFSC5[4]	March 2001	N 38º 49.364′ W 120º 21.622′
Ice House Dam Reach, Upstream of Ice House Road	SFSC4	March 2001	N 38º 49.071′ W 120º 21.919′
Ice House Dam Reach, Downstream of Ice House Road	SFSC3	May 2002	N 38º 49.027′ W 120º 22.431′
Ice House Dam Reach, Midway in Burn Area	SFSC2	November 2000	N 38º 48.393′ W 120º 25.570′
Ice House Dam Reach, Upstream of Junction Reservoir	SFSC1	November 2000	N 38º 51.082′ W 120º 26.800′
SILVER CREEK			
Tells Creek Upstream of Union Valley Reservoir	TC1[4]	October 2000	N 38º 34.097′ W 120º 22.137′

[3] Indicates redundant water temperature loggers at one location.

[4] Indicates redundant water temperature loggers at one location.

Table 3.2-1. Locations of continuous water temperature loggers for relicensing studies of the UARP and Chili Bar Project.

Water Temperature Continuous Monitoring Site	Site Number	Month and year Installed	GPS Coordinates
Big Silver Creek Upstream of Union Valley Reservoir	BSC1[4]	July 2001	N 38º 52.743′ W 120º 21.719′
Jones Fork Silver Creek Upstream of Union Valley Reservoir	JFSC1[4]	July 2001	N 38º 50.908′ W 120º 22.674′
Junction Dam Reach, at Junction Dam	SC4	October 2000	N 38º 51.137′ W 120º 27.480′
Junction Dam Reach, 0.5 mile downstream from Junction Dam	SC3.9	June 2004	N 38º 51.060′ W 120º 27.861′
Junction dam Reach, Upstream of Jaybird Powerhouse	SC3	November 2000	N 38º 49.663′ W 120º 32.072′
Camino Dam Reach, at Camino Dam	SC2	November 2000	N 38º 50.232′ W 120º 32.041′
Camino Dam Reach, Upstream of SF American River Confluence	SC1[4]	November 2001	N 38º 47.403′ W 120º 35.392′
BRUSH CREEK			
Upstream of Brush Creek Reservoir	BC3[5]	May 2002	N 38º 48.882′ W 120º 36.969′
Brush Creek Dam Reach, at Brush Creek Dam	BC2	November 2000	N 38º 48.574′ W 120º 37.307′
Brush Creek Dam Reach, Upstream of Slab Creek Reservoir	BC1[6]	May 2002	N 38º 47.824′ W 120º 40.987′
SOUTH FORK AMERICAN RIVER			
Upstream of Silver Creek Confluence	SFAR12[4]	July 2001	N 38º 47.334′ W 120º 35.394′
SFAR Reach, Downstream of Silver Creek Confluence	SFAR11[4]	July 2001	N 38º 47.376′ W 120º 35.475′
Downstream of Camino Powerhouse	SFAR10	January 2001	N 38º 47.662′ W 120º 37.509′
Slab Creek Dam Reach, at Slab Creek Dam	SFAR9	March 2001	N 38º 46.389′ W 120º 41.951′
SOUTH FORK AMERICAN RIVER			
Slab Creek Dam Reach, Downstream of Walking Bridge	SFAR8	March 2001	N 38º 46.322′ W 120º 42.156′
Slab Creek Dam Reach, Upstream of Mosquito Bridge	SFAR7	November 2000	N 38º 46.555′ W 120º 44.893′
Slab Creek Dam Reach, Upstream of White Rock powerhouse	SFAR6	June 2002	N 38º 45.894′ W 120º 47.121′
Rock Creek Upstream of SF American River Confluence	RC1	June 2003	N 38º 46.986′ W 120º 46.725′
Downstream of White Rock Powerhouse	SFAR5	November 2001	N 38º 45.901′ W 120º 47.315′
Reach Downstream of Chili Bar, at Chili Bar Dam	SFAR4[7]	July 2002	N 38º 46.269′ W 120º 48.937′

[5] Sensor has been removed/washed out. Limited data set available.
[6] Sensor has been removed/washed out. No data available.

Table 3.2-1. Locations of continuous water temperature loggers for relicensing studies of the UARP and Chili Bar Project.

Water Temperature Continuous Monitoring Site	Site Number	Month and year Installed	GPS Coordinates
Reach Downstream of Chili Bar, Downstream of Dutch Creek Confluence	SFAR3[7]	July 2002	N 38º 47.450′ W 120º 52.316′
Reach Downstream of Chili Bar, Downstream of Greenwood Creek Confluence	SFAR2[7]	July 2002	N 38º 49.417′ W 120º 56.765′
Reach Downstream of Chili Bar, Upstream of Weber Creek Confluence	SFAR1[7]	July 2002	N 38º 46.465′ W 120º 59.677′

The water temperature loggers worked continuously from the time of installation through September 2004, with the following exceptions, where limited data is available:

- Jerrett Creek at Gerle Creek (cessation of flow)
- Brush Creek inflow to Brush Creek Reservoir (vandalism or washed out)
- Brush Creek inflow to Slab Creek Reservoir (vandalism or washed out)

Limited data is available also at sites where loggers were placed in service in 2004 (e.g., below Loon Lake and Junction reservoirs).

3.3 Stream Flow and Ambient Air Temperature Estimates

The Licensees estimated stream flow at several water temperature monitoring sites, as documented in Appendix B. The mean daily streamflow data provided on the site-specific graphs were developed from either measured flows at gaging stations or estimated flows from the streamflow data generated by the hydrology study conducted for the UARP/Chili Bar Project relicensing processes in 2002 - 2004. As part of the existing UARP and Chili Bar Project licenses, SMUD and PG&E maintain streamflow records at several locations, mostly, but not entirely, directly downstream of dams. All available data from the monitoring period from these gage locations were added to the site-specific graphs. The locations of these gage sites and their corresponding water temperature monitoring site are:

Rubicon River at Rubicon Dam – RR3
Little Rubicon River at Buck Island Dam – LRR2
Gerle Creek at Loon Lake Dam – GC6
South Fork Rubicon River below Gerle Creek – SFRR1
South Fork Silver Creek at Ice House Dam – SFSC5
Silver Creek at Junction Dam – SC4
Silver Creek at Camino Dam – SC2
South Fork American River at Slab Creek Dam – SFAR9

---

[7] Indicates redundant water temperature loggers at one location.

South Fork American River at Chili Bar Dam– SFAR4

Additional site-specific streamflow information was also generated during the course of the temperature monitoring study at select locations, mostly at natural streams at their point of inflow to reservoirs. This information consists of measured flow values gathered using standard stream gaging techniques. While limited in scope, it provides useful insights into actual flows in study area streams.

Site-specific streamflow information for water temperature sampling sites downstream of these gage sites was computed from the accretion data generated by the hydrology study, where available and appropriate. Because the period of the hydrology study (Water Years 1976-2001) has a limited overlap with the period of the water temperature monitoring study (Water Years 2001-2004), the accretion data used to generate streamflow values at monitoring sites downstream of dams are estimated values. These estimates were generated by first determining the Water Year type of each of the three years in the water temperature monitoring period. Based on this analysis, Water Years 2002 and 2004 fell into the same category of Water Year type, i.e., total Folsom Reservoir annual inflow greater than 2 million acre-ft. Water Year 2001 fell into the category of total Folsom inflow of 1.0-1.499 million acre-ft. The next step was to aggregate mean daily accretion flows for the appropriate representative Water Year types over the period of record (1976-2001). From these aggregated data, a set of daily median accretion values from the group of years of the hydrology was generated. The final step was to add the daily median accretion values to the daily dam release values to generate the estimate at streamflow at each water temperature monitoring site downstream of each dam. As stated above, the resulting streamflow values should be regarded as estimates because of the fact that the data represent median conditions of several different representative water types and because of the fact that the monitoring sites are not situated at the exact locations of the accretion nodes.

A similar technique was employed to estimate streamflow at water temperature monitoring sites that are in natural streams feeding into the reservoirs and reaches, such as South Fork Rubicon River upstream of Robbs Peak Reservoir. For these stations, streamflow information was generated from the unimpaired data of the hydrology study, using the same basic approach of developing median flow statistics for the same Water Year types as 2001-2004.
The mean daily ambient air temperature data were derived from the long-term weather station at Pacific House, which is located approximately midway in elevation (3,440 feet amsl) through the study area. This weather station was used because it was local to the project and contained a complete record of air temperatures for the period of water temperature monitoring. Using the Pacific House record, air temperatures at each monitoring site were computed by applying a standard adiabatic correction factor following the formula:

$T_a = T_o + Ct\,(Z - Z_o)$, where
T_a = air temperature at elevation of site (C),
T_o = air temperature at elevation of meteorological station (C),
Z = average elevation of site (m),
Z_o = elevation of meteorological station (m), and
Ct = moist air adiabatic temperature correction coefficient = -0.00656 C/m

3.4 Water Temperature Modeling

After reviewing various water temperature models, the Aquatic TWG agreed to use the United States Fish and Wildlife Service (USFWS) and US Geological Survey (USGS) SNTEMP water temperature model where a water temperature model was needed for a stream reach. SNTEMP is a mechanistic model that predicts mean water temperatures. SNTEMP has routinely been used in hydro relicensings (Theurer et al. 1984). The model also predicts maximum temperature based on empirical relationships between maximum and mean temperatures). SNTEMP does not analyze in-reservoir dynamics and requires constant river flow. That is, the stream flow conditions can vary with time, but must exist sufficiently long (about one-day-long time step) for the steady-state results to reach the lowest point in the stream network being modeled. SNTEMP is often described as being one-dimensional since it accounts for longitudinal temperature differences between segments of the river reach being modeled. In fact, SNTEMP is technically zero-dimensional for hydraulics and one-dimensional for water temperature since steady state hydraulic conditions apply. The climatic variables used as input to SNTEMP (and similar models) are dynamic (i.e., change as a function of time) but are generally limited to a minimum time-step of one day (due to the steady-flow constraints identified above). Maximum water temperatures are estimated by calculating the amount of heat flux occurring from solar noon to sunset (when maximum water temperatures are assumed to occur). Diurnal water temperature variation is then estimated using a sine curve; minimum temperatures being derived by difference using the maximum temperature estimates. These steady-flow, dynamic temperature models can be quite good (± 0.5°C or less) at predicting mean daily temperatures with steady state flow. Results are less accurate for maximum and minimum daily values; typically ±1°C.

Upon review of continuous water temperature data from 2000 through 2002, the Aquatic TWG agreed that the SNTEMP water temperature model should be applied to the Ice House Dam, Camino Dam, and Slab Creek Dam reaches.

A draft report was issued to the Aquatic TWG in January 2004, which described temperature modeling methods and results. The Forest Service and its consultants provided comments on the draft temperature modeling report. It was suggested that additional documentation be provided to describe the sources of climate data, groundwater temperature values and other input data requirements of the model. It was also suggested to revisit calibration of the Ice House Dam Reach temperature model in order to reduce the magnitude of the calibration adjustments to air temperature, which is used by the model to predict water temperatures. It was further suggested that the synthesized water temperatures for tributaries to the Ice House Dam Reach be considered a calibration parameter, which could then be adjusted to improve model temperature predictions for this reach of South Fork Silver Creek. These modifications were made to the model and discussed in a conference call held on September 9, 2004. During this conference call, it was noted that the temperature model for the Camino Dam Reach appeared acceptable without further modifications. A question was raised on the Slab Creek Dam Reach; it was asked if the model was relying on derived temperatures or the observed temperature record for the upper end of this reach. The Slab Creek Dam Reach model was subsequently revised to include additional nodes in the network to ensure that the model relied on the observed water temperatures below the Camino Dam at the upper end of the Slab Creek Dam Reach. This revised report presents the results of the revisions to the temperature modeling based on the above-mentioned comments on the draft report.

3.5 Meteorological Monitoring

Since water temperature is affected by site-specific meteorological conditions, data was used that is generated from SMUD's meteorological monitoring stations located within the UARP vicinity (Table 3.5-1). Data from these stations are only provided in this report if the information was specifically used in developing models or analyzing water temperature data.

Table 3.5-1. Select meteorological sites monitored by SMUD.

Nearest Project Reach	Designation	Parameters Monitored	Period of Record/Comments
Ice House Dam	Alpha	Air temperature, precipitation	System installed 1965
Ice House Dam	Mud Lake	Air temperature, precipitation	System installed 1971
Upstream of Union Valley Reservoir	Peninsula	Air temperature, precipitation	System installed 1994
Upstream of Union Valley Reservoir	Robbs Peak	Air temperature, precipitation	System installed 1968
Union Valley Reservoir	Big Hill	Air temperature, precipitation, humidity, barometric pressure, wind direction and speed	System installed 1971
Robbs Peak Dam	Robbs Saddle	Air temperature, precipitation	System installed 1971
Loon Lake Dam	Van Vleck	Air temperature, precipitation	System installed 1971
Silver Creek	Fresh Pond	Air temperature, precipitation humidity, barometric pressure, solar radiation, wind direction and speed	System installed 1971; solar data since 2002
Other meteorological sites	Folsom Dam (USBR)	Air temperature, humidity, barometric pressure, wind direction and speed	Unknown
	Blue Canyon	Air temperature	System installed 1944
	Bald Mountain	Air temperature, humidity, barometric pressure, wind direction and speed	Unknown

4.0 RESULTS

4.1 Reservoir Water Temperature Profiling

Provided below is a summary of water temperature profiling conducted in the various UARP reservoirs and in Chili Bar Reservoir both based on historical data and the Licensees' sampling. For all sampling and for simplicity, data are generally reported at a depth of 0.5 metes and at every 2 meters (except in Union Valley Reservoir), although data were generally recorded at a more frequent rate. Additional depths may be included in some tables when it was observed that temperatures were changing rapidly. Raw data files for all reservoirs and stream reaches surveyed are available as an appendix to this report.

4.1.1 Rubicon Reservoir

4.1.1.1 Historic Information

SMUD is unaware of any historic water temperature data collected in Rubicon Reservoir.

4.1.1.2 Relicensing Water Temperature Profiling

Water quality profile measurements at Rubicon Reservoir are available from data collected during the following sample periods:

- 2002 Fall Turnover
- 2003 Summer Low Flow
- 2004 Spring Runoff
- 2004 Summer Low Flow

Efforts to sample Rubicon Reservoir during the 2002 and 2004 First Major Rain sampling/Fall Turnover period (November of each year) were precluded by inclement weather that grounded helicopter access in Desolation Wilderness, or the reservoir was covered with ice. On-site equipment malfunction on June 11, 2003, precluded the recording of water temperature profiles during the 2003 Spring Runoff water quality sampling event.

As in accordance with the Aquatic TWG, 2002 Fall Turnover sampling at Rubicon Reservoir was conducted after Loon Lake Reservoir was observed to turn over on October 1, 2002. During the 2002 Fall Turnover sampling event, Rubicon Reservoir was found to be shallow (2 meters deep, in the center of the reservoir) and isothermal at approximately 12.5°C (Table 4.1-1). The reservoir was similarly isothermal, but warmer (15.5°C) during the 2003 Summer Low Flow sampling period, and cooler (11.8°C) during the 2004 Summer Low Flow sampling. The shallowness of Rubicon Reservoir likely precludes a cold-water hypolimnion from developing during the summer months.

Table 4.1-1. Rubicon Reservoir water quality profiles for 2002 Fall Turnover, 2003 Summer Low Flow, 2004 Spring Runoff and 2004 Summer Low Flow sampling periods

Depth (m)	Temperature (°C)	pH (Units)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (% saturation)	Specific Conductance (µS/cm)[8]
2002 Fall Turnover (October 7, 2002)					
0.5	12.6	6.90	7.8	73.5	12.7
1.0	12.5	6.82	8.0	74.5	12.7
2	12.4	6.76	8.0	75.0	12.7

---

[8] Surveys conducted in 2002 were done with a Hydrolab instrument which records accuracy for specific conductance to one-tenth of a microSiemens; surveys conducted subsequent to 2003 were done with a YSI instrument which records accuracy to one microSiemen.

Table 4.1-1. Rubicon Reservoir water quality profiles for 2002 Fall Turnover, 2003 Summer Low Flow, 2004 Spring Runoff and 2004 Summer Low Flow sampling periods

Depth (m)	Temperature (°C)	pH (Units)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (% saturation)	Specific Conductance (µS/cm)[8]
2003 Summer Low Flow (September 17, 2003)					
0.5	15.6	6.89	9.6	96.3	13
1.0	15.6	6.91	9.6	97.2	13
2	15.6	6.96	9.7	97.2	13
2004 Spring Runoff (May 12, 2004)					
0.5	7.1	6.93	11.9	98.4	9
1.0	7.1	6.87	11.8	97.6	9
2	6.4	6.76	11.9	96.3	9
2004 Summer Low Flow (September 21, 2004)					
0.5	11.7	7.76	8.5	78.3	14
1.0	11.8	7.77	8.5	79.0	14

During all sampling events, Secchi depth readings were in excess of 2.3 meters (on the bottom of the reservoir).

4.1.2 Rockbound Lake

4.1.2.1 Historic Information

SMUD is unaware of any historic water temperature data collected at Rockbound Lake.

4.1.2.2 Relicensing Water Temperature Profiling

Water quality profile measurements obtained during the relicensing studies at Rockbound Lake is available from data collected during the following sample periods:

- 2002 Fall Turnover
- 2003 Summer Low Flow
- 2004 Spring Runoff
- 2004 Summer Low Flow
- 2004 First Major Rain/Fall Turnover

Inclement weather and equipment malfunction precluded sampling at the other times. Nevertheless, the data from these sample periods consistently show a 26-meter-deep, thermally stratified lake. During the 2002 Fall Turnover period, temperatures ranged from 13.4°C at the lake surface to 6.6°C at the bottom, while during the 2003 Summer Low Flow period, temperatures ranged from 16.9°C on the surface to 7.8°C on the bottom. The 2004 Spring Runoff reservoir temperatures ranged from 6.8°C at the surface to 5.1°C at the reservoir bottom. Marked stratification was observed in the 2004 Summer Low Flow survey, where surface temperature was 14.8°C and 6.3°C at reservoir bottom. The 2004 Fall Turnover/First Major Rain event resulted in temperatures of 7.0°C at the surface and 6.2°C at reservoir bottom (Table 4.1-2).

Table 4.1-2. Rockbound Lake water quality profiles for 2002 Fall Turnover, 2003 Summer Low Flow, 2004 Spring Runoff, 2004 Summer Low Flow and 2004 Fall Turnover/First Major Rain sampling periods.

Depth (m)	Temperature (°C)	pH (Units)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (% saturation)	Specific Conductance (µS/cm)
2002 Fall Turnover (October 7, 2002)					
0.5	13.4	6.90	7.7	73.7	8.5
2	13.1	6.65	7.6	72.7	8.3
4	13.0	6.56	7.6	72.5	8.1
6	13.0	6.41	7.7	72.7	8.3
8	9.5	6.09	6.8	59.7	7.3
10	7.6	6.08	4.7	39.5	7.3
12	6.7	6.10	4.3	35.4	7.5
14	6.6	6.21	3.6	29.6	7.5
2003 Summer Low Flow (September 17, 2003)					
0.5	16.9	7.13	9.9	102.5	8.
2	16.8	6.87	9.7	100.5	8.
4	16.8	7.10	9.9	102.5	8.
6	16.6	6.82	10.1	103.4	8.
8	16.2	6.72	10.6	108.1	8.
10	13.9	6.62	10.8	105.4	6.
12	9.1	7.04	12.6	109.5	6.
14	7.8	6.72	13.0	109.5	8.
2004 Spring Runoff (May 12, 2004)					
0.5	6.8	6.94	13.1	107.3	7
2	6.6	6.84	12.4	101.5	7
4	6.2	6.75	12.3	99.7	7
6	5.9	6.69	12.3	98.7	7
8	5.8	6.62	12.3	97.9	7
10	5.4	6.54	12.2	96.7	7
12	5.3	6.50	12.2	96.0	7
14	5.2	6.44	12.1	95.3	7
16	5.2	6.40	12.0	94.8	7
18	5.2	6.36	12.0	94.6	7
20	5.1	6.32	12.0	94.2	7
22	5.1	6.30	12.0	94.0	7
24	5.1	6.27	12.0	93.9	7
26	5.1	6.36	12.0	93.7	7
2004 Summer Low Flow (September 21, 2004)					
0.5	14.8	7.70	7.9	78.0	9
2	14.8	7.65	7.9	77.4	9
4	14.8	7.55	7.8	76.6	9
6	14.7	7.44	7.6	74.7	9

Table 4.1-2. Rockbound Lake water quality profiles for 2002 Fall Turnover, 2003 Summer Low Flow, 2004 Spring Runoff, 2004 Summer Low Flow and 2004 Fall Turnover/First Major Rain sampling periods.

Depth (m)	Temperature (°C)	pH (Units)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (% saturation)	Specific Conductance (µS/cm)
8	14.6	7.27	7.4	72.4	9
10	14.6	7.18	6.9	68.1	9
12	14.3	7.16	5.7	55.8	9
14	9.3	7.19	6.3	54.7	9
16	7.4	7.20	6.4	53.7	9
18	6.9	7.22	6.4	52.8	9
20	6.7	7.26	6.2	50.9	9
22	6.4	7.30	6.1	49.3	9
24	6.3	7.47	6.3	51.0	9
2004 Fall Turnover/First Major Rain (November 2, 2004)					
0.5	7.0	6.99	8.5	69.9	9
2	6.5	6.99	8.5	69.5	9
4	6.4	6.84	8.5	69.1	9
6	6.4	6.80	8.5	69.0	9
8	6.4	6.79	8.4	68.2	9
10	6.4	6.78	8.3	67.5	9
12	6.3	6.77	8.2	66.6	9
14	6.2	6.76	8.1	65.2	9
16	6.2	6.74	7.7	62.5	9
18	6.2	6.71	7.4	60.0	9
20	6.2	6.76	8.6	69.5	9

Secchi depth readings during the 2002 Fall Turnover and 2003 Summer Low Flow sampling events were 8.75 and 8.7 meters, respectively. During the 2004 Spring Runoff, Summer Low Flow and Fall Turnover/First Major Rain events, Secchi disk readings were 10, 9 and 8.1 respectively.

4.1.3 Buck Island Reservoir

4.1.3.1 Historic Information

SMUD is unaware of any historic water temperature data collected at Buck Island Reservoir.

4.1.3.2 Relicensing Water Temperature Profiling

Water quality profile measurements obtained during the relicensing studies at Rockbound Lake is available from data collected during the following sample periods:

- 2002 Fall Turnover
- 2003 Summer Low Flow
- 2004 Spring Runoff

- 2004 Summer Low Flow
- 2004 First Major Rain/Fall Turnover

As was the case at Rubicon Reservoir, water quality profile measurements obtained during the relicensing studies at Buck Island Reservoir were precluded during the 2002 First Major Rain sampling period due to inclement weather. On June 11, 2003, water temperature and quality profile data was not available for the reservoir due to equipment malfunction for the 2003 Spring Runoff sampling period. This effort was attempted again at Buck Island Reservoir and successfully accomplished on June 26, 2003. Throughout the three sampling periods, Buck Island was found to be relatively shallow, and weakly stratified or isothermal (Table 4.1-3). Water temperatures throughout the reservoir water column varied by sampling period with the 2003 Spring Runoff exhibiting the coldest temperatures and the Summer 2003 Low Flow exhibiting the warmest temperatures. At the Summer 2003 Low Flow sampling period, Buck Island Reservoir was isothermal, while the 2003 Spring Runoff sampling period exhibited the highest degree of surface warming, with a temperature differential between surface and bottom waters of approximately 2°C.

Table 4.1-3. Buck Island Reservoir water quality profiles for 2002 Fall Turnover, 2003 Spring Runoff, 2003 Summer Low Flow, 2004 Spring Runoff, 2004 Summer Low Flow and 2004 Fall Turnover/First Major Rain sampling periods.

Depth (m)	Temperature (ºC)	pH (Units)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (% saturation)	Specific Conductance (µS/cm)
2002 Fall Turnover (October 7, 2002)					
0.5	13.7	7.05	8.2	98.6	9.4
2	13.7	7.01	8.1	97.0	9.3
4	13.0	6.84	8.3	98.3	9.5
6	12.8	6.76	8.1	94.9	9.3
8	12.7	6.85	8.1	95.9	9.3
2003 Spring Runoff (June 26, 2003)					
0.5	12.8	7.42	8.3	78.4	6
2	12.7	7.39	8.1	76.3	6
4	11.8	7.34	8.2	75.5	6
6	11.2	7.30	8.3	75.1	6
8	10.7	7.29	8.2	74.0	6
2003 Summer Low Flow (September 17, 2003)					
0.5	16.8	6.81	8.9	97.5	10
2	16.8	6.80	8.9	97.6	10
4	16.7	6.85	9.0	97.7	10
6	16.5	6.89	9.0	97.9	10
2004 Spring Runoff (May 12, 2004)					
0.5	6.9	6.84	11.9	97.3	7
2	6.6	6.82	11.8	96.7	7
4	6.3	6.75	11.8	95.6	7
6	6.0	6.73	11.8	94.8	7

Table 4.1-3. Buck Island Reservoir water quality profiles for 2002 Fall Turnover, 2003 Spring Runoff, 2003 Summer Low Flow, 2004 Spring Runoff, 2004 Summer Low Flow and 2004 Fall Turnover/First Major Rain sampling periods.

Depth (m)	Temperature (ºC)	pH (Units)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (% saturation)	Specific Conductance (µS/cm)
8	5.9	6.74	11.8	94.3	7
10	5.8	6.75	11.7	93.9	7
2004 Summer Low Flow (September 21, 2004)					
0.5	14.3	7.85	7.2	70.6	10
2	14.2	7.9	7.0	68.6	10
4	13.9	7.85	6.6	63.9	10
2004 Fall Turnover/First Major rain (November 2, 2004)					
0.5	6.2	6.73	10.36	83.6	9
2	6.2	6.69	10.32	83.2	9

Secchi depth readings during the 2002 Fall Turnover, 2003 Spring and Summer Low Flow sampling events were 7.2, 11 and 5.7 meters, respectively. Secchi depth readings for the 2004 Spring Runoff and Summer Low Flow events were 10 and 5, respectively. During the Fall Turnover/First Major Rain period, the reservoir was covered with ice and not accessible by boat. Other water quality measurements were made from the shore in as deep of water as was safely accessible.

4.1.4 Loon Lake Reservoir

4.1.4.1 Historic Information

Historically, water temperature profiling has been conducted in Loon Lake Reservoir on four occasions: in October 1980 by Ecological Analysts (EA Inc., 1982); in June and September 1996 by the United States Geological Survey (USGS); and at seven locations in the reservoir in November 1999; and June 2000 by SMUD (Tetra Tech 2000a and 2000b). A complete set of graphical displays of the historical temperature profiles developed for Loon Lake Reservoir are provided in Appendix A. SMUD notes that some of the Tetra Tech data and other data profiles show “wavering” in the water temperature values and other parameters (e.g., pH). This plot profile occurs because of recording both the descent and ascent of the probe through the column, in which two values may be generated for a given depth.

In general, this historic profiling consistently shows that Loon Lake Reservoir is a cold, clear, well-oxygenated water body. In the October 1980 and November 1999 profiling, separated by 19 years, water temperatures were between 11°C and 12°C throughout the water column. The June 2000, profiling exhibited weak stratification at all sampling locations. Maximum surface temperatures were between 13°C and 15°C, while minimum temperatures at the bottom of the reservoir were approximately 8°C (reservoir bottom ranged between 45 and 70 feet below the surface). Profiles at the deepest sampling locations (70 feet) showed a broad metalimnion gradually dropping to the low temperatures (8°C) and a poorly defined hypolimnion. Similar results were obtained in a limnological survey conducted by the USGS in June 1996 (USGS web site).

4.1.4.2 Relicensing Water Temperature Profiling

Water quality profile measurements obtained during the relicensing studies at Loon Lake Reservoir is available from data collected during the following sample periods:

- 2002 Fall Turnover
- 2002 First Major Rain
- 2003 Spring Runoff
- 2003 Summer Low Flow
- 2004 Spring Runoff
- 2004 Summer Low Flow
- 2004 First Major Rain/Fall Turnover

The results of the relicensing studies over these seven periods are generally consistent with those of the historical investigations. Additional insights into the water temperature profiles at Loon Lake Reservoir can also be gleaned from the stream-based water temperature monitoring results, as discussed below in Section 4.2. A complete set of temperature profiles graphs for Loon Lake Reservoir is provided in Appendix A. Profile data were collected at three sampling stations: 1) near Loon Lake Dam; 2) at the northeast water body (Pleasant Lake area); and 3) mid reservoir. For illustrative purposes, Table 4.1-4 contains an abbreviated set of profile data for the sampling location nearest Loon Lake Dam, although data sets for the other locations are available. Selective sampling locations along the vertical profile have been highlighted in the table to illustrate the shape of the thermal profile.

Reservoir profiling and stream data for Loon Lake Reservoir indicate the reservoir turned over and was isothermal at approximately 12.5 to 14.5°C. These results are consistent with the stream-based water temperature monitoring results, which indicated that Loon Lake Reservoir turned over between mid-September and early October for 2002 and 2004. Water temperatures in water released from Loon Lake Dam in early October 2002 were 13°C, consistent with the bottom temperatures of the reservoir. The Fall 2002 Turnover sampling at Loon Lake Reservoir occurred on October 8, 2002 and September 22, 2004. Similar sampling conducted on October 22, 1980 showed an isothermal 12.0°C water column, which conforms to 2002 data. The 2002 First Major Rain sampling at Loon Lake Reservoir on November 11, 2002, also exhibited an isothermal condition, but the reservoir had cooled to approximately 9°C. The 2004 First Major Rain sampling conducted on November 10, 2004 exhibited a similar trend with an isothermal temperature of 6.7°C throughout the 13.5-meter water column. This is consistent with sampling conducted on November 5, 1999, which showed an isothermal condition of approximately 11°C. The rapid cooling of Loon Lake Reservoir from the point of turnover in late September through the month of November is clearly exhibited in the equally rapid cooling of water emanating from the dam outlet at Gerle Creek.

Table 4.1-4. Loon Lake Reservoir water quality profiles at the sampling site near Loon Lake Dam over seven sampling periods.

Depth (m)	Temperature (ºC)	pH (Units)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (% saturation)	Specific Conductance (µS/cm)
Fall 2002 Turnover (October 8, 2002)					
0.5	13.7	6.98	8.0	96.4	8.4
2	13.6	6.96	8.2	98.6	8.1
4	13.6	6.95	8.2	98.5	8.1
6	13.6	6.90	8.2	98.2	8.1
8	13.6	6.88	8.1	97.6	8.1
10	13.6	6.89	8.1	96.8	8.1
12	13.6	6.83	8.2	98.3	8.3
14	13.6	6.89	8.1	97.6	8.1
16	13.6	6.82	8.1	96.6	8.1
18	13.6	6.84	8.1	97.0	8.1
20	13.6	6.79	8.1	97.4	8.1
2002 First Major Rain (November 11, 2002)					
0.5	9.3	7.43	8.5	97.4	7.8
2	9.2	7.43	8.4	96.2	7.8
4	9.1	7.37	8.3	95.8	7.6
6	9.1	7.34	8.4	95.5	7.6
8	9.1	7.32	8.4	95.5	7.6
10	9.1	7.32	8.4	95.4	7.6
12	9.0	7.34	8.4	93.2	7.7
14	8.9	7.33	8.5	92.4	7.7
16	8.9	7.33	8.5	92.1	7.8
18	8.8	7.31	8.7	91.1	7.7
20	8.8	7.22	8.6	91.2	7.8
2003 Spring Runoff (May 14, 2003)					
0.5	8.2	6.82	12.9	109.6	9
2	7.6	6.82	13.0	108.9	9
4	6.0	6.70	12.4	100.0	9
6	5.9	6.80	13.3	106.2	9
8	5.6	6.76	13.2	104.7	9
10	5.5	6.71	12.6	99.8	9
12	5.5	6.78	12.7	101.0	9
Summer 2003 Low Flow (September 16, 2003)					
0.5	17.0	6.65	8.7	90.1	9
2	17.0	6.66	8.8	91.2	9
4	17.	6.66	8.7	90.2	9
6	17.0	6.65	8.7	90.3	9
8	17.0	6.66	8.7	90.3	9
10	17.0	6.64	8.7	90.2	9
12	16.9	6.64	8.7	89.8	9
14	16.9	6.63	8.7	89.8	9
16	16.9	6.63	8.8	90.9	9

Table 4.1-4. Loon Lake Reservoir water quality profiles at the sampling site near Loon Lake Dam over seven sampling periods.

Depth (m)	Temperature (ºC)	pH (Units)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (% saturation)	Specific Conductance (µS/cm)
2004 Spring Runoff (May 6, 2004)					
0.5	8.4	6.23	10.3	87.7	7
2	8.3	6.18	10.2	86.5	7
4	8.3	6.15	10.1	86.1	7
6	8.3	6.14	10.1	86.0	7
8	7.8	6.16	10.2	85.7	7
10	7.3	6.18	10.3	85.3	7
12	7.1	6.16	10.3	85.1	8
14	6.9	6.16	10.3	84.7	8
16	6.6	6.15	10.4	84.6	8
18	6.5	6.15	10.4	84.5	8
20	5.8	6.36	10.4	83.1	8
2004 Summer Low Flow (September 22, 2004)					
0.5	14.9	7.46	6.9	68.7	8
2	14.8	7.41	7.0	68.7	9
4	14.8	7.35	7.0	68.7	9
6	14.8	7.33	7.0	68.8	9
8	14.8	7.31	7.0	68.8	9
10	14.7	7.29	7.0	68.8	9
12	14.7	7.27	7.0	68.8	9
14	14.7	7.28	7.0	68.8	9
16	14.7	7.29	7.0	68.8	9
18	14.7	7.36	7.0	69.0	9
2004 Fall Turnover/First Major Rain (November 10, 2004)					
0.5	6.7	7.42	9.6	78.4	9
2	6.7	7.44	9.6	78.4	9
4	6.7	7.40	9.6	78.5	9
6	6.7	7.36	9.7	78.9	9
8	6.7	7.29	9.6	78.2	9
10	6.7	7.23	9.5	77.9	9
12	6.7	7.18	9.4	76.6	9
14	6.8	7.12	9.8	80.0	9

Secchi depth readings near Loon Lake Dam during the 2002 Fall Turnover, First Major Rain, 2003 Spring and Summer Low Flow sampling events were 13.25, 14.5, 11, and 8 meters, respectively. Readings during the 2004 Spring Runoff, Summer Low Flow and Fall Turnover/First Major Rain were 8.0, 13.0, and 10.2 meters, respectively.

During the 2003 Spring Runoff Sampling that occurred on May 14, 2003, at Loon Lake Reservoir, the reservoir was beginning to exhibit the signs of developing stratification. Water temperatures at the surface of the reservoir were near 8°C, while bottom water temperatures were

5.5°C. Further development of the stratification is exhibited in the data of the historic record. On June 5, 2000, Loon Lake Reservoir had developed a weak stratification with a surface water temperature of approximately 14°C and bottom temperature of 8°C. A similar stratification was observed on June 4, 1996. Stream temperature sensor data from 2001 through 2004 support this observation. Beginning in May of each year, the reservoir begins to slowly increase its hypolimnion layer temperature from a static 2°C to a maximum of 15 – 16.5°C around October 1 each year.

The 2003 Summer Low Flow sampling at Loon Lake Reservoir occurred on September 16, 2003 and September 22, 1004. By this time, the reservoir had nearly completely turned over and was isothermal at approximately 17°C. This finding is again consistent with the stream-based water temperature sampling during the same time period, and with the findings of temperature profile studies conducted on September 17, 1996, when the lake was isothermal at 16.5°C.

4.1.5 Gerle Creek Reservoir

4.1.5.1 Historic Information

Historic reservoir profiling was conducted by SMUD at two locations in Gerle Creek Reservoir in November 1999 and June 2000. In November 1999, water temperature profiles in the reservoir were isothermal at approximately 10°C. Gerle Creek Reservoir water temperature profiles reflected slight surface warming in the shallow center of the reservoir, but the deeper section near the dam exhibited a constant temperature with depth (up to 33 feet deep) of 10.5°C. The lake of surface warming at near the reservoir dam may be due to the fact that Loon Lake Powerhouse tailrace enters the reservoir directly adjacent to the dam, such that potential turbulence and short residence time of this water results in limited or no surface warming.

4.1.5.2 Relicensing Water Temperature Profiling

Water quality profile measurements obtained during the relicensing studies at Gerle Creek Reservoir is available from data collected during the following sample periods:

- 2002 Fall Turnover
- 2002 First Major Rain
- 2003 Spring Runoff
- 2003 Summer Low Flow
- 2004 Spring Runoff
- 2004 Summer Low Flow
- 2004 First Major Rain/Fall Turnover

The results of the relicensing temperature profile studies for Gerle Creek Reservoir, conducted in 2002 – 2004 over seven sampling events mid-reservoir, generally showed thermal conditions similar to those observed in the historical data (Table 4.1-5). The survey conducted during the 2002 Fall Turnover showed a slight differential in water temperatures (1.5°C) between the surface and bottom of the reservoir. By November 2002, Gerle Creek Reservoir was isothermal throughout the water column at 7.6°C. At the 2003 Spring Runoff sampling period, Gerle Creek Reservoir exhibited a slight difference in water temperature (2.5°C), but at the Summer 2003 Low Flow sampling period, the reservoir was isothermal at 16.5°C. Similar trends were observed for the 2004 sampling season. Spring Runoff sampling showed a 2°C difference between hypolimnion and bottom of the reservoir; Summer Low Flow sampling showed a 1.4°C difference; First Major Rain sampling showed no difference in reservoir profile temperature (6.9°C).

Table 4.1-5. Gerle Creek Reservoir water quality profiles at the sampling site located in the center of the reservoir, over seven sampling periods.

Depth (m)	Temperature (ºC)	pH (Units)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (% saturation)	Specific Conductance (µS/cm)
2002 Fall Turnover (October 8, 2002)					
0.5	14.4	7.12	7.7	75.4	12.1
2	14.0	7.08	7.9	76.4	12.1
4	13.7	6.85	8.1	77.9	12.3
6	13.3	6.84	7.8	74.6	11.7
8	12.9	6.79	7.7	72.6	11.7
2002 First Major Rain (November 11, 2002)					
0.5	7.7	7.34	9.4	77.7	10.3
2	7.7	7.38	9.4	77.5	10.3
4	7.6	7.31	9.4	78.8	10.3
6	7.7	7.35	9.3	77.3	10.1
8	7.7	7.32	9.4	79.7	10.3
2003 Spring Runoff (May 14, 2003)					
0.5	7.5	6.77	10.9	90.7	10
2	6.9	6.68	10.8	88.5	11
4	6.0	6.72	10.9	87.3	12
6	5.4	6.66	10.4	82.7	10
8	5.2	6.66	10.9	85.7	10
2003 Summer Low Flow (September 18, 2003)					
0.5	16.9	6.68	10.4	99.9	10
2	16.7	6.68	10.4	99.8	10
4	16.6	6.71	10.6	101.4	10
6	16.6	6.70	10.6	101.4	10
8	16.2	6.66	10.6	100.0	10
2004 Spring Runoff (May 6, 2004)					
0.5	10.5	7.25	10.7	95.5	7
2	10.2	7.17	10.8	95.7	7
4	8.2	7.10	11.4	96.5	7
2004 Summer Low Flow (September 15, 2004)					
0.5	17.2	7.09	10.6	110.3	11
2	17.0	7.11	10.8	111.6	11
4	16.8	7.09	11.85	122.3	11

Table 4.1-5. Gerle Creek Reservoir water quality profiles at the sampling site located in the center of the reservoir, over seven sampling periods.

Depth (m)	Temperature (ºC)	pH (Units)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (% saturation)	Specific Conductance (µS/cm)
6	16.5	7.03	11.2	114.8	13
8	16.1	7.01	11.0	112.0	15
10	15.8	7.01	11.3	114.2	12
2004 First Major Rain/Fall Turnover (November 10, 2004)					
0.5	6.9	7.01	11.2	91.9	12
2	6.9	6.95	11.2	91.6	12
4	6.9	6.89	11.2	91.8	12
6	6.9	6.84	11.1	91.2	12

Secchi depth readings during the 2002 Fall Turnover, 2002 First Major Rain, 2003 Spring Runoff and 2003 Summer Low Flow sampling events were 8.25 (on the bottom), 4.5, 9, and 8.4 meters, respectively. Readings during the 2004 Spring Runoff, Summer Low Flow and Fall Turnover/First Major Rain 4.0 (on the bottom), 8.0 and 6.2 meters, respectively.

4.1.6 Robbs Peak Reservoir

As discussed above, reservoir profiling was not conducted in Robbs Peak Reservoir due to the limited storage and retention time associated with its small size (30 ac-ft). SMUD is unaware of any historic water temperature profiling in Robbs Peak Reservoir.

4.1.7 Ice House Reservoir

4.1.7.1 Historic Information

Historic limnological investigations of Ice House Reservoir were conducted by the California Department of Fish and Game (CDFG) in 1961 (Nicola and Borgeson 1970) and shortly after Ice House Dam construction, by Ecological Analysts in July and September 1980 (EA, Inc. 1980). Other investigations were conducted by the USGS in 1996, and by SMUD in 1999 and 2000 (Tetra Tech 2000a and Tetra Tech 2000b). CDFG also collected limited data in 1961 during one-to-two-week intervals throughout the summer. Nicola and Borgeson found that surface water temperature in Ice House Reservoir was highest in July and August. A thermocline, ranging from a depth of 15 to 60 feet, formed in June and persisted through early October. Mean monthly Secchi disk readings ranged from about 20 to 30 feet.

Ecological Analysts conducted reservoir profiling in Ice House Reservoir at three locations in July and September 1980, and SMUD did profiling at four locations in November 1999 and June 2000. These data show that at over 110 feet maximum depth, Ice House Reservoir is a relatively deep reservoir, and strong stratification occurs at the deeper sampling locations. A temperature profile in June 2000 was similar to that described above for Loon Lake Reservoir, although surface temperatures were warmer at Ice House Reservoir (17°C to 19°C vs. 14°C) and bottom temperatures colder (7°C vs. 8°C). The June 2000 data are nearly identical to those of July 1980 and June 1996, when surface water temperatures averaging 18.7°C across three sampling stations and bottom temperatures were 7°C. These data also agree with the June data from the 1960s (Nicola and Borgeson 1970), which exhibited epilimnetic water temperatures of approximately 20°C and bottom temperatures of 7°C. All historical information for this reservoir is presented in Appendix A.

Other water temperature data were collected at Ice House Reservoir as part of a 7-year monitoring study conducted shortly after construction of Ice House Dam (Livesay 1972). Between the years 1963-1969, weekly *in situ* temperature measurements were taken in the epilimnion of Ice House Reservoir (at surface, 3 feet, and 6 feet below surface) over a 14-week period from June through September. Temperature measurements were taken roughly between 9:00 am and noon throughout the study period. Recorded temperatures typically ranged from a low of 15°C to 16°C to a high of 20°C to 21°C, with the maximum temperatures occurring in August of most years. The warmest temperatures recorded occurred in 1964, reaching a maximum of 23°C in the first week of August.

4.1.7.2 Relicensing Water Temperature Profiling

Water quality profile measurements obtained during the relicensing studies at Ice House Reservoir is available from data collected during the following sample periods:

- 2002 Fall Turnover
- 2002 First Major Rain
- 2003 Spring Runoff
- 2003 Summer Low Flow
- 2004 Spring Runoff
- 2004 Summer Low Flow
- 2004 First Major Rain
- 2004 Fall Turnover

The relicensing water temperature profiling at Ice House Reservoir, began on October 1, 2002, in keeping with the water quality study plan, which called for sampling after Ice House Reservoir had turned over and was mixed. The sampling site adjacent to the reservoir dam was selected to evaluate the timing of mixing at Ice House Reservoir. Because the reservoir was clearly stratified and had not turned over on October 1, 2002, subsequent water temperature profile information was collected at Ice House Reservoir on a roughly weekly basis through the fall of 2002 to determine when mixing occurred. Appendix A contains a graph of the steady change in the thermal profile of Ice House Reservoir during the weeks leading up to turnover. The data from this progressive sampling regime show a reservoir that maintains a well-defined epilimnion and hypolimnion separated by a sharp thermocline throughout September and into October. This thermal profile dynamic observed in the fall of 2002 and 2004 is supported by the historical record, in particular the data from October 1970 and November 5, 1999, which also show a stratified reservoir late into the fall. The stream-based water temperature data show that Ice House Reservoir mixes in later November or early December each year.

In addition to the turnover sampling, Ice House Reservoir was also sampled consistently with the water quality seasonal sampling regime. All relicensing temperature profiles at each of the three sampling sites within Ice House Reservoir for the different seasons are contained in Appendix A. For illustrative purposes in this discussion, Table 4.1-6 has been developed that contains an abbreviated set of profile data for the sampling location near the reservoir dam. Selective sampling locations (every two meters) along the vertical profile have been highlighted in the table to illustrate the shape of the thermal profile.

From the data presented in Table 4.1-6, Ice House Reservoir mixes beginning in early December, continuing to mix for the following 3-4 weeks until isothermal conditions of approximately 8.3°C are reached. This is consistent with the water temperature data recorded from Ice House Reservoir Dam. The quick drop in outlet water temperatures from 8°C to 4°C in approximately one month suggests that Ice House Reservoir cools quickly in the isothermal condition, dropping to a low value of 4°C. As the reservoir gradually warms in the spring, it begins to stratify with a well-developed thermal profile evident in the 2003 Spring Runoff sampling period data of June 12, 2003. By this time, the epilimnion temperatures are near 18°C and the hypolimnetic water is near 7°C. These conditions are in keeping with the historical record, as described in Section 4.1.7.1. By the 2003 Summer Low Flow Period (September 18, 2003), the surface water temperatures are still near 18°C, but the depth of the epilimnion has increased. Hypolimnetic water temperatures remain at 7°C, which is corroborated by the data of 1970 and by the fact that throughout the summers of 2001-2003 water temperatures emanating from Ice House Reservoir were a constant at 7°C. The constant release of 7°C water is only interrupted by reservoir turnover.

Table 4.1-6. Ice House Reservoir water quality profiles at the sampling site located near the reservoir dam, over nine sampling periods (including stratified and mixed conditions in 2002).

Depth (m)	Temperature (ºC)	pH (Units)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (% saturation)	Specific Conductance (µS/cm)
2002 Fall Turnover (stratified) (October 16, 2002)					
0.5	15.0	6.81	8.0	95.1	9.7
2	15.0	6.77	8.1	95.7	9.5
4	15.0	6.69	8.1	95.3	9.5
6	15.0	6.75	8.1	94.7	9.7
8	14.9	6.65	7.99	93.9	9.4
10	14.9	6.57	8.0	94.1	9.7
12	14.8	6.41	7.9	93.0	9.7
14	14.8	6.34	7.78	91.4	9.5
16	14.5	6.09	7.1	83.5	9.5
18	8.7	6.04	5.6	58.0	10.5
20	7.6	6.03	4.9	49.0	11.2
22	7.3	6.04	4.9	48.5	11.1
24	7.1	6.11	4.4	44.3	11.4
26	6.9	6.07	4.8	47.0	11.6
28	6.9	6.22	3.8	37.3	11.9
30	6.9	6.13	3.5	33.8	12.4

Table 4.1-6. Ice House Reservoir water quality profiles at the sampling site located near the reservoir dam, over nine sampling periods (including stratified and mixed conditions in 2002).

Depth (m)	Temperature (ºC)	pH (Units)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (% saturation)	Specific Conductance (µS/cm)
2002 Fall Turnover (mixed) (November 26, 2002)					
0.5	8.3	7.05	9.6	97.4	10.0
2	8.3	6.96	9.6	97.9	10.0
4	8.3	6.99	9.6	98.0	10.0
6	8.3	6.95	9.6	99.0	9.8
8	8.4	6.96	9.6	98.0	10.0
10	8.4	7.01	9.9	98.8	10.0
12	8.3	6.95	9.6	97.6	10.0
14	8.3	7.04	9.4	95.2	10.0
16	8.3	6.93	9.7	98.3	9.9
18	8.3	6.95	9.7	98.3	9.7
20	8.3	6.97	9.7	98.5	9.8
22	8.3	7.05	9.68	98.4	9.7
24	8.3	6.94	9.6	97.6	9.7
26	8.3	6.86	9.3	96.6	10.0
28	8.3	6.94	9.5	96.8	9.7
2002 First Major Rain (November 14, 2002)					
0.5	9.7	6.87	9.3	97.8	9.8
2	9.7	6.78	9.2	97.6	9.8
4	9.7	6.77	9.2	97.5	9.8
6	9.7	6.75	9.2	97.4	9.8
8	9.7	6.77	9.2	97.0	9.8
10	9.7	6.75	9.3	98.0	9.8
12	9.7	6.75	9.3	98.0	9.8
16	9.7	6.60	8.9	93.6	9.8
18	9.5	6.58	8.7	91.7	10.0
20	9.6	6.51	8.3	87.5	9.8
22	8.0	6.28	5.0	50.2	12.1
24	7.25	6.34	4.6	45.5	12.0
26	7.0	6.35	4.0	39.2	12.8
28	7.0	6.36	4.0	39.7	12.8
30	6.90	6.36	3.1	30.7	14.0
2003 Spring Runoff (June 12, 2003)					
0.5	18.2	7.31	7.5	79.2	12
2	18.8	7.21	7.82	84.0	11
4	18.8	7.19	7.8	84.2	11
6	14.2	7.21	9.2	89.3	11
8	11.8	7.22	9.8	90.6	10
10	10.3	7.20	10.5	93.3	10
12	9.14	7.17	10.72	93.1	11
14	8.15	7.12	11.0	93.3	11
16	7.5	7.07	11.1	92.5	11
18	18.1	7.01	11.1	91.3	11
20	6.5	6.94	11.1	90.0	11

Table 4.1-6. Ice House Reservoir water quality profiles at the sampling site located near the reservoir dam, over nine sampling periods (including stratified and mixed conditions in 2002).

Depth (m)	Temperature (ºC)	pH (Units)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (% saturation)	Specific Conductance (µS/cm)
22	6.3	6.89	10.9	88.1	12
24	6.17	6.84	10.7	86.2	12
26	6.1	6.8	10.5	84.6	12
28	6.1	6.8	10.3	83.2	12
30	6.0	6.76	10.2	82.1	12
32	6.0	6.73	10.1	81.1	12
34	6.0	6.71	10.0	80.3	12
Summer 2003 Low Flow (September 18, 2003)					
0.5	18.9	7.00	9.9	106.2	11
2	18.9	7.00	9.9	106.3	11
4	18.7	7.00	9.9	106.4	11
6	18.4	6.99	10.0	106.1	11
8	18.3	6.99	10.0	105.9	11
10	18.3	6.98	10.0	105.7	11
12	13.6	6.92	11.3	108.4	10
14	11.8	6.74	11.9	109.8	10
16	9.2	6.58	12.5	108.5	11
18	7.3	6.39	12.1	100.3	12
20	7.1	6.28	10.4	86.1	13
2004 Spring Runoff (May 11, 2004)					
0.5	13.2	6.75	9.7	92	10
2	13.2	6.72	9.5	90.9	10
4	12.9	6.64	9.5	90.5	10
6	10.0	6.74	10.3	91.0	10
8	9.4	6.87	10.4	91.0	10
10	8.2	6.89	10.8	92.1	10
12	7.3	6.81	11.1	92.4	10
14	6.8	6.75	11.3	92.4	10
16	6.4	6.67	11.2	91.2	10
18	6.3	6.61	11.0	89.4	10
20	6.2	6.56	11.0	88.5	10
22	6.1	6.51	10.8	87.0	10
24	6.1	6.47	10.7	86.2	10
26	6.1	6.45	10.6	85.4	10
28	6.0	6.40	10.5	84.4	10
30	6.0	6.39	10.4	83.5	10
32	6.0	6.56	9.9	79.2	10
2004 Summer Low Flow (September 20, 2004)					
0.5	17.5	7.38	7.7	80.2	11
2	17.4	7.38	7.7	80.0	11
4	17.3	7.37	7.6	79.4	11
6	17.3	7.31	7.6	78.8	11
8	17.3	7.26	7.4	77.1	11
10	17.2	7.21	7.2	74.4	11

Table 4.1-6. Ice House Reservoir water quality profiles at the sampling site located near the reservoir dam, over nine sampling periods (including stratified and mixed conditions in 2002).

Depth (m)	Temperature (ºC)	pH (Units)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (% saturation)	Specific Conductance (µS/cm)
12	17.2	7.02	6.5	67.1	11
14	15.6	6.96	5.2	52.1	10
16	9.5	6.95	4.9	43.2	11
18	7.5	6.94	4.9	40.6	12
20	7.0	6.96	4.8	39.1	12
22	6.9	6.96	4.5	37.2	12
24	6.8	6.99	4.2	34.7	12
26	6.7	7.02	3.9	31.8	13
28	6.7	7.09	4.0	32.9	14
2004 First Major Rain (November 1, 2004)					
0.5	11.0	6.77	8.1	73.2	11
2	10.4	6.74	8.2	72.9	11
4	10.2	6.67	8.1	72.1	11
6	10.2	6.68	8.0	71.5	11
8	10.1	6.71	7.9	70.4	11
10	10.1	6.63	7.6	67.7	11
12	10.1	6.58	7.3	64.3	11
14	10.1	6.53	6.4	56.9	11
16	10.1	6.47	5.4	48.2	11
18	10.0	6.45	4.1	35.8	12
20	9.74	6.46	3.2	28.6	12
22	7.37	6.51	3.9	32.3	14
24	7.25	6.65	4.7	38.6	15
2004 Fall Turnover (December 1, 2004)					
0.5	10.8	7.00	10.0	89.7	8
2	10.5	6.87	9.2	82.3	8
4	10.4	6.85	9.2	82.4	8
6	10.3	6.83	9.1	80.8	8
8	10.3	6.80	8.9	79.6	8
10	10.2	6.74	9.0	79.6	8
12	10.2	6.72	8.9	78.7	8
14	10.1	6.67	8.7	77.8	8
16	10.1	6.51	8.6	76.6	8
18	10.0	6.49	8.6	75.9	8
20	10.0	6.46	8.6	75.6	8
22	8.6	6.46	9.0	76.7	9
24	7.5	6.53	9.2	76.9	9
26	7.3	6.59	9.0	74.3	9

Secchi depth readings near Ice House Dam during the 2002 Fall Turnover, 2003 Spring and Summer Low Flow sampling events were 5.25, 9, 7.6 meters, respectively. Readings during the 2004 Spring Runoff, Summer Low Flow, First Major Rain and Fall Turnover sampling events were 6.0, 6.8, 7.0 and 6.8 meters, respectively.

4.1.8 Union Valley Reservoir

4.1.8.1 Historic Information

Historic limnological investigations of Union Valley Reservoir were conducted by the California Department of Fish and Game (CDFG) in 1961 (Nicola and Borgeson 1970) shortly after Ice House Dam construction, by Ecological Analysts in 1980, by the USGS in 1996, and by SMUD in 1999 and 2000 (Tetra Tech 2000). The thermal profile data of June 2000 and July 1980 demonstrate strong summer stratification, with surface temperatures between 17°C and 18°C and bottom temperature of 7°C, a range of temperatures that is nearly identical to that observed at Ice House Reservoir. Despite the separation of the sampling efforts by 20 years, the shapes of the temperature profiles were similar in June and July. In each case, the epilimnion was about 20 feet deep, followed by a distinct metalimnion where temperatures dropped approximately 10°C within 40 feet. The data of September 1980 indicated a warming of the reservoir, with a deeper epilimnion at 20°C. In November 1999, Union Valley Reservoir was isothermal at 14.5°C.

4.1.8.2 Relicensing Water Temperature Profiling

Water quality profile measurements obtained during the relicensing studies at Union Valley Reservoir is available from data collected during the following sample periods:

- 2002 Fall Turnover
- 2002 First Major Rain
- 2003 Spring Runoff
- 2003 Summer Low Flow
- 2004 Spring Runoff
- 2004 Summer Low Flow
- 2004 Fall Turnover/ First Major Rain

The relicensing water temperature profiling at Union Valley Reservoir began on October 1, 2002, in accordance with the Water Quality Study Plan, which called for sampling after Union Valley Reservoir was no longer stratified and had turned over. The sampling site adjacent to Union Valley Reservoir Dam was selected to evaluate the timing of turnover at the reservoir. Because the reservoir was strongly stratified on October 1, subsequent water temperature profile information was collected at Union Valley Reservoir on a roughly weekly basis. Appendix A contains a graph of the steady change in the thermal profile of Union Valley Reservoir during the weeks leading up to turnover. The data from this progressive sampling regime show a reservoir that maintains an epilimnion and hypolimnion through the fall. The thermocline is gradual, not sharply defined as in Ice House Reservoir. As the weekly sampling progressed during the fall of 2002, the epilimnion cooled and deepened. On October 1, 2002, the epilimnion was 18°C and approximately 17 meters deep. In contrast, the epilimnion was 12°C and approximately 57 meters deep on November 11. In essence, by November 11, 2002, Union Valley Reservoir had mixed throughout much of the reservoir, except for a small pool in the deepest portion of the reservoir. Water temperature profiling on November 8, 1999 showed essentially isothermal condition to 140 ft (43 m) at approximately 14.5°C. This is approximately 1°C warmer than recorded on November 6, 2002. Profiles taken during the 2004 First Major Rain event showed about 1°C difference from surface temperature (12.9°C) to a depth of nearly 50 meters (11.83°C).

In addition to the turnover sampling, Union Valley Reservoir was also sampled consistent with the water quality seasonal sampling regime. All relicensing temperature profiles at each of the four sampling sites within Union Valley Reservoir for the different seasons are contained in Appendix A. For illustrative purposes in this discussion, Table 4.1-7 has been developed with an abbreviated set of profile data for the sampling location nearest the reservoir dam. Selective sampling locations along the vertical profile have been highlighted in the table to illustrate the shape of the thermal profile.

From the data presented in Table 4.1-7, Union Valley Reservoir mixes in mid-November under isothermal conditions of approximately 11°C or 12°C. The November 14, 2002, profile does exhibit a small cool hypolimnion below 60 meters. Once the reservoir is fully mixed, it cools down through the winter as does other project reservoirs. As Union Valley Reservoir gradually warms in the spring, it begins to stratify with a developing thermal profile evident in the 2004 and 2003 Spring Runoff sampling period data of May 5, 2004 and May 7, 2003. At this sampling period, the developing epilimnion exhibited temperatures of approximately 13.2 and 8°C respectively, while the hypolimnetic water is near 5°C. As discussed in Section 4.1.8.1, Union Valley Reservoir develops a more well-defined stratification in June and July. During these mid-summer months, Union Valley Reservoir develops a relatively shallow (5 meter) epilimnion of 17°C and deep (60 meter) hypolimnion of 6°C. By the 2004 and 2003 Summer Low Flow Period (September 14 2004 and September 18, 2003 respectively), the surface water temperatures warmed to about19.5°C and deepened to 18 meters. The thermocline between the epilimnion and hypolimnion was indistinct on September 18, but very closely paralleled the thermal profile observed on October 1, 2002.

Table 4.1-7. Union Valley Reservoir water quality profiles at the sampling site located in the middle of the reservoir, near the dam, over six sampling periods.

Depth (m)	Temperature (ºC)	pH (Units)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (% saturation)	Specific Conductance (µS/cm)
Fall 2002 Turnover (stratified) (October 16, 2002)					
0.5	16.4	6.93	7.9	80.9	11.8
10	16.2	6.77	7.9	80.4	11.8
20	16.1	6.64	7.8	78.8	11.8
26	14.6	6.28	6.2	60.5	11.6
30	13.4	6.31	6.00	57.4	11.6
36	12.1	6.34	6.2	57.4	11.7
40	11.0	6.38	6.20	56.2	11.5
46	10.3	6.44	6.2	55.0	11.5
50	9.7	6.56	5.3	46.7	12.1
56	9.5	6.62	6.8	59.3	12.4
60	7.9	7.11	5.8	48.1	12.7
66	6.3	7.27	5.6	44.9	13.6

Table 4.1-7. Union Valley Reservoir water quality profiles at the sampling site located in the middle of the reservoir, near the dam, over six sampling periods.

Depth (m)	Temperature (ºC)	pH (Units)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (% saturation)	Specific Conductance (µS/cm)
2002 First Major Rain (November 14, 2002)					
0.5	12.4	6.95	7.64	71.4	12.0
10	12.1	6.96	7.60	70.5	11.9
20	12.1	6.89	7.43	68.9	12.1
30	11.9	6.89	7.45	68.9	12.3
40	11.5	7.05	7.67	70.2	12.4
50	11.2	6.82	7.75	70.5	12.3
56	11.0	6.54	5.63	53.7	12.4
60	6.9	6.52	4.29	35.2	13.5
70	6.1	7.02	3.82	30.7	14.2
2003 Spring Runoff (May 7, 2003)					
0.5	7.9	7.92	9.6	80.6	13
6	7.6	7.68	9.5	79.4	14
10	6.9	6.89	9.0	74.2	14
16	6.1	6.80	9.00	72.5	14
20	5.9	7.35	9.6	77.0	14
30	5.5	6.75	9.1	71.9	14
40	5.4	6.74	9.1	71.6	14
50	5.4	6.99	9.1	72.0	14
54	5.3	6.83	9.0	70.7	14
Summer 2003 Low Flow (September 18, 2003)					
0.5	19.5	6.52	9.2	100.5	13
10	19.4	6.35	8.7	94.4	13
16	17.9	6.09	7.9	82.7	13
20	15.8	6.05	8.2	82.8	13
26	13.3	6.04	8.9	84.9	13
30	11.8	6.04	9.3	85.4	13
36	10.5	6.03	9.5	84.9	13
40	9.9	6.16	9.9	87.2	13
46	9.0	6.06	9.4	80.9	13
50	8.6	6.06	9.1	77.5	14
56	8.2	6.04	10.2	86.6	14
2004 Spring Runoff (May 5, 2004)					
0.5	13.2	7.11	10.1	95.9	12
5	11.8	6.95	10.5	96.7	12
10	9.6	6.91	10.9	95.4	12
15	8.3	6.85	11.0	93.6	12
20	7.3	6.78	11.0	91.5	12
25	6.4	6.70	10.8	87.6	12
30	6.1	6.65	10.7	85.8	12
35	5.8	6.60	10.5	83.9	12
40	5.6	6.55	10.5	82.8	12
46	5.4	6.53	10.5	82.8	12

Table 4.1-7. Union Valley Reservoir water quality profiles at the sampling site located in the middle of the reservoir, near the dam, over six sampling periods.

Depth (m)	Temperature (ºC)	pH (Units)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (% saturation)	Specific Conductance (µS/cm)
50	5.3	6.48	10.4	78.2	12
55	5.1	6.70	10.0	78.2	13
2004 Summer Low Flow (September 14, 2004)					
0.5	19.7	7.51	10.1	110.0	13
5	19.5	7.48	10.0	109.0	14
10	19.5	7.44	10.4	113.0	13
15					
20	17.0	7.18	9.3	96.5	13
25					
30	13.4	7.13	8.1	78.4	13
35					
40	11.7	7.13	7.6	70.1	13
45	11.3	7.20	7.4	67.8	16
2004 Fall Turnover/First Major Rain (November 8, 2004)					
0.5	12.9	6.74	8.9	84.0	13
5	12.9	6.65	8.9	84.1	13
10	12.9	6.58	8.8	83.1	13
15	12.8	6.53	8.8	82.3	13
20	12.8	6.47	8.7	82.0	13
25	12.6	6.32	8.7	81.5	13
30	12.4	6.27	8.7	81.4	13
35	12.3	6.12	8.6	80.6	13
40	12.0	5.98	8.7	80.9	13
45	11.9	5.80	8.8	81.5	13
50	11.8	5.75	8.7	80.4	13

Secchi depth readings in the middle of Union Valley Reservoir during the 2002 Fall Turnover, First Major Rain, 2003 Spring Runoff and Summer Low Flow sampling events were 5.0, 6.0, 6.0, and 8.4 meters, respectively. Readings during the 2004 Spring Runoff, Summer Low Flow and Fall Turnover/First Major Rain sampling events were 6.6, 6.0, and 5.4 meters, respectively.

4.1.9 Junction Reservoir

4.1.9.1 Historic Information

SMUD conducted water quality profiling at five locations in Junction Reservoir in November 1999 and June 2000 (reservoir elevation of 4,429 and 4,441 feet, respectively). Stratification was evident during June 2000, but the epilimnion was very shallow and temperatures decreased sharply below approximately 15 feet. Surface temperatures approached 19°C, approximately 10°C warmer than observed in November 1999. Bottom temperatures (maximum depth of about 110 feet) were approximately 7°C.

4.1.9.2 Relicensing Water Temperature Profiling

Water quality profile measurements obtained during the relicensing studies at Junction Reservoir is available from data collected during the following sample periods:

- 2002 Fall Turnover
- 2002 First Major Rain
- 2003 Spring Runoff
- 2003 Summer Low Flow
- 2004 Spring Runoff
- 2004 Summer Low Flow
- 2004 Fall Turnover/ First Major Rain

The sampling time for Junction Reservoir was predicated on the fall turnover of Union Valley Reservoir. As discussed in Section 4.1.8.2, Union Valley Reservoir was largely mixed at the time of the 2002 first major rain event, in mid-November 2002. Hence, Junction Reservoir was sampled on November 14, 2002, as part of a 2002 Turnover/First Major Rain event and on November 8, 2004 for the same seasons. All relicensing temperature profiles at Junction Reservoir for the different seasons are contained in Appendix A. For illustrative purposes in this discussion, Table 4.1-8 has been developed with an abbreviated set of profile data for the sampling location in the middle of the reservoir. Selective sampling locations along the vertical profile have been highlighted in the table to illustrate the shape of the thermal profile.

The thermal profile of Junction Reservoir on November 14 2002 showed a reservoir of near isothermal conditions, with a surface water temperature of 11.5°C and bottom temperature of 9.5°C. This profile compares to one of November 7, 1999, when temperatures ranged from approximately 9°C to 8°C. Junction Reservoir likely cooled down through the winter similar to other UARP reservoirs, then warmed in spring leading to a stratified reservoir on May 5, 2003. The stratification on May 15 exhibited a shallow epilimnion of 2 meters at 10.5°C, a sharp thermocline, and a deep epilimnion of 24 meters at 6°C. A similar profile was observed in June of 2000. The Summer 2003 Low Flow sampling period showed a shallow epilimnion, but warmer hypolimnion of approximately 9°C.

Table 4.1-8. Junction Reservoir water quality profiles at the sampling site located in the middle of the reservoir, over six sampling periods.

Depth (m)	Temperature (°C)	pH[9] (Units)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (% saturation)	Specific Conductance (µS/cm)
2002 Fall Turnover/First Major Rain (November 14, 2002)					
0.5	11.5	6.6	7.2	66.8	11.6
2	10.8	-	7.4	68.4	11.3

---

[9] pH was taken with a hand-held meter at the surface and retrieved water from mid-column.

Table 4.1-8. Junction Reservoir water quality profiles at the sampling site located in the middle of the reservoir, over six sampling periods.

Depth (m)	Temperature (°C)	pH[9] (Units)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (% saturation)	Specific Conductance (µS/cm)
6	10.5	-	7.5	66.7	11.1
10	10.4	6.6	7.2	64.1	11.1
12	9.8	-	7.8	68.9	11.8
14	9.6	-	7.8	68.0	12.0
16	9.6	-	7.6	67.0	12.0
20	9.5	-	6.7	67.1	12.0
2003 Spring Runoff (May 13, 2003)					
0.5	10.5	7.16	8.9	79.4	19
2	9.8	8.83	9.7	85.5	18
6	6.7	8.46	10.2	83.4	16
8	6.0	7.17	9.7	77.8	14
10	6.0	8.27	10.1	81.3	14
16	5.8	8.04	9.9	79.2	14
18	5.8	7.28	9.8	77.9	14
20	5.7	7.31	9.8	77.9	14
28	5.7	7.74	9.8	78.3	14
2003 Summer Low Flow (September 16, 2003)					
0.5	11.5	6.61	11.7	107.3	15
2	9.7	6.61	12.5	109.8	14
6	9.2	6.56	12.5	108.6	14
8	9.	6.51	12.3	106.4	14
10	8.8	6.42	11.9	102.7	14
16	8.5	6.33	11.4	97.2	14
20	8.5	6.31	11.3	96.3	14
26	8.4	6.26	11.0	93.9	14
28	8.4	6.24	10.9	93.2	14
2004 Spring Runoff (May 5, 2004)					
0.5	14.6	6.75	9.1	89.0	16
2	13.7	6.75	9.2	89.0	15
4	10.6	6.75	10.1	90.8	15
6	8.8	6.73	10.5	90.6	14
8	8.3	6.72	10.5	89.0	14
10	7.8	6.73	10.6	88.7	13
12	7.4	6.70	10.5	87.8	13
14	7.2	6.68	10.5	87.2	13
16	7.1	6.64	10.5	86.8	13
18	7.1	6.59	10.5	86.5	13
20	7.0	6.54	10.5	86.2	13
22	6.8	6.50	10.5	86.0	13
24	6.6	6.47	10.6	86.0	13

Table 4.1-8. Junction Reservoir water quality profiles at the sampling site located in the middle of the reservoir, over six sampling periods.

Depth (m)	Temperature (ºC)	pH[9] (Units)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (% saturation)	Specific Conductance (µS/cm)
2004 Summer Low Flow (September 14, 2004)					
0.5	12.1	6.94	4.4[10]	40.9[12]	14
2	10.3	6.92	4.1	36.9	14
4	9.6	6.88	3.8	33.3	13
6	9.4	6.88	3.8	33.5	13
8	9.4	6.87	3.8	33.2	13
10	9.4	6.87	3.8	33.8	13
12	9.4	6.85	3.8	32.9	13
14	9.3	6.83	3.7	32.4	13
16	9.3	6.79	3.7	32.6	13
18	9.3	6.78	3.7	32.3	14
20	9.3	6.77	3.6	31.7	14
22	9.3	6.75	3.6	31.2	14
24	9.2	6.74	3.5	30.6	14
26	9.2	6.77	3.5	30.3	14
28	9.2	6.78	3.5	30.2	14
30	9.1	6.79	3.4	29.6	14
2004 Fall Turnover/First Major Rain (November 8, 2004)					
0.5	11.4	6.69	9.5	86.1	14
2	11.4	6.65	9.4	86.1	14
4	11.3	6.52	9.2	84.9	14
6	11.2	6.47	9.2	84.7	14
8	11.0	6.51	9.2	83.7	14
10	10.6	6.53	9.4	84.2	14
12	10.5	6.57	9.4	84.5	14
14	10.4	6.58	9.4	84.1	14
16	10.4	6.61	9.5	84.6	14
18	10.3	6.65	9.4	84.0	14
20	10.3	6.55	9.4	84.1	14
22	10.2	6.56	9.4	83.5	14
24	10.2	6.59	9.4	84.3	15
26	10.2	6.60	9.4	84.1	15
28	10.2	6.59	9.5	84.3	15
30	10.1	6.6	9.5	84.6	15

Secchi depth readings during the 2002Fall Turnover, First Major Rain, 2003 Spring Runoff and Summer Low Flow sampling events were 3.3, 11, and 7.8 meters, respectively. The readings for the 2004 Spring Runoff and Summer Low Flow was 3.3 and 7.0 meters, respectively. No Secchi disk data is available for the 2004 Fall Turnover and First Major Rain sampling events.

---

[10] Data set is suspect for dissolved oxygen, however is included for comparison.

4.1.10 Camino Reservoir

4.1.10.1 Historic Information

SMUD conducted water temperature profiling in Camino Reservoir on June 2000 when the reservoir elevation was 2,906 feet. Water quality profiles were recorded at three locations in the reservoir. Despite the short retention time, the temperature profile recorded nearest the dam, where the depth of water was nearly 50 feet, exhibited a weakly stratified water column. At this sampling station, there was 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).

4.1.10.2 Relicensing Water Temperature Profiling

Water quality measurements obtained during the relicensing studies at Camino Reservoir is available from data collected during the following sample periods:

- 2002 Fall Turnover
- 2002 First Major Rain
- 2003 Spring Runoff
- 2003 Summer Low Flow
- 2004 Spring Runoff
- 2004 Summer Low Flow
- 2004 Fall Turnover/ First Major Rain

The sampling of Camino Reservoir was predicated on the fall turnover of Union Valley Reservoir. As discussed in Section 4.1.8.2, Union Valley Reservoir was largely mixed at the time of the 2002 First Major Rain Event, in mid-November 2002. Hence, Camino Reservoir was sampled for on November 13, 2002, as part of a 2002 Turnover/First Major Rain event. The data were taken from the shore of the reservoir at a maximum depth that was safely accessible, since boats are not allowed into the reservoir due to SMUD safety policy.

Water temperatures recorded on November 13, 2002, indicated surface water temperatures of 10.06°C and 10.05°C at a depth of 2 meters. Deeper water temperatures at Camino Reservoir can be inferred from the water temperatures emanating from the Camino Dam release point, which draws water from the bottom of the reservoir (see Appendix B). In mid-November, the stream-based water temperatures below the dam were measured at approximately 9°C.

On May 6, 2003, the water temperature of Camino Reservoir at 1 meter of depth was 7.0°C for the 2003 Spring Runoff period. The reservoir was likely isothermal on this date, as the bottom release was also 7°C. On September 16, 2003, the water temperature of Camino Reservoir at 1 meter of depth had warmed to 10.7°C for the Summer 2003 Low Flow sampling. Again, temperatures in the range of 10°C to 11°C were recorded emanating from the reservoir in mid-September. On September 12, 2004 the surface water temperature was recorded at 9.3°C. It is likely the reservoir was mixed at this time as well, again comporting with historic temperatures for this date at the base of the dam (10 - 11°C). On November 24, 2004, surface temperature was recorded as 12.9°C. A slight stratification was present on this date since the temperature at the base of the dam for this date ranges from 8.7 to 9.6°C for years 2001 to 2003.

Only one Secchi depth reading was taken in the middle of Camino Reservoir. During the Fall 2002 Turnover sampling, the Secchi depth reading was 3.25 meters.

4.1.11 Brush Creek Reservoir

4.1.11.1 Historic Information

SMUD conducted water temperature profiling in Brush Creek Reservoir in June 2000 when the reservoir elevation was 2,909 feet. No thermocline was evident in the temperature profile, although temperatures dropped steadily with depth from near 17°C at the surface to near 7°C at a maximum depth of approximately 100 feet.

4.1.11.2 Relicensing Water Temperature Profiling

Water quality profile measurements obtained during the relicensing studies at Brush Creek Reservoir is available from data collected during the following sample periods:

- 2002 Fall Turnover
- 2002 First Major Rain
- 2003 Spring Runoff
- 2003 Summer Low Flow
- 2004 Spring Runoff
- 2004 Summer Low Flow
- 2004 Fall Turnover/ First Major Rain

The sampling of Brush Creek Reservoir was predicated on the fall turnover of Union Valley Reservoir. As discussed in Section 4.1.8.2, Union Valley Reservoir was largely mixed at the time of the 2002 and 2004 First Major Rain event, in mid-November. Hence, Brush Creek Reservoir was sampled for on November 13, 2002 and November 1, 2004 as part of the Fall Turnover/First Major Rain events. On these dates, Brush Creek Reservoir was found to be essentially isothermal at approximately 10.5°C and 9.5 – 12°C respectively (Table 4.1-9). By the 2003 Spring Runoff sampling period, Brush Creek Reservoir was weakly stratified with a surface temperature of 9.9°C and bottom temperature of 6.3°C. By the Summer 2003 Low Flow sampling period, Brush Creek Reservoir had warmed to the point of exhibiting strong stratification with a surface water temperature of 20.1°C and a bottom temperature of 8.9°C. A dissimilar trend is observed for the 2004 Spring Runoff sampling (May 4, 2004), which showed an epilimnion at 17.7°C and the hypolimnion at 5.7°C at the deepest part of the reservoir. Summer Low Flow sampling, however, mirrored the 2003 sampling with an epilimnion of 18.2°C and the hypolimnion at 9.1°C

Table 4.1-9. Brush Creek Reservoir water quality profiles at the sampling site located in the middle of the reservoir, over seven sampling periods.

Depth (m)	Temperature (ºC)	pH (Units)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (% saturation)	Specific Conductance (µS/cm)
2002 Fall Turnover/First Major Rain (November 13, 2002)					
0.5	10.9	7.21	8.5	76.5	21.60
6	10.8	7.20	8.4	75.1	21.60
8	10.8	7.20	8.3	75.7	21.80
10	10.8	7.22	8.3	75.5	21.80
16	10.6	7.19	8.4	76.9	21.80
20	10.5	7.20	8.5	77.0	22.00
26	10.5	7.19	8.4	76.1	21.90
28	10.5	7.19	8.4	75.2	22.00
2003 Spring Runoff (May 6, 2003)					
0.5	9.9	7.98	9.	83.4	21
2	9.8	7.78	9.	84.9	21
4	9.2	7.17	9.6	83.3	21
6	9.0	7.62	9.9	85.4	20
8	8.4	7.13	9.7	82.3	20
10	8.3	7.11	9.6	81.1	20
16	8.0	7.47	10.0	84.7	21
20	7.7	6.98	8.7	73.2	21
26	7.1	7.30	10.0	82.4	22
30	6.3	6.82	7.9	63.9	24
36	6.3	6.94	8.6	69.6	25
2003 Summer Low Flow (September 16, 2003)					
0.5	20.1	7.01	9.3	102.8	35
6	19.8	6.92	9.2	101.1	27
8	19.6	6.86	9.1	99.4	24
10	19.5	6.76	8.8	96.3	24
16	19.0	6.40	6.4	69.3	26
18	17.6	6.17	5.2	54.0	26
20	10.5	6.11	5.6	50.5	26
26	9.6	6.10	2.0	17.4	26
28	9.3	6.12	1.6	14.2	26
30	8.9	6.12	1.6	14.1	26
2004 Spring Runoff (May 4, 2004)					
0.5	18.7	7.19	9.4	100.3	19
2	16.0	7.28	9.6	97.4	21
4	15.2	7.27	9.6	95.8	21
6	13.7	7.28	9.9	95.7	21
8	13.0	7.24	10.1	96.2	21
10	12.3	7.21	10.3	96.7	20
12	11.8	7.21	10.4	96.4	20
14	11.2	7.18	10.6	96.1	20
16	10.4	7.15	10.7	95.6	20
20	9.3	7.13	10.9	95.0	19

Table 4.1-9. Brush Creek Reservoir water quality profiles at the sampling site located in the middle of the reservoir, over seven sampling periods.

Depth (m)	Temperature (ºC)	pH (Units)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (% saturation)	Specific Conductance (µS/cm)
22	7.3	7.07	11.1	91.7	19
24	6.7	7.08	11.0	89.6	19
26	6.3	7.06	10.8	87.5	20
28	6.0	7.02	10.8	86.5	20
30	5.7	6.99	10.5	84.1	21
2002 Summer Low Flow September 20, 2004)					
0.5	18.2	7.74	8.2	86.8	27
2	18.2	7.74	8.2	86.7	27
4	18.2	7.70	8.2	86.5	27
6	18.2	7.67	8.1	86.0	27
8	18.1	7.63	8.0	84.8	27
10	18.1	7.59	7.8	82.7	27
12	18.0	7.47	7.6	79.8	27
14	17.3	7.43	7.2	75.3	27
16	14.6	7.47	7.4	72.7	23
18	10.7	7.50	8.26	74.3	20
20	9.7	7.53	8.3	73.2	17
22	9.5	7.53	8.1	70.8	17
24	9.4	7.54	7.21	62.9	17
26	9.3	7.55	6.49	56.4	17
28	9.1	7.55	6.9	59.9	19
2004 Fall Turnover/First Major Rain (November 1, 2002)					
0.5	12.0	7.15	9.3	86.2	26
2	12.0	7.12	9.3	86.1	26
4	12.0	7.11	9.3	86.2	26
6	12.0	7.10	9.3	86.1	26
8	12.0	7.09	9.3	86.0	26
10	12.0	7.08	9.2	85.6	26
12	12.0	7.07	9.2	85.5	26
14	12.0	7.05	9.2	85.1	26
16	12.0	7.06	9.1	84.3	26
18	11.8	7.03	8.8	80.8	26
20	11.9	6.98	8.2	75.4	26
22	11.6	6.90	6.9	63.3	25
24	11.2	6.91	5.7	52.1	22
26	10.2	6.97	4.0	35.4	21
28	9.4	7.08	5.25	45.8	27

Secchi depth readings during the 2002 First Major Rain, 2003 Spring Runoff and Summer Low Flow sampling events were 7.5, 7, and 8.2 meters, respectively. Readings during the 2004 Spring Runoff, Summer Low Flow and Fall Turnover/First Major Rain sampling events were 12.0, 8.6 and 3.7 meters, respectively.

4.1.12 Slab Creek Reservoir

4.1.12.1 Historic Information

SMUD conducted water quality studies in Slab Creek Reservoir in November 1999 and June 2000, when reservoir elevations were 1,830 and 1,838 feet, respectively. Water quality data were collected at six locations along the 5-mile-long reservoir. 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.

4.1.12.2 Relicensing Water Temperature Profiling

Water quality profile measurements obtained during the relicensing studies at Slab Creek Reservoir is available from data collected during the following sample periods:

- 2002 Fall Turnover
- 2002 First Major Rain
- 2003 Spring Runoff
- 2003 Summer Low Flow
- 2004 Spring Runoff
- 2004 Summer Low Flow
- 2004 Fall Turnover/ First Major Rain

Water temperature profiling at Slab Creek Reservoir began on October 1, 2002, consistent with the water quality study plan, which called for sampling after Slab Creek Reservoir had turned over and was mixed. A sampling site upstream of Slab Creek Reservoir Dam was selected to evaluate the timing of mixing within the reservoir. The October 2002 thermal profile showed there was a difference of approximately 2.5°C between top and bottom temperatures; hence, the reservoir was not stratified. Similar results were obtained during the September 2004 profiling event where the temperature difference was 3.9°C (Table 4.1-10). The 2002 First Major Rain sample event on November 12, 2002, produced a similar, though somewhat cooler, thermal profile. During this event, the temperature differential between surface and bottom of the reservoir was approximately 1.5°C. The November 2004 sampling again produced similar results in that the temperature difference was 3.9°C. These two sampling efforts in 2002 and 2004 are consistent with the November 8, 1999 profile, which exhibited a gradual decline in temperature from a surface value of approximately 13°C to a bottom value of approximately 11.5°C. Overall, these results show that Slab Creek Reservoir does not establish the same strong and stable summer stratification, with a well define epilimnion, metalimnion, and hypolimnion, that is characteristic of the upstream UARP storage reservoirs, or even Rockbound Lake. The weak thermal stratification, as demonstrated by the shallow or poorly defined epilimnion, likely results from the fact that Slab Creek Reservoir experiences a high turnover rate (or short retention time) during the summer months when releases from upstream storage pass through the reservoir. This high turnover rate, does not allow for an extended period of quiescence during summer months that would otherwise lead to the development of a stable and deep epilimnion.

The stream-based water temperatures from water that is discharged from the Slab Creek Dam during the fall of 2002, 2003 and 2004 are consistent with the bottom temperatures of Slab Creek Reservoir described above. It is likely, then, that water temperatures in the reservoir continued to decline through the winter consistent with the drop of water temperatures emanating from the bottom of the dam. As temperatures warmed during the spring, the Spring Runoff sampling event indicated the beginning of thermal stratification, with a surface water temperature of 18.7°C; in 2004, the surface temperature was 16.0°C. An interesting trend to note is that during the 2004 Summer Low Flow sampling the surface temperature decreased by one degree from the 2004 Spring Runoff sampling and by only two more degrees during the 2004 Fall Turnover/ First Major Rain event.

Table 4.1-10. Slab Creek Reservoir water quality profiles at the sampling site located near the dam (fall turnover) and in the middle of the reservoir, over seven sampling periods.

Depth (m)	Temperature (ºC)	pH (Units)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (% saturation)	Specific Conductance (µS/cm)
2002 Fall Turnover (October 1, 2002)					
0.5	13.4	-	10.1	101.8	20.0
4	13.3	-	10.3	100.5	18.4
6	11.5	-	10.3	100.5	18.4
10	11.3	-	10.1	97.6	18.5
16	11.1	-	9.9	95.1	18.4
20	11.0	-	9.8	94.3	18.4
26	10.9	-	10.1	96.1	18.0
30	10.7	-	10.0	95.1	17.7
36	10.7	-	10.1	96.7	17.4
40	10.6	-	9.9	94.7	17.2
46	10.5	-	9.6	91.2	17.6
50	10.5	-	9.6	90.4	17.8
2002 First Major Rain (November 12, 2002)					
0.5	11.1	7.09	10.3	99.6	18.8
2	10.2	7.05	10.4	98.0	18.5
6	10.1	7.08	10.4	98.3	18.7
10	10.1	7.11	10.3	97.6	18.7
16	10.0	7.16	10.2	96.6	19.3
18	9.8	7.15	10.4	96.7	23.9
20	9.7	7.20	10.5	97.6	23.0
26	9.6	7.22	10.4	97.1	22.5
28	9.6	7.26	10.4	97.3	22.6
2003 Spring Runoff (June 25, 2003)					
0.5	18.7	7.65	9.8	104.9	26
2	17.5	7.65	10.1	106	27
6	16.3	7.53	10.0	102.4	28
8	16.1	7.51	10.0	101.5	28
10	16.0	7.49	10.0	101.6	28
16	15.6	7.46	9.9	99.7	28
20	15.4	7.44	9.9	99.5	28

Table 4.1-10. Slab Creek Reservoir water quality profiles at the sampling site located near the dam (fall turnover) and in the middle of the reservoir, over seven sampling periods.

Depth (m)	Temperature (ºC)	pH (Units)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (% saturation)	Specific Conductance (µS/cm)
26	15.2	7.44	10.0	100.0	27
30	14.9	7.40	10.2	100.4	27
2003 Summer Low Flow (September 15, 2003)					
0.5	17.6	6.7	9.8	102.9	21
2	17.3	6.59	9.4	98.7	20
4	15.1	6.47	9.6	95.6	18
6	13.8	6.47	10.0	96.5	17
10	13.3	6.49	10.4	98.8	17
16	13.1	6.55	10.8	102.7	17
20	13.1	6.54	10.9	103.2	17
26	12.9	6.54	11.0	103.7	17
30	12.8	6.52	11.1	104.8	17
40	12.4	6.55	11.4	105.9	15
46	12.2	6.6	11.5	106.5	15
2004 Spring Runoff (May 3, 2004)					
0.5	16.0	7.48	9.6	97.7	21
2	15.9	7.27	9.3	94.1	21
4	15.2	7.20	9.4	94.0	21
6	13.8	7.19	9.7	94.2	21
8	13.0	7.22	10.0	95.2	20
10	12.3	7.27	10.3	95.9	20
12	11.7	7.24	10.4	96.1	20
14	11.2	7.19	10.5	96.0	20
16	10.4	7.15	10.7	95.7	20
18	9.2	7.13	10.8	94.1	19
20	8.2	7.12	11.0	93.3	19
22	7.4	7.11	10.9	90.8	19
24	6.8	7.07	10.9	89.6	19
26	6.4	7.03	10.7	86.8	20
28	5.9	6.96	10.6	85.0	21
30	5.7	6.88	10.4	82.7	21
32	5.7	6.89	9.5	75.9	22
2004 Summer Low Flow (September 13, 2004)					
0.5	14.9	7.19	-	61.8	19
2	14.7	7.20	-	61.2	19
4	13.6	7.19	-	57.5	19
6	12.5	7.18	-	54.4	18
8	11.8	7.17	-	52.0	18
10	11.7	7.15	-	52.5	18
12	11.6	7.15	-	51.0	17
14	11.6	7.14	-	50.9	17
16	11.5	7.13	-	51.3	17
18	11.4	7.14	-	51.3	17
20	11.4	7.14	-	51.4	17

Table 4.1-10. Slab Creek Reservoir water quality profiles at the sampling site located near the dam (fall turnover) and in the middle of the reservoir, over seven sampling periods.

Depth (m)	Temperature (^oC)	pH (Units)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (% saturation)	Specific Conductance (µS/cm)
22	11.3	7.14	-	51.0	17
24	11.2	7.12	-	50.6	17
26	11.2	7.11	-	49.9	17
28	11.2	7.12	-	51.1	17
30	11.2	7.12	-	50.9	17
32	11.1	7.12	-	50.5	17
34	11.1	7.11	-	50.6	17
36	11.1	7.13	-	52.5	180
2004 Fall Turnover/First Major Rain (October 25, 2004)					
0.5	13.1	6.98	9.7	92.7	22
2	12.9	7.05	9.8	92.5	22
4	12.7	7.08	9.8	92.0	22
6	12.7	7.05	9.7	91.7	22
8	12.6	6.99	9.7	91.5	22
10	12.4	7.02	9.9	92.3	23
12	12.3	7.03	9.9	92.4	23
14	12.3	7.01	9.9	92.2	23
16	12.2	7.02	9.9	92.4	23
18	12.2	7.02	9.9	92.5	23
20	12.1	7.00	10.0	92.7	23
22	12.1	7.01	10.0	92.7	23
24	12.0	7.02	10.0	92.6	23
26	12.0	7.00	10.0	93.1	24
28	12.0	7.01	10.1	93.4	23
30	12.0	7.02	10.1	93.4	23
32	11.9	7.03	10.1	93.3	23
34	11.9	7.04	10.0	93.0	23
36	11.9	7.04	10.0	92.4	23
38	11.8	7.08	9.9	91.4	23
40	11.8	7.08	9.8	90.6	24
42	11.8	7.14	9.7	89.4	24
44	11.8	7.09	9.6	88.3	25

Secchi depth readings in the middle of Slab Creek Reservoir during the 2002 First Major Rain, 2003 Spring Runoff and Summer Low Flow sampling events were 7, 3.4 and 7.3 meters, respectively. Readings during the 2004 Spring Runoff, Summer Low Flow and Fall Turnover/First Major Rain sampling events were 3.0, 8.5 and 4.4 meters, respectively.

4.1.12.3 Water Temperature Profiling at Iowa Hill Development Intake Structure

As identified in Initial Information Package prepared for the UARP relicensing, one change that was contemplated by SMUD was the addition of the Iowa Hill Pumped Storage Development (IHPSD). The IHPSD would be a new development that would make use of Slab Creek

Reservoir as a lower reservoir and a new 6,400 acre-ft reservoir built on top of the adjacent Iowa Hill as the upper reservoir. Water would be pumped from Slab Creek Reservoir through a multi-port intake at a depth of approximately 80 feet below the reservoir surface. Water temperature profile data were collected in Slab Creek Reservoir from June through November 2003 between the dam and the proposed intake structure location in anticipation of developing a water temperature model of Slab Creek Reservoir. The model was designed to assess the effects of water temperature changes associated with the operation of the IHPDS. The results of this modeling study are contained in the *Iowa Hill Pumped Storage Development Water Temperature Study Report* (DTA and EES 2005a).

The thermal profile data from the sampling location near the intake structure show an indistinct development of an epilimnion throughout the summer of 2003. In June, an epilimnion of 18°C is shown to extend approximately 20 feet from the reservoir surface. However, in July and August, the well-defined epilimnion is replaced by a gradual metalimnion that grades directly into the hypolimnion. This demonstrates the ephemeral nature the epilimnion at Slab Creek Reservoir. The hypolimnion was also shown to cool from approximately 15°C in June to 13°C in August. In late October, the data show that the reservoir begins to mix, narrowing the temperature range from 11.3 to 13.2°C throughout the water column. By November, the reservoir is fully mixed, as evidenced by the temperature range of 9.3 to 10.2°C.

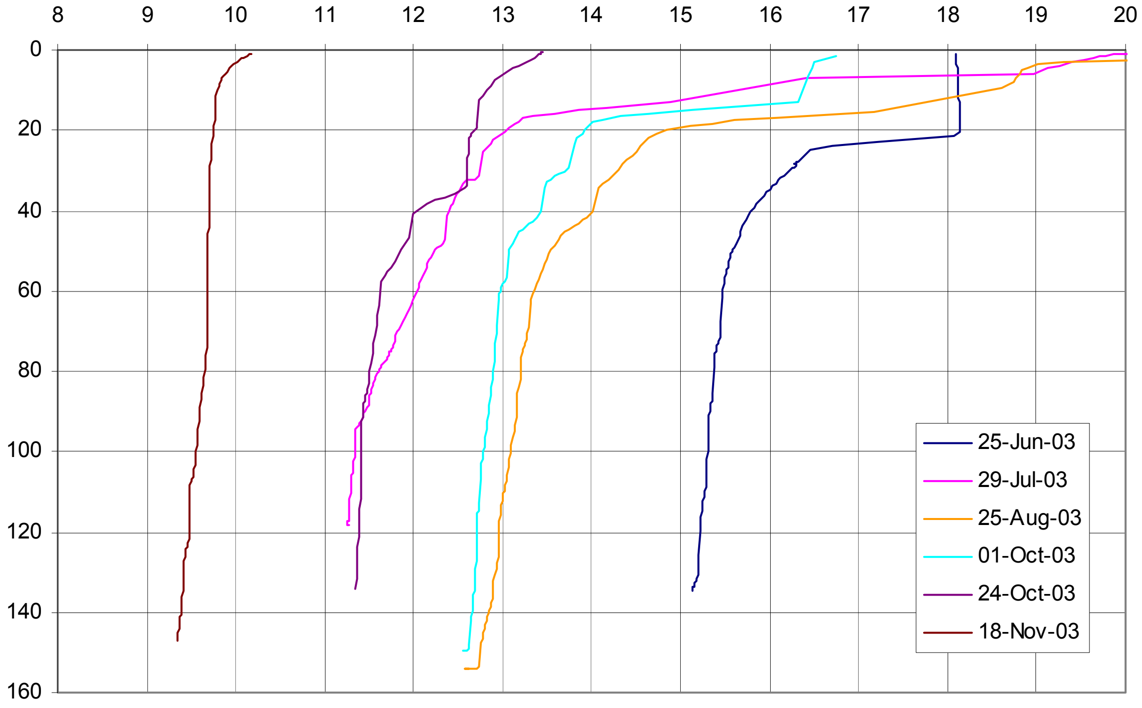


Figure 4.1-1. Thermal Profile of Slab Creek Reservoir, near the proposed intake structure of the Iowa Hill Pumped Storage Development, June – November 2003.

4.1.13 Chili Bar Reservoir

4.1.13.1 Historic Information

SMUD and Pacific Gas and Electric Company are unaware of any historic water temperature data collected in Chili Bar Reservoir. Temperature profiles at Chili Bar Reservoir for the different seasons in 2002 - 2004 are contained in Appendix A.

4.1.13.2 Relicensing Water Temperature Profiling

Water quality profile measurements obtained during the relicensing studies at Chili Bar Reservoir are available from data collected during the following sample periods:

- 2002 Fall Turnover
- 2002 First Major Rain
- 2003 Spring Runoff
- 2003 Summer Low Flow
- 2004 Spring Runoff
- 2004 Summer Low Flow
- 2004 Fall Turnover/ First Major Rain

For illustrative purposes in this discussion, Table 4.1-11 has been developed with an abbreviated set of profile data for the sampling location in the middle of the reservoir or near the dam. Selective sampling locations along the vertical profile have been highlighted in the table to illustrate the shape of the thermal profile.

The thermal profiles of Chili Bar Reservoir show an unstratified reservoir during the 2002 Fall Turnover, First Major Rain, and 2003 Spring Runoff sampling periods. While the water temperature in the reservoir varied between these periods the profile essentially indicated isothermal conditions in each of these sampling periods. During the Summer 2003 Low Flow sampling period, the thermal profile showed surface warming. Surface temperatures on September 15, 2003 were approximately 17°C, while bottom temperatures were approximately 13.5°C.

Table 4.1-11. Chili Bar Reservoir water quality profiles over seven sampling periods.

Depth (m)	Temperature (ºC)	pH (Unit)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (% saturation)	Specific Conductance (µS/cm)
2002 Fall Turnover (October 9, 2002)					
0.5	11.5	6.75	10.6	99.3	20.2
2	11.3	6.73	10.6	99.2	20.1
6	11.2	6.69	10.6	99.3	20.1
8	11.0	6.70	10.6	99.7	19.8
10	11.0	6.70	10.7	100.1	19.7
14	11.0	6.66	10.7	99.1	19.7

Table 4.1-11. Chili Bar Reservoir water quality profiles over seven sampling periods.

Depth (m)	Temperature (ºC)	pH (Unit)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (% saturation)	Specific Conductance (µS/cm)
2002 First Major Rain (November 13, 2002)					
0.5	10.2	7.08	10.7	N/A	26.0
2	9.8	7.09	10.8	98.2	26.0
6	9.8	7.03	10.8	98.1	26.1
10	9.9	7.04	11.0	99.5	26.2
14	9.7	7.02	10.8	97.8	25.0
16	9.7	6.97	10.6	95.8	25.0
2003 Spring Runoff (May 5, 2003)					
0.5	8.7	7.77	N/A[11]	N/A	37.0
2	8.2	7.68	N/A	N/A	37.0
4	8.2	7.60	N/A	N/A	37.0
6	8.2	7.56	N/A	N/A	37.0
8	8.2	7.50	N/A	N/A	37.0
2003 Summer Low Flow (September 15, 2003)					
0.5	17.6	7.43	10.0	102.6	24.0
2	15.8	7.34	10.2	100.4	24.0
4	14.5	7.27	10.6	100.9	24.0
6	14.4	7.26	10.6	100.4	24.0
8	13.9	7.16	10.6	99.4	23.0
10	13.6	7.11	10.7	99.3	23.0
16	13.4	6.99	10.7	99.1	23.0
2004 Spring Runoff (May 3, 2004)					
0.5	13.0	6.89	12.9	122.3	27
2	12.1	6.90	12.9	120.1	27
4	11.6	6.90	13.1	120.2	23
6	11.5	6.91	13.0	119.2	23
8	11.5	6.92	13.2	120.9	23
10	11.4	6.92	12.7	116.4	23
12	11.4	6.92	12.8	117.3	26
14	11.4	6.94	13.0	118.6	23
16	11.4	6.95	13.0	118.9	26
18	11.9	6.97	12.7	115.7	26
2004 Summer Low Flow (September 13, 2004)					
0.5	13.4	6.97	9.1	92.9	18
2	12.7	6.95	9.3	94.5	18
4	12.1	6.96	9.4	93.3	17
6	12.0	6.94	9.4	93.3	17
8	11.7	6.89	9.5	94.0	17
10	11.6	6.86	9.4	92.8	17

---

[11] Oxygen levels were not within range. Possible calibration error.

Table 4.1-11. Chili Bar Reservoir water quality profiles over seven sampling periods.

Depth (m)	Temperature (ºC)	pH (Unit)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (% saturation)	Specific Conductance (µS/cm)
12	12.0	6.83	9.3	91.7	17
14	11.4	6.81	9.2	90.6	17
16	11.4	6.73	9.5	93.4	17
2004 Fall Turnover (October 25, 2004)					
0.5	12.3	7.12	10.5	97.9	28
2	12.2	7.12	10.5	98.0	28
4	12.2	7.13	10.6	98.3	28
6	12.2	7.13	10.6	98.5	28
8	12.1	7.17	10.6	98.9	27
10	12.1	7.18	10.7	99.2	27
12	12.0	7.2	10.7	99.1	27
14	12.0	7.2	10.7	99.1	27
16	12.0	7.3	10.7	98.9	27
18	12.0	7.2	10.7	98.8	27

Secchi depth readings near Chili Bar Dam during the 2002 Fall Turnover, First Major Rain, 2003 Spring Runoff, Summer Low Flow sampling events were 6.3, 3.5, 5.4 and 1.5 meters, respectively. Readings during the 2004 Spring Runoff, Summer Low Flow, Fall Turnover/First Major Rain sampling events were 3.7, 6.0 and 2.7 meters, respectively.

4.2 Temperature Needs of Various Species

At a July 6, 2004 meeting, the Aquatic TWG requested that the Licensees include in the Water Temperature Technical Report a range of water temperatures that may be needed for various aquatic species. First, it is important that one of the Basin Plan designates beneficial uses for the waters in the vicinity of the two projects is Cold Freshwater Habitat. However, the Basin Plan does not provide a quantitative definition for this use. One can infer that "Cold Freshwater" is characterized by mean daily water temperatures of less than 20°C, which is normally considered the upper optimum growth limit for rainbow trout, and daily maximum water temperatures less than 25°C, which is a conservative estimate of the lethal temperature for rainbow trout (Hokanson et al. 1977, Raleigh et al. 1984). CDFG's temperature policy for stocking catchable trout supports the general use of these temperature criteria. This policy states that *"Catchable trout shall not be stocked in streams when water temperatures reach 75°F (23.9°C) and it appears that such temperatures will continue to occur regularly, or when stream flows drop below 10 cfs. The exception is that suitable streams with flows between 2 and 10 cfs may be planted if water temperatures do not exceed 70°F (21.1°C) and other conditions are satisfactory."* (http://dfg.ca.gov/fishplant/criteria.html).

It should also be noted that two of the study reaches have dual designations within the Basin Plan with respect to water temperature. The Slab Creek Dam Reach and the Reach Downstream of Chili Bar are designated as both Cold Freshwater Habitat and Warm Freshwater Habitat.

The effects of water temperature on various aquatic species that occur in the area of the Projects are addressed in other technical reports (e.g. Amphibians and Aquatic Reptiles Technical Report, Stream Fisheries Technical Report).

4.3 Stream Water Temperature Monitoring

This section contains a summary of the results of historical and relicensing stream water temperature monitoring. As discussed in Section 3.2, relicensing water temperature studies were conducted at a total of 51 sampling sites. The results of the relicensing water temperature monitoring program are provided in a series of graphical time series plots contained in Appendix B.

In addition to the site-specific time series graphs, two other graph formats were developed that illustrated reach-specific water temperatures. The first format consisted of plotting mean daily water temperatures for all stations within a given reach throughout the entire monitoring period. This display allows for comparison of all water temperatures recorded at the different sites within the reach. The second format was more focused, displaying mean daily water temperatures at different monitoring sites for specific days of the year – June 15, July 15, and August 15. This graph allows for a comparison of mean daily water temperatures between sites for specific days of the summer months, when water temperatures are more responsive to streamflow and ambient conditions.

Where available, DO levels from the relicensing water quality study have been provided for certain sites that coincide with the water temperature logger locations. Because of the difficulty of applying these values to the data-rich graphical displays provided in Appendix B, DO levels are provided below in text or tabular format.

Table 4.3-1 shows the amount of time that mean daily water temperatures exceeded 20°C and maximum daily water temperatures for many of the logger sites in each UARP reach, excluding the Rubicon Tunnel and Rockbound Dam reaches for which data are not available, and the Reach Downstream of Chili Bar. Based on the Cold Freshwater temperature criteria in Section 4.2 and the results of the Licensees studies, the UARP reaches and the Reach Downstream of Chili Bar can be subdivided into 18 segments: nine cold segments equaling about 50 river miles (62 % of the project reaches and Reach Downstream of Chili Bar), and eight stream segments that exceed one or both of the temperature criteria equaling about 31 river miles (38%).

Stream segments with mean daily temperatures less than 20°C and maximum temperatures 25°C or less):

- All of Loon Lake Dam Reach (8.5 miles)
- All of Gerle Creek Dam Reach (1.2 miles)
- Downstream portion of Robbs Peak Dam Reach (about 4 miles)
- Upstream portion of Ice House Dam Reach (about 7 miles)
- All of Junction Dam Reach (8.3 miles)
- Upstream portion of Camino Dam Reach (about 3 miles)
- All of Brush Creek Dam Reach (2.2 miles)

- Upstream portion of Slab Creek Dam Reach (about 4 miles)
- Upstream portion of Reach Downstream of Chili Bar (11.5 miles)

Stream segments with mean daily temperatures exceeding 20°C and or maximum temperatures greater than 25°C):

- All of Rubicon Dam Reach (4.2 miles): mean daily water temperature exceeds 20.0°C about 7-8% of the time but maximum daily water temperature always less than 24.1°C
- Buck Island Dam Reach (2.5 miles): 11-13% and 26.4°C in the downstream portion
- Upstream portion of Robbs Peak Dam Reach (about 2 miles): 3%, but maximum daily water temperature always less than 23.1°C
- Lower middle and downstream portions of Ice House Dam Reach (about 4 miles): 0.6-2% of the time and maximum daily temperature of 26.0°C
- Downstream portion of Camino Dam Reach (about 3 miles): 10% and 25.6°C
- All of the SFAR Reach (2.8 miles): 15% and 26.7°C
- Downstream portion of Slab Creek Dam Reach (about 4 miles): 25% and 26.7°C)
- Downstream portion of Reach Downstream of Chili Bar (7.6 miles): (1.7%, but maximum daily water temperature of 23.6°C)

Table 4.3-1. The frequency that mean daily water temperatures exceed 20.0°C in project reaches and the maximum instantaneous water temperature, 2002 - 2004.

Location		Monitoring Period	Days with Readings	Number of Days with Mean Daily Temperature Equal to or Greater than 20.0 C						% of Monitoring Period	Maximum Mean Daily Value	Maximum Daily Value
Description	**Site**	**Dates**	**#**	**2000**	**2001**	**2002**	**2003**	**2004**	**Total**	**% of Period**	**C**	**C**
Rubicon Dam Reach (4.2 miles)												
Above Reservoir	RR4	5/13/02-8/27/04	838	-----	-----	10	7	16	33	3.94%	21.3	26.8
At Dam	RR3	10/28/00-9/30/04	1,434	0	30	22	26	33	111	7.74%	22.2	22.7
At Rubicon Springs	RR2	5/14/02-9/30/04	871	-----	-----	14	13	13	40	4.59%	21.9	24.1
Below Rubicon River/SFRR Confluence	RR1	10/28/00-9/30/04	1,435	-----	26	25	21	23	95	6.62%	22.9	23.7
Buck Island Dam Reach (2.5 miles)												
At Dam	LRR2	10/28/00-9/30/04	1,434	-----	65	43	36	36	180	12.55%	22.9	23.7
Mid-Reach	LRR1	7/24/02-9/30/04	800	-----	-----	21	28	37	86	10.75%	23.7	26.4
Loon Lake Dam Reach (8.5 miles)												
At Dam	GC6	10/18/00-9/30/04	1,423	0	0	0	0	0	0	0.00%	16.9	17.1
Above Gerle Creek Reservoir	GC3	10/27/00-9/30/04	1,435	0	0	0	0	0	0	0.00%	19.8	24.3
Gerle Creek Dam Reach (1.2 miles)												
At Dam	GC2	4/7/01-9/30/04	1,209	-----	0	0	0	0	0	0.00%	18.4	18.6

Table 4.3-1. The frequency that mean daily water temperatures exceed 20.0°C in project reaches and the maximum instantaneous water temperature, 2002 - 2004.

Location		Monitoring Period	Days with Readings	Number of Days with Mean Daily Temperature Equal to or Greater than 20.0 C						% of Monitoring Period	Maximum Mean Daily Value	Maximum Daily Value
Description	**Site**	**Dates**	**#**	**2000**	**2001**	**2002**	**2003**	**2004**	**Total**	**% of Period**	**C**	**C**
Above Gerle Creek/SFRR Confluence	GC1	5/24/02-9/30/04	854	-----	-----	0	0	0	0	0.00%	17	19.3
Robbs Peak Dam Reach (5.9 miles)												
Above Reservoir	SFRR4	7/20/01-9/30/04	1,169	-----	-----	3	9	0	12	1.03%	21.3	24.5
At Dam	SFRR3	5/10/01-9/30/04	1,240	-----	34	0	0	0	34	2.74%	22.5	23.1
Above Gerle Creek Confluence	SFRR2	5/24/02-9/30/04	861	-----	-----	0	0	0	0	0.00%	18.4	20.2
Below Gerle Creek and SFRR Confluence	SFRR1	10/27/00-9/30/04	1,435	0	0	0	0	0	0	0.00%	18.8	20.4
Ice House Dam Reach (11.5 miles)												
Above Reservoir	SFSC6	7/23/01-9/30/04	1,166	-----	0	0	0	0	0	0.00%	19.7	21.7
At Dam	SFSC5	3/24/01-9/30/04	1,287	-----	0	0	0	0	0	0.00%	8	8.6
Mid-Reach	SFSC2	11/3/00-9/30/04	1,428	0	6	0	0	0	6	0.42%	20.7	26
Above Junction Reservoir	SFSC1	10/20/00-9/30/04	1,442	0	15	3	7	0	25	1.73%	21.3	26
Junction Dam Reach (8.3 miles)												
Jones Fork Silver Creek	JFSC1	7/20/01-9/30/04	1,169	-----	5	12	13	0	30	2.57%	22	25

Table 4.3-1. The frequency that mean daily water temperatures exceed 20.0°C in project reaches and the maximum instantaneous water temperature, 2002 - 2004.

Location		Monitoring Period	Days with Readings	Number of Days with Mean Daily Temperature Equal to or Greater than 20.0 C						% of Monitoring Period	Maximum Mean Daily Value	Maximum Daily Value
Description	**Site**	**Dates**	**#**	**2000**	**2001**	**2002**	**2003**	**2004**	**Total**	**% of Period**	**C**	**C**
At Dam	SC4	10/21/00-9/22/04	1,433	0	0	0	0	0	0	0.00%	11.2	13.5
Above Camino Reservoir	SC3	11/3/00-9/30/04	1,428	0	1	0	1	0	2	0.14%	20.2	22
Camino Dam Reach (6.2 miles)												
At Dam	SC2	11/3/00-9/30/04	1,306	0	0	0	0	0	0	0.00%	12.7	14.7
Above SFAR Confluence	SC1	11/9/00-9/30/04	1,422	0	71	25	16	33	145	10.20%	23.2	25.6
SFAR Reach (2.8 miles)												
Above Silver Creek/SFAR Confluence	SFAR12	7/30/01-9/30/04	1,159	-----	27	46	42	63	178	15.36%	24.3	26.7
Below Silver Creek/SFAR Confluence	SFAR11	7/30/01-9/30/04	1,159	-----	27	44	32	66	169	14.58%	23.7	25.9
Brush Creek Dam Reach (2.2 miles)												
At Dam	BC2	11/10/00-9/30/04	1,420	0	0	0	0	0	0	0.00%	18.7	19
Slab Creek Dam Reach (8.0 miles)												
At Slab Creek Powerhouse	SFAR9	3/23/01-9/30/04	1,288	-----	0	0	0	0	0	0.00%	16.2	16.7
Above White Rock Powerhouse	SFAR6	6/1/02-9/30/04	852	-----	-----	70	66	75	211	24.77%	24.4	26.7

Table 4.3-1. The frequency that mean daily water temperatures exceed 20.0°C in project reaches and the maximum instantaneous water temperature, 2002 - 2004.

Location		Monitoring Period	Days with Readings	Number of Days with Mean Daily Temperature Equal to or Greater than 20.0 C						% of Monitoring Period	Maximum Mean Daily Value	Maximum Daily Value
Description	**Site**	**Dates**	**#**	**2000**	**2001**	**2002**	**2003**	**2004**	**Total**	**% of Period**	**C**	**C**
Rock Creek	RC1	6/6/03-9/30/04	483	-----	-----	-----	22	38	60	12.42%	23.1	24.4
Reach Downstream of Chili Bar (19.1 miles)												
At Dam	SFAR4	7/9/02-9/30/04	815	-----	-----	0	0	0	0	0.00%	18	18.6
Above Weber Creek	SFAR1	7/10/02-8/11/04	783	-----	-----	10	0	3	13	1.66%	21.7	23.6

A discussion of water temperature in each reach is provided below.

4.3.1 Rubicon Dam Reach

SMUD is unaware of any historic water temperature data collected in the Rubicon Dam Reach.

During the relicensing studies, water temperature monitoring was conducted at three sites in the Rubicon Dam Reach: 1) downstream of the confluence of Rubicon River and the Little Rubicon River (RR1); 2) at Rubicon Springs (RR2); and 3) directly downstream of Rubicon Dam (RR3). In addition, SMUD installed and maintained a water temperature logger in the Rubicon River upstream of Rubicon Reservoir (RR4). (Table 3.2-1.) The period of monitoring at these four sites varies, determined by the time when the logger was first deployed and the time of the last download.

The results of the licensing studies in the Rubicon Dam Reach show a thermal regime throughout the reach that ranges from wintertime lows of near zero water temperatures to summertime daily mean values of between 18°C and 22°C. This trend is generally consistent throughout the 2000 – 2004 monitoring period. The inflowing water to Rubicon Reservoir exhibits mean daily water temperatures during the summer months of as high as 21°C. Mean daily water temperatures in the Rubicon River downstream of the confluence with Little Rubicon River, by contrast, reached values as high as 22°C to 23°C during the summer months of July and August (2003). Streamflows in the reach during the summer period are between 1 and 6 cfs. Under current UARP operations, releases from Rubicon Dam during the summer months are tied to the volume of water flowing into Rubicon Reservoir. As the natural streamflow of the Rubicon River drops below 6 cfs (Table 4.3-2), SMUD operators reduce the Rubicon Dam releases because of the limited storage capability of the reservoir.

Table 4.3-2. Rubicon River streamflow measurements of inflowing water to Rubicon Reservoir during summer 2002 - 2004.

2002		2003		2004	
Date	**Flow (cfs)**	**Date**	**Flow (cfs)**	**Date**	**Flow (cfs)**
July 15	11.6	August 13	4.2	No data in 2004	-
July 30	6.0	August 19	2.3		
August 5	3.6	September 2	1.6		
August 14	1.5	September 12	0.01		
August 21	0.5	October 15	No Flow		
September 17	No Flow				

DO data exists for the Rubicon Dam reach, limited to the extent of water quality surveys conducted during 2002 - 2004. Three stations were sampled that coincide with the location of temperature logger sites: above Rubicon Reservoir and below Rubicon dam. These sites were sampled on the dates as noted in Table 4.3-3.

Table 4.3-3. Dissolved oxygen in mg/l (percent saturation) at water quality monitoring stations that coincide with or are near to water temperature monitoring sites in the Rubicon Reservoir Dam Reach, 2002 - 2004

Date	Rubicon River inflow to Rubicon River (Station 1/RR4)	Rubicon River outflow from Rubicon Reservoir (Station 2/RR3)
October 7, 2002	No flow	9.6 mg/l (NA)
June 11, 2003	9.7 mg/l (NA)	11.2 mg/l (NA)
September 17, 2003	9.5 mg/l (100%)	9.3 mg/l (93%)
May 12, 2004	10.5 mg/l (NA)	10.9 mg/l (NA)
September 21, 2004	8.4 mg/l (83%)	7.9 mg/l (76%)
November 2, 2004	11.3 mg/l (79%)	10.9 mg/l (79%)

4.3.2 Buck Island Dam Reach

SMUD is unaware of any historic water temperature data collected in Buck Island Dam Reach.

During the relicensing studies, water temperature monitoring was conducted at two sites in the Buck Island Dam Reach: 1) directly upstream of the confluence with Rubicon River (LRR1); and 2) and directly downstream of Buck Island Dam (LRR2) (Table 3.2-1). The period of monitoring at these two sites varies, determined by the time when the logger was first deployed and the time of the last download.

The results of the relicensing studies in the Buck Island Dam Reach show a thermal regime similar to that of the Rubicon Dam Reach, with winter minimum values in the bypass reach ranging from near zero during wintertime to mean daily values in the summer months of 22°C to 23°C from 2001 to 2004 water years. During the entire course of the monitoring program, releases from Buck Island Dam varied between 2 - 6 cfs.

Limited DO data exists for the Buck Island Dam Reach. One water quality station was sampled that coincides with the location of logger site LRR2. The site was water quality station 6 (Buck Island Dam outlet). These sites were sampled on the dates as noted in Table 4.3-4.

Table 4.3-4. Dissolved oxygen in mg/l (percent saturation) at water quality monitoring stations that coincide with or are near to water temperature monitoring sites in the Buck Island Dam Reach, 2002 - 2004

Date	Little Rubicon River outflow from Buck Island Reservoir (Station 6/LRR2)
October 7, 2002	9.53 mg/l (92%)
June 11, 2003	10.0 mg/l (86.9%)
September 17, 2003	9.4 mg/l (94.6%)
May 12, 2004	11.3 mg/l (NA)
September 21, 2004	7.3 mg/l (70%)
November 2, 2004	NA

4.3.3 Loon Lake Dam Reach

4.3.3.1 Historic Information

Historically, i*n situ* water temperature (and DO) data were collected at the mouths of the feeder streams and near the terminus of the Buck Island–Loon Lake Tunnel in June 2002 by SMUD. The temperature of inflowing water was 21°C from Ellis Creek (DO of 6.1 mg/l) and 11°C from the Buck Island-Loon Lake Tunnel (9 mg/l). Water year 2000 was generally considered to be an above normal water year.

4.3.3.2 Relicensing Water Temperature Monitoring

During the relicensing studies, water temperature monitoring was conducted at six sites along Loon Lake Dam Reach: 1) Gerle Creek above Gerle Creek Reservoir (GC3); 2) Gerle Creek downstream of Barts Creek (GC4); 3), Gerle Creek upstream of Jerrett Creek (GC5); 4) Gerle Creek about 1.5 miles downstream of Loon Lake dam (GC5.8); 5) Gerle Creek about 0.5 miles downstream of Loon Lake Dam (GC 5.9) and 6) Gerle Creek at Loon Lake Dam (GC6). In addition, SMUD installed and maintained a water temperature data logger in Jerrett Creek at the mouth (JC1) as a reference. (Table 3.2-1) The period of monitoring at these sites varies, determined by the time when the logger was first deployed and the time of the last download. Note that the Jerrett Creek logger was removed because of the ephemeral nature of the creek.

Water temperatures from the relicensing studies in the Loon Lake Dam Reach show a thermal regime that is generally cooler than that of the Rubicon Dam Reach. This is due to a variety of factors, including the influence of Loon Lake Reservoir water storage and a higher level of shading provided by riparian vegetation in the lower elevations. Water released from Loon Lake Dam varies in temperature over the year from a low of less than 2°C to a high of roughly 16 - 17°C. Limnological investigations of Loon Lake Reservoir show a reservoir that establishes a weak thermal stratification (Section 4.1.4). The range of summertime (June through September) temperatures of the water released from Loon Lake Dam into Gerle Creek reflects the range of water temperatures in the hypolimnion of the reservoir. As the summer progresses, the water flowing from the base of the dam gradually warms as the water from the lowermost and coolest portions of the hypolimnion is used up and gradually replaced by the progressively higher, and warmer, levels of the hypolimnion. In the late September/early October timeframe, Loon lake Reservoir turns over with the cooler hypolimnetic water mixing with the warmer epilimnetic water. This results in a decrease in water temperature of flows from Loon Lake Dam over the following two months, decreasing from a peak of about 16°C to around 2°C in late December.

Water temperatures throughout the 8.5-mile-long bypass reach are similar at the different logger sites. In the winter months, water temperatures hover slightly above zero, while in the peak summer months (July and August) mean daily water temperatures range from 15°C to 19°C. There is a gradual warming of water temperatures from the top of the reach to the bottom during the summer months and a gradual cooling from top to bottom in the fall and winter months. Water temperatures recorded at the Jerrett Creek logger show similar temperature ranges while the stream was flowing, with a mean daily water temperature on July 1, 2002 of 15.7°C measured before the stream dried up.

Water releases from Loon Lake Dam throughout the monitoring period were a constant 8 cfs. During the winter and spring runoff accretion flows from Jerrett, Barts, Dellar, and an un-named creek added to the 8 cfs release. Streamflow measurements were taken at these primary tributaries as well as in Gerle Creek directly upstream of Gerle Creek Reservoir during the summer and fall of 2002 - 2004 (Table 4.3-5.).

Table 4.3-5. Streamflow measurements of inflowing water from four tributaries to Gerle Creek, and Gerle Creek at the point of inflow to Gerle Creek Reservoir, summer and fall 2002 - 2004.

Date	Jerrett Creek Flow (cfs)	Dellar Creek Flow (cfs)	No name Creek Flow (cfs)	Barts Creek Flow (cfs)	Gerle Creek at Gerle Creek Reservoir (cfs)
2002					
June 5	11.0	2.9	--	8.1	--
June 13	5.2	1.3	2.8	4.5	21.0
June 20	2.9	1.0	2.2	3.4	16.8
June 30	--	0.4	0.9	1.7	--
July 10	0.2	0.2	0.5	1.1	--
August 8	No Flow	No Flow	0.1	0.4	9.7
Sept 18			No Flow	--	7.6
October 17				0.1	7.7
2003					
May 29	--	14.0	25.0	25.0	--
May 30	--	14.7	21.0	24.8	--
June 5	23.5	8.0	10.8	16.1	82.8
June 11	--	5.0	5.0	9.0	54.8
June 17	--	1.9	2.9	5.6	30.8
July 10	--	0.5	0.6	1.5	11.8
July 24	0.1	0.1	0.3	0.8	10.3
August 11	No Flow	No Flow	0.1	0.4	8.5
August 28			No Flow	0.1	8.1
September 10				0.1	7.9
September 30				0.1	7.1
2004					
May 7	-	9.6	14.0	16.3	-
June 10	3.1	1.0	1.4	2.4	20.0
June 21	-	0.4	0.8	1.5	-
July 14	-	No flow	0.2	0.7	-
August 10	-		No flow	0.2	-
September 8	No flow			-	-
September 30				0.1	-
October 1				-	8.6

DO measurements were taken at three stations within the Loon Lake Dam Reach that coincide generally with the location of temperature logger locations. The results of these sampling efforts are summarized in Table 4.3-6.

Table 4.3-6. Dissolved oxygen in mg/l (percent saturation) at water quality monitoring stations that coincide with or are near to water temperature monitoring sites in the Loon Lake Dam Reach, 2002 - 2004

Date	Below Loon Lake Dam (Station 7/GC6)	Upstream of Jerrett Creek (Station 9/GC5)	Upstream of Gerle Creek Reservoir (Station 14/GC3)
10/08/02	NA	NA	8.4 mg/l (78%)
11/11/02	10.0 mg/l(84%)	NA	12.7 mg/l (94%)
05/12/03	12.2 mg/l(97%)	NA	12.3 mg/l (101%)
09/17/03	8.7 mg/l(88%)	10.3 mg/l (94%)	11.3 mg/l (97%)
05/10/04	9.3 mg/l (NA)	10.8 mg/l (NA)	10.2 mg/l (NA)
09/19-22/04	7.4 mg/l (73%)	9.0 mg/l (84%)	9.6 mg/l (83%)
11/10/04	9.7 mg/l (79%)	NA	NA

4.3.4 Gerle Creek Dam Reach

4.3.4.1 Historic Information

The historical stream water temperature record for this reach of Gerle Creek is limited to water temperature data collected in November 1999 and June 2000, which were generally considered to be wet and above normal water years, respectively. In November 1999, inflowing water temperature from the Loon Lake Powerhouse tailrace was 11°C and water temperature in Gerle Creek was 5°C. Angel Creek was dry. In June 2000, the Loon Lake Powerhouse tailrace water was cold at 9°C and Gerle Creek and Angel creeks water temperatures were 13°C and 11°C, respectively.

4.3.4.2 Relicensing Water Temperature Monitoring

During the relicensing studies, water temperature monitoring was conducted at two sites in Gerle Creek Dam Reach: 1) upstream of the confluence of Gerle Creek with the South Fork Rubicon River (GC1); and 2) directly downstream of Gerle Creek Reservoir Dam (GC2) (Table 3.2-1). The period of monitoring at these two sites varies, determined by the time when the logger was first deployed and the time of the last download.

Water temperatures from the relicensing studies show moderate water temperatures that range from wintertime lows of 2°C to 5°C to summer highs of 12°C to 19°C. The temperature of the water released from Gerle Creek Dam showed a representative pattern of seasonal change, except for summer of 2001 when a steady increase in water temperatures were observed beginning about mid-July and continuing through mid-August, reaching a peak value in mid-August of just over 18°C, then falling sharply to a value of 16°C. Similar trends occurred in September 2003 and 2004, however the temperature did not peak above 18°C in those years. The 2001 event occurred at a time when the Loon Lake Powerhouse was not operating, thereby limiting a contribution of cold water to the downstream reaches. The start up of the powerhouse coincided with the sharp drop in water temperature in mid-August. By contrast, a similar event did not occur throughout the summer of 2002, a period of time when the Loon Lake Powerhouse was regularly in operation. Thus, the elevated spike in water temperature that was observed in the summer of 2001 was likely due to the fact that little to no water from the Loon Lake Reservoir hypolimnion was delivered into Gerle Creek Reservoir. Despite some of these yearly differences in summertime water temperatures emanating from Gerle Creek Reservoir, the thermal regime 1.2 miles downstream of the reservoir are very similar between years. In both 2002, 2003 and 2004, mean daily summer water temperatures at the bottom of the reach were approximately 12.5°C to 16°C.

DO data for the Gerle Creek Dam Reach is limited to one water quality station that coincides with the location of logger site. The site is water quality station 15 (Gerle Creek Dam outlet). The results of these sampling efforts are summarized in Table 4.3-7.

Table 4.3-7. Dissolved oxygen in mg/l (percent saturation) at water quality monitoring stations that coincide with or are near to a water temperature monitoring site in the Gerle Creek Dam Reach, 2002 – 2004.

Date	Below Gerle Creek Dam (Station 15/GC2)
10/08/02	8.2 mg/l (77%)
11/11/02	10.5 mg/l (88%)
05/12/03	13.1 mg/l (104%)
09/17/03	9.4 mg/l (96%)
05/10/04	9.4 mg/l (NA)
09/19/04	8.4 mg/l (83%)
10/31/04	11.1 mg/l (87%)

4.3.5 Robbs Peak Dam Reach

SMUD is unaware of any historic water temperature data collected in Robbs Peak Dam Reach. During the relicensing studies, water temperature monitoring was conducted at three sites on Robbs Peak Dam Reach: 1) about 2 miles downstream of the confluence of South Fork Rubicon River and Gerle Creek (SFRR0.5; 2) immediately downstream of the confluence of South Fork Rubicon River and Gerle Creek (SFRR1); 3) upstream of the same confluence (SFRR2); and 4) directly downstream of Robbs Peak Reservoir Dam (SFRR3). For reference, SMUD installed and maintained a water temperature logger upstream of Robbs Peak Reservoir (SFRR4) on South Fork Rubicon River (Table 3.2-1.).

The relicensing monitoring data depict a thermal regime that is similar to that of the Gerle Creek Dam Reach. This outcome is expected as both reaches are relatively short and lie within the same elevational range. Both Gerle Creek Reservoir and Robbs Peak Reservoir are at the same elevation (5,231 ft.), both reaches are less than 1.5 miles in length, and both end at the confluence of South Fork Rubicon River and Gerle Creek. Water inflowing to Robbs Peak Reservoir from South Fork Rubicon River ranges in temperature from mean daily wintertime lows of near zero to summertime peaks of 19°C to 21°C. The high summertime water temperatures occur as natural flows in South Fork Rubicon River transition from values of approximately 10 cfs in early July to less than 1 cfs at the end of August (Table 4.3-8).

Table 4.3-8. South Fork Rubicon River streamflow measurements of inflowing water to Robbs Peak Reservoir during summer and fall 2002 – 2004.

Date	SF Rubicon River inflow to Robbs Peak Reservoir Flow (cfs)
2002	
June 20	19.8
June 10	2.9
August 6	0.2
September 18	<0.05
2003	
May 30	133.0
June 6	121.0
June 18	34.7
July 10	3.7
July 24	1.4
August 11	0.4
August 28	0.2
September 10	0.1
September 30	<0.05
2004	
June 8	20.2
June 21	11.0
July 14	1.4
August 10	0.1
September 7	0.04
October 1	0.07

The thermal regime of water downstream of Robbs Peak Reservoir is very similar to that of the water downstream of Gerle Creek Reservoir. The same warming event that was described in mid-July through mid-August of 2001 below Gerle Creek Dam was also evident in the South Fork Rubicon River below Robbs Peak Dam. Below Robbs Peak Dam, the water temperatures during this period reached a high of 22°C before sharply falling to 16°C, coincident with the upstart of Loon Lake Powerhouse operations. During 2002, 2003 and 2004 water temperatures from Robbs Peak Reservoir were generally between 14°C and 19°C. Water temperatures 1.3 miles downstream, above the confluence with Gerle Creek, were very similar to that of the water temperature at the dam. Downstream of the confluence, summer water temperatures were somewhat cooler than upstream of the confluence. This was particularly evident in the summer of 2001, where the elevated water temperatures from Robbs Peak Reservoir had cooled at the confluence, clearly indicating that the high water temperatures from the reservoir were above the natural equilibrium temperature of the stream.

DO measurements were taken at two stations within the Robbs Peak Dam Reach that coincide generally with the location of temperature logger locations. The results of these sampling efforts are summarized in Table 4.3-9.

Table 4.3-9. Dissolved oxygen in mg/l (% saturation) at water quality monitoring stations that coincide with or are near to water temperature monitoring sites in the Robbs Peak Dam Reach, 2002 – 2004.

Date	Station 20 South Fork Rubicon River above Robbs Peak Reservoir	Station 17 South Fork Rubicon River below Gerle Creek Confluence
10/08/02	8.9 mg/l (82%)	7.4 mg/l (74%)
11/11/02	11.4 mg/l (90%)	11.6 mg/l (86%)
5/18/03 & 5/12/03	12.6 mg/l (96%)	11.9 mg/l (101%)
09/17/03	10.3 mg/l (99%)	8.8 mg/l (82%)
05/10/04	10.6 mg/l (NA)	10.3 mg/l (NA)
09/22/04	9.3 mg/l (89%)	8.6 mg/l (80%)
11/01/04	11.4 mg/l (87%)	12.2 mg/l (86%)

4.3.6 Ice House Dam Reach

4.3.6.1 Historic Information

SMUD collected *in situ* water temperature measurements in November 1999 (KEA 2000) when the South Fork Silver Creek entering Ice House Reservoir was flowing at 3 cfs. The water temperature was 4.5°C. Similar measurements in June 2000 were taken when the creek was flowing at 123 cfs and was measured at 13°C.

4.3.6.2 Relicensing Water Temperature Monitoring

During the relicensing studies, water temperature monitoring was conducted at five sites along the Ice House Dam Reach: 1) directly upstream of the point of inflow to Junction Reservoir (SFCR1); 2) midway within burned area (SFSC2); 3) downstream of Ice House Road bridge (SFSC3); 4) upstream of Ice House Road bridge (SFSC4); and 5) at Ice House Reservoir Dam (SFSC5). In addition, SMUD installed and maintained a continuous water temperature logger upstream of Ice House Reservoir on South Fork Silver Creek (SFSC6). (Table 3.2-1)

Water temperatures of the South Fork Silver Creek as it enters Ice House Reservoir are similar to the thermal regime exhibited by other naturally flowing stream segments of the UARP area. Temperatures range from near zero values in the winter months to summertime mean daily peaks of 17°C to 19°C. Streamflows measured above Ice House Reservoir in the summer of 2002, 2003 and 2004 show flows in July of approximately 10 to 20 cfs and in August of approximately 2 to 5 cfs (Table 4.3-10).

Table 4.3-10. South Fork Silver Creek streamflow measurements of inflowing water to Ice House Reservoir and at two locations downstream of the reservoir, summer and fall 2002 - 2004.

Date	SF Silver Creek above Ice House Reservoir Flow (cfs)	SF Silver Creek below Big Hill Creek Flow (cfs)	SF Silver Creek above Junction Reservoir Flow (cfs)
2002			
June 27	--	21.3	22.1
June 28	31.5	--	--

Table 4.3-10. South Fork Silver Creek streamflow measurements of inflowing water to Ice House Reservoir and at two locations downstream of the reservoir, summer and fall 2002 - 2004.

Date	SF Silver Creek above Ice House Reservoir Flow (cfs)	SF Silver Creek below Big Hill Creek Flow (cfs)	SF Silver Creek above Junction Reservoir Flow (cfs)
July 9	--	27.2	--
2003			
May 29	150	--	--
July 11	--		36.3
July 25	10.3	--	31.9
August 11	2.7	--	28.0
August 15		1.6	27.6
August 28	1.8	--	27.0
September 10	0.7	--	25.0
September 30	0.6	--	25.0
October 27	0.7	--	20.5
2004			
May 27	-	-	--
June 9	42.0	-	21.7
June 21	35.0	-	18.4
July 7	-	-	24.0
July 14	12.0	-	25.3
August 6	-	-	23.8
August 13	0.8	-	-
September 7	0.5	-	-
September 10	-	-	23.0
October 1	0.6	-	-
October 22	-	-	23.0

Water temperatures from flow as the base of Ice House Dam are generally constant, ranging from wintertime lows of approximately 4°C to summertime highs of 7°C, a nearly predictable annual range of temperatures. This is in marked contrast to the flows from Loon Lake Dam. The reason for the uniform cold temperatures flowing from the reservoir is because Ice House Reservoir forms a strong stratification marked by a substantial volume of hypolimnetic water at a nearly constant temperature of 7°C. Thus, as the summer progresses, releases from Ice House Dam do not change substantially in water temperature. Turnover of Ice House Reservoir occurs late in the season (around December 1 of each year) and results in a very slight increase in water temperature emanating from the reservoir.

Water temperatures throughout the reach warm substantially from the 7°C at Ice House Dam in the summer months. Water temperatures at the bottom of the reach attained mean daily values of 20°C to 21°C in 2001 - 2003. In 2004, mean daily temperatures did not exceed 20°C. Measured streamflows during these summer months ranged from 20 to 30 cfs. During the winter months, water temperatures in the reach were generally less than 5°C.

DO measurements were taken at three stations within the Ice House Dam Reach that coincide generally with the location of temperature logger locations. The results of these sampling efforts are summarized in Table 4.3-11.

Table 4.3-11. Dissolved oxygen in mg/l (% saturation) at water quality monitoring stations that coincide with or are near to water temperature monitoring stations in the Ice House Dam Reach.

Date	Station 24 South Fork Silver Creek Above Ice House Res.	Station 25 South Fork Silver Creek At Ice House Dam	Station 27 South Fork Silver Creek Above Junction Res.
11/14/02	11.9 mg/l (86%)	10.2 mg/l/ (88%)	10.3 mg/l (88%)
5/11/03	14.7 mg/l (99%)	11.6 mg/l/ (92%)	12.0 mg/l (103%)
9/18/03	11.0 mg/l/ (96%)	12.0 mg/l/ (98%)	NA
05/12/04	10.6 mg/l (NA)	10.7 mg/l (NA)	11.4 mg/l (NA)
09/23/04	10.5 mg/l (91%)	7.5 mg/l (62%)	9.8 mg/l (85%)
11/01/04	11.9 (83%)	9.3 mg/l (75%)	11.8 mg/l (88%)

4.3.7 Junction Dam Reach

4.3.7.1 Historic Information

The Licensee found historical stream water temperature data from both inflowing streams to Union Valley Reservoir, which include tailrace outflow of the Robbs Peak and Jones Fork powerhouses, and natural inflow of Tells, Big Silver, Wolf, Yellow Jacket, and Jones Fork Silver creeks and inflows to Junction Reservoir, which include the Union Valley tailrace outflow and regulated inflow from South Fork Silver Creek. *In situ* water quality data at the mouths of the streams that feed Union Valley Reservoir in 1999 and 2000, while limited in scope (essentially only covering the days of November 5, 1999, when the reservoir elevation was 4,815 feet, and June 5, 2000, when the reservoir elevation was 4,868 feet) demonstrated that surface water runoff into Union Valley Reservoir, such as at Wolf Creek, can rise as high as 20°C in June, while maintaining DO levels of 9.5 mg/l. The coldest water inflowing water temperatures were 10°C, recorded at two small (unnamed) streams entering the reservoir from the south with the DO concentrations of 9 mg/l. Specific conductance of the feeder streams ranged from 6.6 to 67.8 µS/cm. Temperatures measured for South Fork Silver Creek in June 2000 exceeded 19°C with an estimated flow of 47.3 cfs.

4.3.7.2 Relicensing Water Temperature Monitoring

During the relicensing studies, water temperature monitoring was conducted at two sites along Junction Dam Reach: 1) Silver Creek downstream of Junction Dam (SC4); and 2) Silver Creek directly upstream of Camino Reservoir (GC3). In addition, SMUD installed and maintained continuous water temperature loggers at three reference locations: 1) Tells Creek at its point of inflow to Union Valley Reservoir (TC1); 2) Big Silver Creek at its point of inflow to Union Valley Reservoir (BSC1); and 3) Jones Fork Silver Creek at its point of inflow to Union Valley Reservoir. (Table 3.2-1)

Water temperatures in Silver Creek directly downstream of Junction Reservoir range from winter lows of 2-5°C to summer highs of 8-10°C. These patterns are fairly constant from year to year, influence by hypolimnetic water temperatures of Junction Reservoir. The summer temperatures of 8°C and 10°C represent a warmed summer regime than the water emanating from Ice House Reservoir. At the bottom of the reach, water temperatures are relatively unchanged in the winter, but warm to mean daily summer values of 18°C to 20°C. This thermal regime is not substantially different from that of the feeder streams that flow into Union Valley Reservoir. The differences lie in the extremes. The feeder streams exhibit colder winter temperatures and warmer summer temperatures. In the winter, all three tributary streams exhibit water temperatures that are near zero, while in the summer, Big Silver and Jones Fork creeks reached peak mean daily temperatures of between 20°C to 22°C. Measured flows in the tributary streams were highly variable during the monitoring period (Table 4.3-12).

Table 4.3-12. Streamflow measurements of inflowing water of three tributaries to Union Valley Reservoir, summer and fall 2002 - 2004.

Date	Tells Creek Flow (cfs)	Big Silver Creek Flow (cfs)	Jones Fork Silver Creek Flow (cfs)
2002			
June 20	4.5	--	--
June 21	--	65.9	30.9
June 28	2.7	31.3	13.5
July 10	1.1	6.9	4.5
August 8	0.4	1.5	1.0
September 18	0.2	1.3	0.8
October 17	0.1	0.8	0.9
May 30	--	770	210.0
June 4	80	480	155.0
June 18	--	150	61.0
June 19	10.4	116	60.0
July 3	--	33.6	--
July 5	--	27.3	--
July 9	2.9	16.8	9.4
July 23	0.9	4.4	3.3
2003			
August 11	0.6	1.7	1.9
August 28	0.3	1.2	1.2
September 10	0.4	1.1	1.2
September 30	0.1	0.7	1.1
October 27	0.05	0.8	1.2
2004			
April 27	--	300	--
June 8/9/10	4.1	50.5	24.5
June 21	2.0	25.0	13.1
July 14	0.8	3.0	1.7
August 10	0.2	0.6	0.8
September 7	0.15	0.5	1.0
October 1	0.25	0.6	0.8

DO measurements were taken at three tributaries to Union Valley Reservoir and at two stations within the Junction Dam Reach that coincide within the general location of temperature logger locations. The results of these sampling efforts are summarized in Tables 4.3-13 and 4.3-14.

Table 4.3-13. Dissolved oxygen in mg/l (% saturation) at water quality monitoring stations of three tributary streams to Union Valley Reservoir.

Date	Station 21 Tells Creek	Station 22 Big Silver Creek	Station 23 Jones Fork Silver Cr.
11/14/02	11.9 mg/l (87%)	12.1 mg/l (88%)	11.5 mg/l (86%)
5/08/03	13.9 mg/l (98%)	14.0 mg/l (98%)	13.2 mg/l (95%)
9/17/03	10.2 mg/l (94%)	10.5 mg/l (103%)	10.0 mg/l (89%)
05/11/04	10.9 mg/l (NA)	11.5 mg/l (NA)	10.9 mg/l (NA)
09/20/04	9.5 mg/l (83%)	9.2 mg/l (86%)	8.8 mg/l (77%)
11/01/04	11.8 mg/l (85%)	11.5 mg/l (84%)	11.6 mg/l (85%)

Table 4.3-14. Dissolved oxygen in mg/l (% saturation) at water quality monitoring stations that coincide with or are near to water temperature monitoring stations in the Junction Dam Reach.

Date	Station 29 Silver Creek below Junction Reservoir	Station 32 Silver Creek above Camino Reservoir
11/14/02	10.1 mg/l (84%)	10.8 mg/l (92%)
5/08/03	13.3 mg/l (101%)	11.9 mg/l (98%)
9/16/03	10.8 mg/l (94%)	10.1 mg/l (98%)
05/05/04	10.8 (NA)	10.2 mg/l (NA)
09/14/04	NA	NA (102%)
11/08/04	10.4 mg/l (88%)	11.3 mg/l (97%)

4.3.8 Camino Dam/SFAR Reaches

SMUD is unaware of any historic water temperature data collected in Camino Dam Reach or the South Fork American River Reach.

During the relicensing studies, water temperature monitoring was conducted at three sites along Camino Dam/SFAR Reaches: 1) Silver Creek downstream of Camino Dam (SC2); 2) Silver Creek directly upstream of South Fork American River (GC1); and 3) South Fork American River downstream of the mouth of Silver Creek (SFAR11). In addition, SMUD installed and maintained a water temperature logger in the South Fork American River upstream of the mouth of Silver Creek (SFAR12). (Table 3.2-1)

The water temperatures of flows from Camino Dam are slightly warmer, but in general, very similar to those temperatures from Junction Dam. Winter temperatures range between 2°C and 5°C, while summer temperatures range between 10°C and 12°C for all years recorded. At the mouth of the Silver Creek, winter temperatures have increased slightly above the temperatures below the dam, but the summer water temperatures have warmed to mean daily high values of between 20°C and 23°C. This thermal regime is similar to that of the South Fork American River, above and below Silver Creek. At both South Fork American River sites, winter water temperatures are generally colder than Silver Creek in the winter and warmer than Silver Creek in the summer. A comparison of the two South Fork American River sites shows nearly identical water temperature values throughout the year, indicating that the inflow from Silver Creek did not significantly influence water temperatures in the South Fork American River.

Limited DO data exists for the Camino Dam Reach. One water quality station was sampled that coincides with the location of as temperature logger sites. The site was water quality station 34 (Camino Dam outlet). The results of these sampling efforts are summarized in Table 4.3-15.

Table 4.3-15. Dissolved oxygen in mg/l (percent saturation) at water quality monitoring stations that coincide with or are near to a water temperature monitoring site in the Camino Dam Reach, 2002 - 2004.

Date	Below Camino Dam (Station 34)
11/13/02	10.6 mg/l (92%)
05/05/03	NA (97%)
09/16/03	11.2 mg/l (99%)
05/04/04	11.0 mg/l (NA)
09/12/04	11.1 mg/l (102%)
10/24/04	10.3 mg/l (94%)

4.3.9 Brush Creek Dam Reach

The Licensee is unaware of any historic water temperature data collected in Brush Creek Dam Reach.

Water temperature monitoring in the Brush Creek Reach was conducted at two sites within the reach, but data is available only at a single site directly downstream of the Brush Creek Dam (BC2) (Table 3.2-1). Water temperatures recorded at this site exhibited winter lows in the range of 6°C to 8°C and summer high values of 12°C to 18°C. Although limited data is available from the logger at the downstream end of the reach near Slab Creek Reservoir (viz., <17°C daily mean in July), water temperatures in this reach are not predicted to warm significantly from the BC2 site values due to the incised canyon and closed riparian canopy throughout the reach.

Limited DO data exists for the Brush Creek Dam Reach. One water quality station was sampled that coincides with the location of water temperature station. The site was water quality station 40 (Brush Creek Dam outlet). The results of these sampling efforts are summarized in Table 4.3-16.

Table 4.3-16. Dissolved oxygen in mg/l (percent saturation) at water quality monitoring stations that coincide with or are near to a water temperature monitoring site in the Brush Creek Dam Reach, 2002 – 2004.

Date	Below Brush Creek Dam (Station 40)
11/13/02	10.1 mg/l (92%)
05/06/03	NA (95%)
09/16/03	9.2 mg/l (93%)
05/04/04	10.8 mg/l (NA)

Table 4.3-16. Dissolved oxygen in mg/l (percent saturation) at water quality monitoring stations that coincide with or are near to a water temperature monitoring site in the Brush Creek Dam Reach, 2002 – 2004.

Date	Below Brush Creek Dam (Station 40)
09/12/04	10.7 mg/l (90%)
11/01/04	10.7 mg/l (97%)

4.3.10 Slab Creek Dam Reach

4.3.10.1 Historic Information

SMUD's water quality studies in 1999 and 2000 included water temperature measurement sites on Slab and Brush creeks located on the north side of Slab Creek Reservoir, a site on the South Fork American River upstream of the reservoir, and a site in Long Canyon Creek on the south end of the reservoir. Temperatures of the inflow streams ranged from 12°C to 14°C. DO ranged from 9.5 to 11.5 mg/l, and pH ranged from 6.7 to 7.1 at sites upstream of the UARP.

4.3.10.2 Relicensing Water Temperature Monitoring

During the relicensing studies, water temperature monitoring was conducted at four sites along Slab Creek Dam Reach: 1) South Fork American River downstream of Slab Creek Dam (SFAR9); 2) South Fork American River below the walking bridge (SFAR8, located about 300 feet below the dam); 3) South Fork American River at Mosquito Road Bridge (SFAR7); and 4) South Fork American River upstream of White Rock Powerhouse (SFAR6).

In keeping with the warming trend moving downriver, the water temperature of water discharged from Slab Creek Dam are warmer than those of Camino Dam (14°C at Slab Creek Dam compared with 10.5°C at Camino Dam in July). Winter temperatures range between 2.8°C and 9.2°C, while summer temperatures range between 10.2°C and 16°C. Approximately halfway through the reach at Mosquito Road Bridge, summer water temperatures increased to mean daily peak value of 20.5°C, while at the bottom of the reach, just upstream of White Rock Powerhouse, mean daily value peaked at 24°C. Winter water temperatures upstream of White Rock Powerhouse range between 3.6°C and 13.3°C.

Limited DO data exists for the Slab Creek Dam Reach. One water quality station was sampled that coincides with the location of logger sites (water quality station 43 - Slab Creek Dam Outlet) (Table 4.3-17).

Table 4.3-17. Dissolved oxygen in mg/l (percent saturation) at water quality monitoring stations that coincide with or are near to a water temperature monitoring site in the Slab Creek Dam Reach, 2002 – 2004.

Date	Below Slab Creek Dam (Station 43)
10/09/02	10.3 mg/l (94%)
11/12/02	10.0 mg/l (89%)

Table 4.3-17. Dissolved oxygen in mg/l (percent saturation) at water quality monitoring stations that coincide with or are near to a water temperature monitoring site in the Slab Creek Dam Reach, 2002 – 2004.

Date	Below Slab Creek Dam (Station 43)
05/11/03	12.5 mg/l (105%)
09/15/03	10.2 mg/l (97%)
05/03/04	11.5 mg/l (NA%)
09/13/04	10.4 mg/l (NA)
10/25/04	10.2 mg/l (95%)

4.3.11 Reach Downstream of Chili Bar Dam

4.3.11.1 Historic Information

Historic water temperature data monitoring information for the Reach Downstream of Chili Bar is limited to the record of the USGS gage downstream of Chili Bar Dam near Lotus (USGS Station 11445500 below Lotus). A summary of the data from this recording station for selected months of the years 1983-1994 is provided in Table 4.3-18.

Table 4.3-18. Summary statistics of 1983-1994 record of mean daily water temperature data (°C), in the Reach Downstream of Chili Bar (USGS Station 11445500, below Lotus).

Statistic	March	June	September	December
Maximum	10.6	18.0	18.5	11.0
Minimum	5.0	12.5	12.0	4.0
Mean	7.4	15.6	14.5	6.9

Water temperatures at the monitoring site generally ranged from winter lows of approximately 5-10ºC to summer highs of 15-18ºC, which is consistent with the results of the Licensees' relicensing water temperature monitoring.

4.3.11.2 Relicensing Water Temperature Monitoring

Water temperature monitoring was conducted at four sites along the Reach Downstream of Chili Bar: 1) South Fork American River downstream of Chili Bar Dam (SFAR4); 2) South Fork American River directly upstream of Dutch Creek (SFAR3); 3) South Fork American River directly upstream of Greenwood Creek (SFAR2); and 4) South Fork American River directly upstream of Weber Creek (SFAR1) (Table 3.2-1).

The results of the monitoring study show mean daily water temperatures downstream of Chili Bar Dam (SFAR4) of between 4.8°C and 9.2°C during the winter and between 11°C and 18°C during summer. A gradual warming trend is observed over the course of the reach. At the most downstream monitoring site below Weber Creek (SFAR1), mean daily winter temperatures range between 5°C and 12°C, representing limited wintertime warming throughout the reach. Summer mean daily water temperatures reach values of between 13°C and 21.7°C.

DO measurements were taken at three stations within the Reach Downstream of Chili Bar that coincide generally with the location of the temperature logger locations. The results of these sampling efforts are summarized in Table 4.3-19.

Table 4.3-19. Dissolved oxygen in mg/l (% saturation) at water quality monitoring stations that coincide with or are near to water temperature monitoring sites in the Reach Downstream of Chili Bar.

Date	Station 48 SF American River At Chili Bar Dam	Station 51 SF American River Below Greenwood Cr.	Station 54 SF American River Below Weber Cr.
10/09/02	11.3 mg/l (103%)	11.4 mg/l (108%)	11.2 mg/l (108%)
11/12/02	10.3 mg/l (91%)	11.2 mg/l (100%)	11.6 mg/l (104%)
5/12/03	13.0 mg/l (110%)	12.6 mg/l (108%)	7.4 mg/l (74%)
9/18/03	10.3 mg/g (102%)	10.5 mg/l (108%)	10.6 mg/l (102%)
05/10/04	11.2 mg/l (NA)	10.7 mg/l (NA)	11.0 mg/l (NA)
09/13/04	10.3 mg/l (NA)	9.7 mg/l (63%)	9.8 mg/l (100%)
10/25/04	10.4 mg/l (98%)	10.6 mg/l (102%)	10.7 mg/l (102%)

4.4 Water Temperature Modeling

Provided below is a summary of SMUD's water temperature modeling efforts. SMUD is unaware of any historic efforts to model water temperature in any of the UARP reaches.

4.4.1 Ice House Dam Reach Modeling

South Fork Silver Creek between Ice House Reservoir and Junction Reservoir was partitioned into 60 nodes to account for topographic shading, channel geometry and basin drainage network. The two largest tributaries, Peavine and Big Hill Creeks, were included in the model network. The SNTEMP calibrated model input files are provided in Appendix C. These files include the geometry, climate, shade, meteorology, and hydrology data used in this model.

The minimum time step allowed by SNTEMP (1-day) was used in this model application. An average velocity of 0.213 m/s (0.7 f./s) equates to a travel time of 24 hours for this reach, which is approximately 19 km long. Velocity data collected along multiple transects within the lower South Fork Silver Creek reach as part of the instream flow studies suggests that this is a reasonable travel time estimate for summer baseflow conditions.

Channel geometry data used in the SNTEMP model was derived from several sources. Channel node distances, elevation, latitude and azimuth data were derived from the project Geographic Information System (GIS). The model computes stream width as a function of flow using the equation Width = aQ^b where Q is discharge, a is the width coefficient and b is the width exponent. An overall width to flow relationship for the reach was determined through a review of data provided from the instream flow study for lower South Fork Silver Creek. A default width coefficient and width exponent were calculated, which were then adjusted during model calibration within sub-reaches between temperature verification points. Manning's n values used in the model primarily affect the range between predicted maximum and mean temperatures.

Manning's n values were used as a calibration factor to achieve a best fit to the observed daily mean and maximum temperature records. SNTEMP does not have the capability to model stratified reservoirs. The SNTEMP model knows nothing of conditions upstream of the model's designated starting point. Maximum temperature predictions are empirically derived by extending the current reach's stream geometry indefinitely upstream to simulate conditions that a parcel of water would travel between solar noon (assumed time of mean daily water temperature) and solar sunset (assumed time of maximum daily water temperature. Hypolimnetic releases from Ice House Reservoir exhibit almost no diurnal variation. Starting mean daily temperatures just below the reservoir are provided as a boundary condition to the model. In order to force the model to predict maximum daily temperatures characteristic of a near constant temperature hypolimnetic release, very high Manning's n values and an extremely narrow width coefficient were employed at the starting node below the reservoir. Manning's n values were similarly set relatively high for the more upstream nodes within the model stream network to reflect that temperatures are affected by the hypoliminetic release. In the context of SNTEMP modeling, Manning's n values should be considered a calibration adjustment factor and may appear unrealistic at times relative to traditional concepts of Manning's n being a hydraulic retardance index.

The SNTEMP model incorporates both topographic and vegetation shade. Topographic shade was estimated separately for eastside and Westside of each segment within the main channel network based on basin topography. The average topographic altitude (radians) was computed with GIS for each streambank for each segment.

Vegetation shade data includes vegetation height, crown diameter and vegetation offset relative to channel width. Analysis of aerial photos and limited ground truthing data available from recent terrestrial riparian studies formed the basis for vegetation shade data used in the model. Riparian vegetation that provides shade is lacking for a large portion of the stream network for the Ice House model due to fire. Vegetation shade geometry data was set to provide zero shade within reaches where the aerial photos indicated that the burn had eliminated overhead canopy within riparian areas. Willows and other vegetation with canopy heights of less than 5 m were considered to provide no effective shade for modeling purposes.

The model requires hydrologic data (mean daily flow) to be provided at all headwaters, and tributary junctions as well as any internal flow calibration points. Mean daily flow data just downstream of Ice House Reservoir area are available at the USGS gaging station No. 11441500. SMUD partitioned natural inflow into Junction Reservoir (acre feet) based on proportion of the total drainage basin within each of the following sub-basins.

- (p) Accretion to S. F. Silver Creek below of Peavine Ridge excluding inflow to Ice House Reservoir
- (q)Accretion to S. F. Silver Creek below Windmiller Ridge excluding (p)
- (r) Accretion to S. F. Silver Creek below Big Hill Canyon excluding (q)
- (s) Accretion to S. F. Silver Creek at Junction Reservoir excluding (r).

The accretion (r) below Big Hill Canyon was subsequently allocated as 50% to Big Hill Creek and 50% to lateral inflow along the main channel S. F. Silver Creek between Windmiller Ridge and Big Hill Canyon based on approximate drainage area. Hydrology nodes were established within the model framework to provide estimated flow at each of the above points where streamflow data were provided as boundary conditions for the model. An arbitrary flow of 1 cfs was established at headwaters of Peavine and Big Hill tributaries. The model then computes the lateral inflow (groundwater) as the difference between the headwater flow and the mean daily flow provided at the tributary junction node.

Mean daily and maximum daily temperatures were calculated based on continuous hourly temperature records available at five points along the main channel.

Name	**Description**	**Distance (km) from downstream endpoint**
SFSC1	S.F. Silver Creek upstream of Junction Reservoir	0.12
SFSC2	S.F. Silver Creek midway between burn area	8.92
SFSC3	S.F. Silver Creek downstream of Ice House Road	16.57
SFSC4	S.F. Silver Creek above Ice House Road	17.7
SFSC5	S.F. Silver Creek below Ice House Dam	19.0

Water temperature data were not available for either Peavine Creek or Big Hill Creek. The modeled mean daily temperatures at the tributary mouths (T node) were “forced” by adding a calibration node (K node) 0.1 km upstream of the tributary mouth. The model overrides predicted daily water temperatures with user-provided mean daily water temperature data at these K nodes. Concurrent thermograph data from the mouth of Jones Fork Silver Creek (JFSC1) were used for the K node at the mouth of Big Hill Creek. Concurrent thermograph data from Silver Creek upstream of Ice House Reservoir (SFSC6) were used for the initial values for a K node at the mouth of Peavine Creek. Temperatures for Peavine Creek were then adjusted as part of the calibration process for the mainstem. The model predicts daily maximum temperatures for the K nodes. Manning’s *n* values were adjusted for each tributary to achieve the best fit for the surrogate maximum daily water temperature record.

Meteorological data for each time step required by the model includes air temperature, wind speed, relative humidity, solar radiation and percent possible sun. The user specifies the latitude and elevation of the source reference station for climate data. The model adjusts the climate data to the elevation for each segment within the model network (the model adds a meteorological node for every 300 m elevation change). For the Ice House model, air temperature data from the nearby Pacific House NCDC climate station (Coop I.D. No. 04659; elevation 1048.5 m) were used. Relative humidity values from the Camino climate station (elev. 847.3 m) were adjusted for air temperature at Pacific House. Data for wind speed, solar radiation and percent possible sun are also from the Camino climate station.

Predicted daily mean and maximum temperatures are compared to observed temperatures during model calibration. Air temperature is a calibration consideration that is positively correlated with water temperature. Relative humidity and wind speed are inversely correlated with water temperature. Relative humidity is a primary calibration factor for mean daily temperature that was adjusted, as necessary, for selected days within the metrological file. The model is relatively sensitive to this parameter, especially as humidity drops below 50%. Sensitivities of the SNTEMP model are reported in Sullivan et al (1990). Relative humidity was rarely adjusted by more than ±15% and kept within a range observed within a few days of the adjusted data. Solar radiation and percent possible sun were also adjusted, as necessary, within the metrological file. Precipitation and cloud cover data from other nearby climate stations were reviewed to identify appropriate time periods and ranges for solar adjustment. The time file for SNTEMP allows for time period specific (daily) calibration factor adjustments for air temperature and windspeed. Calibration factors for air temperature and wind speed as well as other user specified model input coefficients are listed in Table 4.4-1

Table 4.4-1. Calibration constants and value ranges for the lower Silver Creek temperature model

Dust coefficient	0.04
Width exponent	0.0879 default with range 0.1250 – 0.0879
Width coefficient	14.21550 default with range 7.0 – 14.2150 except 0.1 at dam outlet
Ground reflectivity	0ld snow = 0.6 Apr 01 – Jun 03; vegetation/rock = 0.22 (TVA 1972)
Evaporation factor (EFA)	40
Evaporation factor (EFB)	15
Evaporation factor (EFC)	0
Lateral Inflow temperature	10°C
Air calibration coefficient range	0.7 – 1.1
Air temperature calibration exponent range	0.9 -1.0
Wind speed calibration coefficient	0.7 – 2.0
Wind speed calibration exponent range	1.0 – 1.3
Manning's n Silver Creek	0.001 to 0.5; 0.999 used just below dam to force low diurnal predicted temperatures
Travel time	7,054 sec/km

The predicted daily mean and maximum temperatures for the calibrated model relative to observed temperatures are shown in Figures 4.4-1 through 4.4-4. Statistics on the accuracy and bias of the calibrated model for South Fork Silver below Ice House Reservoir are shown in Table 4.4-2.

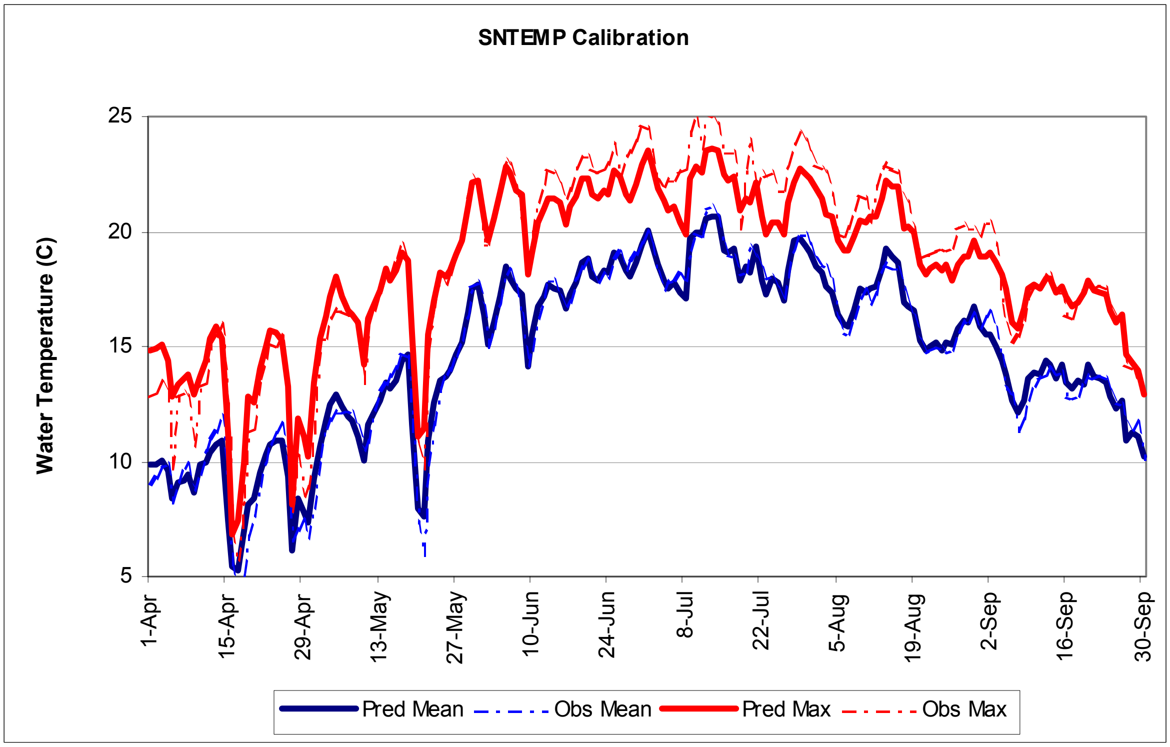


Figure 4.4-1. **SNTEMP calibration results for South Fork Silver Creek above Junction Reservoir (SFSC1).**

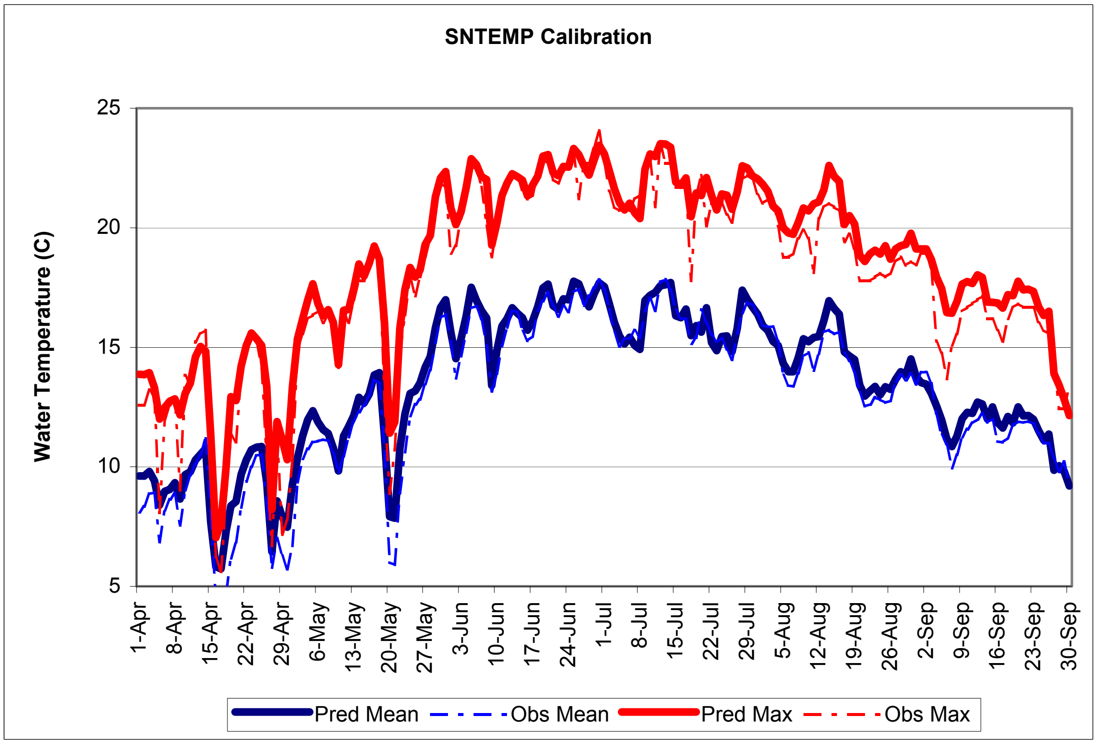


Figure 4.4-2. **SNTEMP calibration results for South Fork Silver Creek mid-way between burn area (SFSC2).**

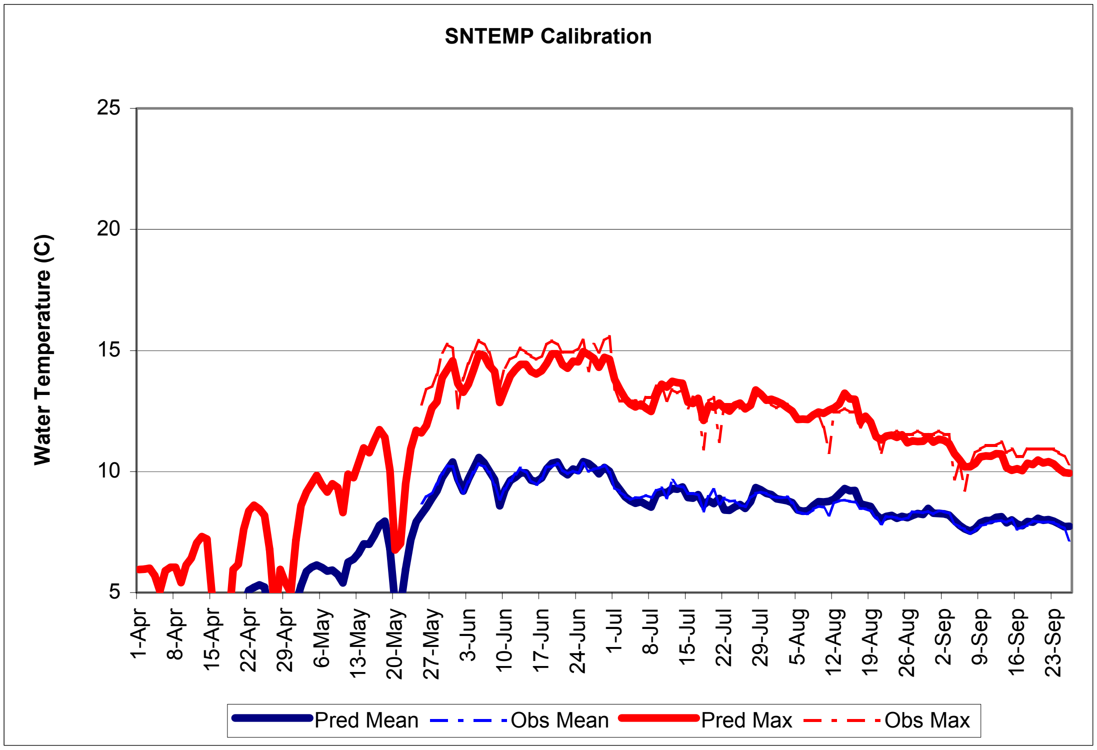


Figure 4.4-3. SNTEMP calibration results for South Fork Silver Creek below Ice House Dam Road (SFSC3).

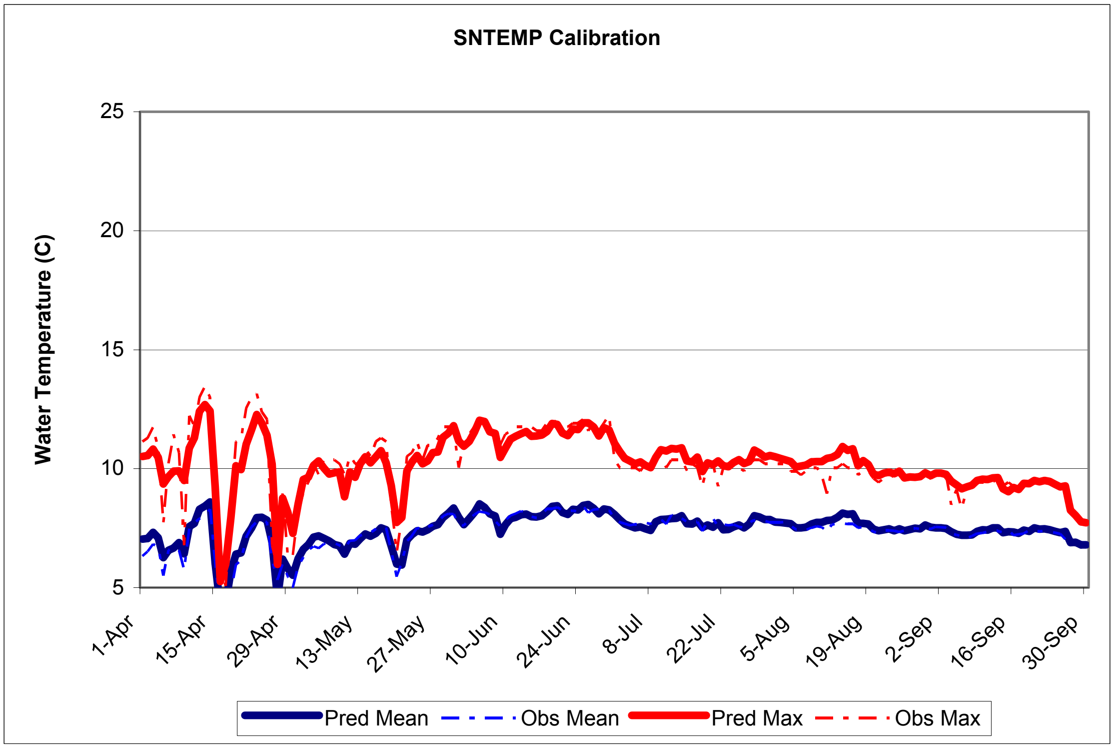


Figure 4.4-4. SNTEMP calibration results for South Fork Silver Creek above Ice House Dam Road (SFSC4).

Table 4.4-2. Calibration statistics for lower South Fork Silver Creek temperature model: predicted mean daily water temperatures.

Station		Absolute Mean Error (°C)	Bias (°C)	Maximum Error (°C)	Correlation R^2
SFSC1	April 1- Sept 30 2002	0.41	0.02	2.16	0.99
	Jul 1 - Aug 31 2002	0.33			
SFSC2	April 1- Sept 30 2002	0.6	0.02	3.2	0.99
	Jul 1 - Aug 31 2002	0.42			
SFSC3	April 1- Sept 30 2002	0.15	0.09	0.57	0.97
	Jul 1 - Aug 31 2002	0.18			
SFSC4	April 1- Sept 30 2002	0.17	0.01	1.1	0.97
	Jul 1 - Aug 31 2002	0.13			

The goodness-of-fit for the calibrated SNTEMP model for lower South Fork Silver Creek is considered excellent for mean daily water temperature Most of the calibration sites had an absolute mean error (AME) less than 0.5 °C as well as low bias. The maximum error in predicted mean daily temperature occurred early within the model period on days when significant precipitation was recorded at the nearby climate station.

Predictions for maximum daily temperature showed a similar trend but absolute mean errors were larger than the corresponding AME for mean temperatures. Table 4.4-3 lists the AME for predicted maximum daily water temperatures. Error bias for maximum was similar to mean temperatures.

Table 4.4-3. Calibration statistics for lower Silver Creek temperature model: predicted maximum daily water temperatures

Station		Absolute Mean Error (°C)
SFSC1	April 1- Sept 30 2002	0.91
	Jul 1 - Aug 31 2002	1.24
SFSC2	April 1- Sept 30 2002	0.82
	Jul 1 - Aug 31 2002	0.78
SFSC3	April 1- Sept 30 2002	0.46
	Jul 1 - Aug 31 2002	0.3
SFSC4	April 1- Sept 30 2002	0.44
	Jul 1 - Aug 31 2002	0.33

Alternate flow releases from Ice House Reservoir were modeled while keeping all other factors in the calibrated model unchanged. Accretion within the lower Silver Creek bypass reach was kept the same as in the calibrated model. Figures 4.4-5 through Figure 4.4-8 show the predicted temperature regimes in lower South Fork Silver Creek associated with releases of 5 cfs, 15 cfs, 30 cfs and 60 cfs, respectively.

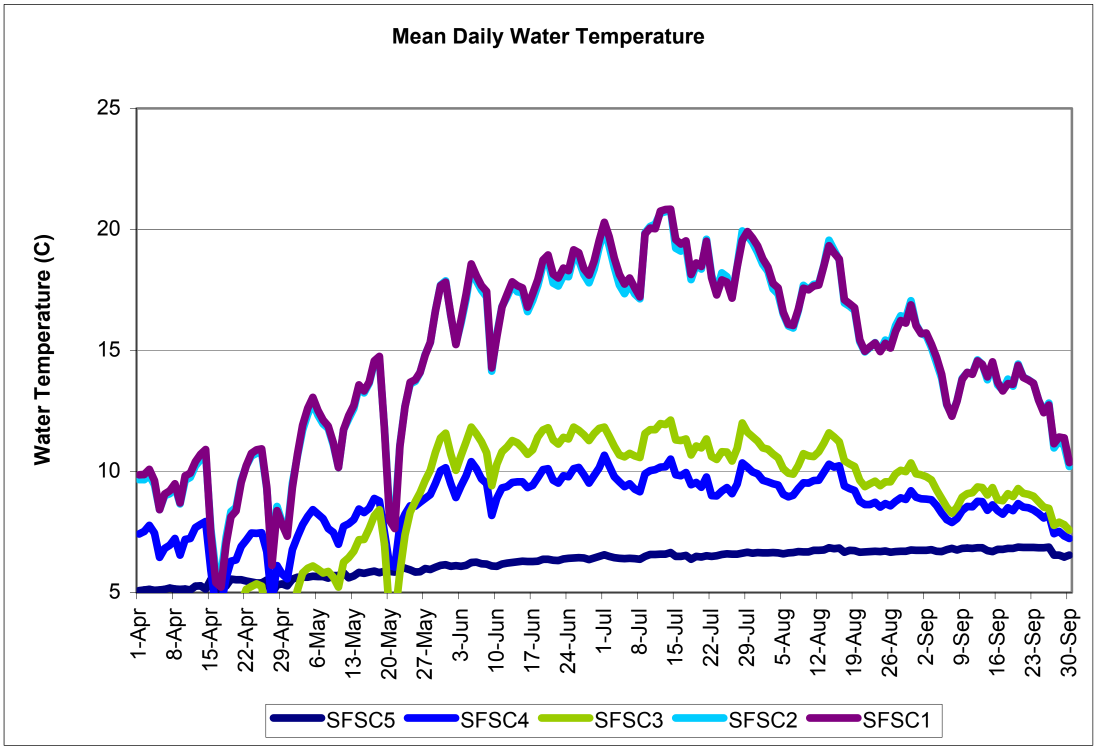


Figure 4.4-5. **Predicted mean daily temperatures with a 5 cfs constant release from Ice House Reservoir.**

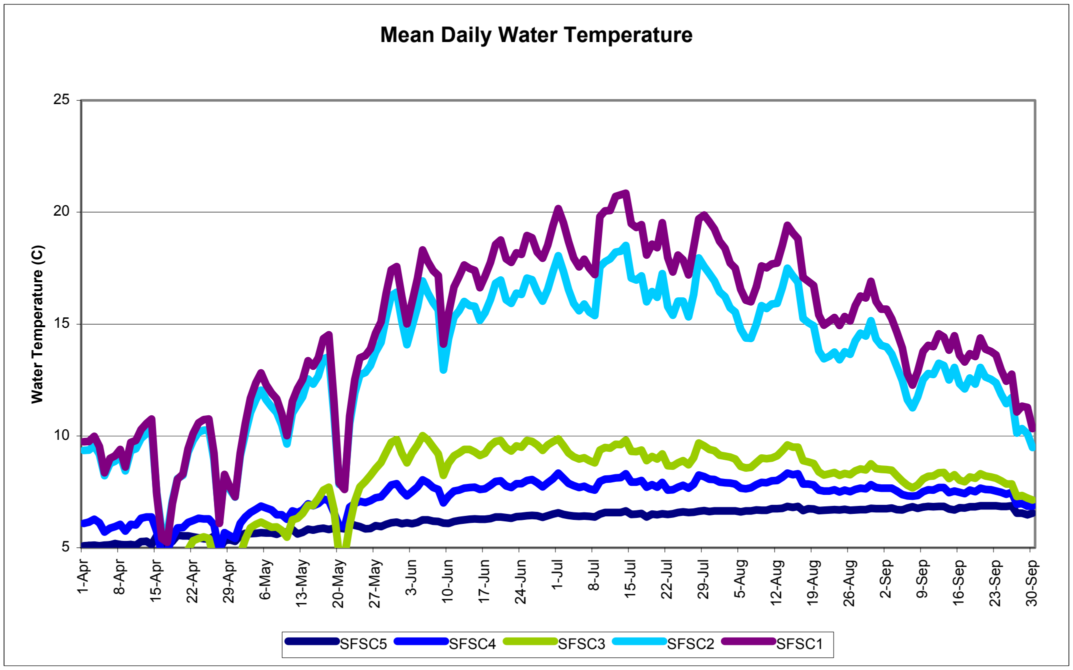


Figure 4.4-6. **Predicted mean daily temperatures with a 15 cfs constant release from Ice House Reservoir.**

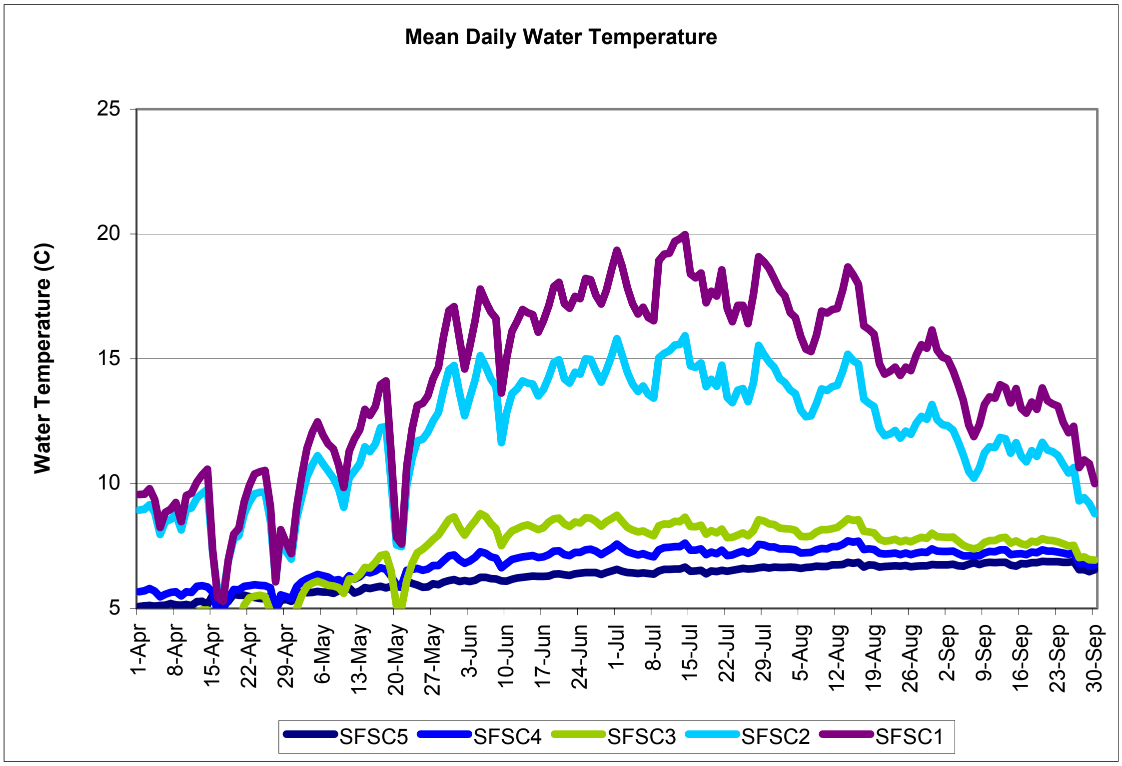


Figure 4.4-7. **Predicted mean daily temperatures with a 30 cfs constant release from Ice House Reservoir.**

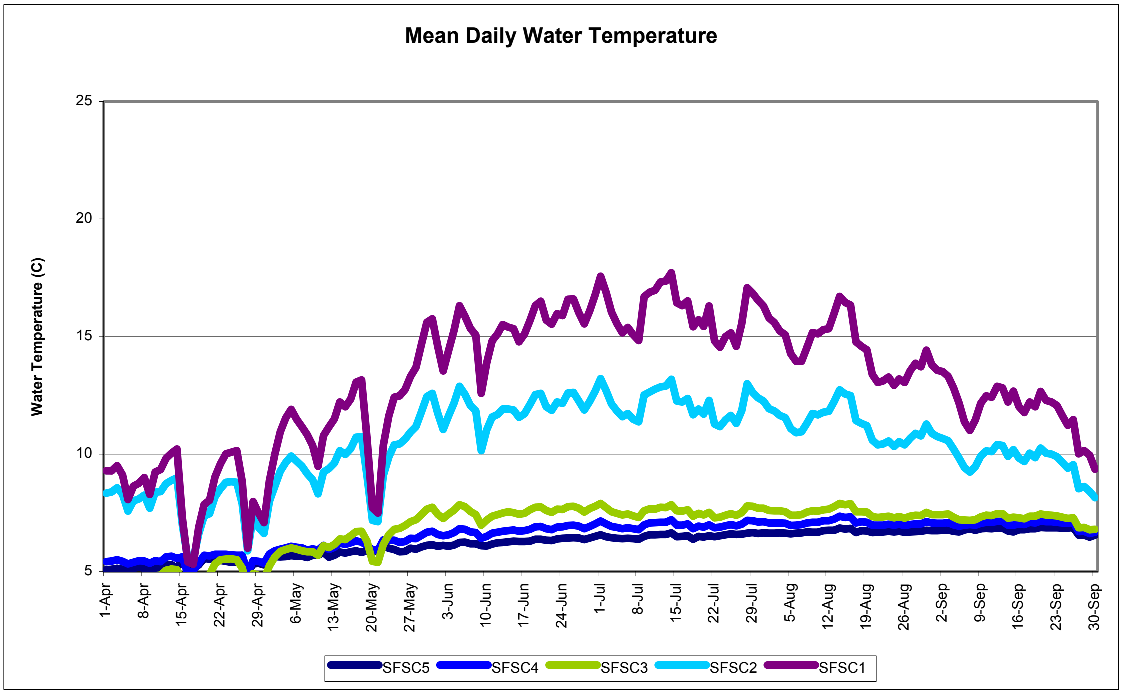


Figure 4.4-8. **Predicted mean daily temperatures with a 60 cfs constant release from Ice House Reservoir.**

Figure 4.4-9 compares the pattern in predicted daily mean water temperatures at the mouth of South Fork silver Creek (just above Junction Reservoir (SFSC1) for various flow releases from Ice House Reservoir.

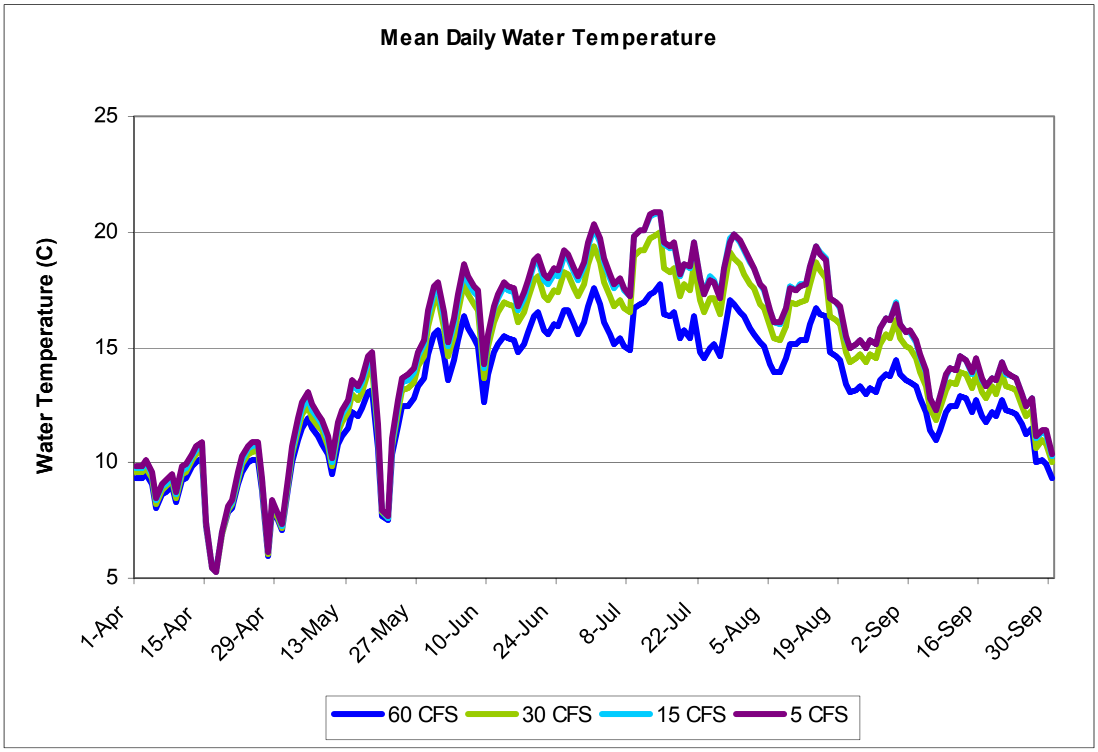


Figure 4.4-9. **Predicted daily mean water temperatures at the mouth of South Fork Silver Creek just above Junction Reservoir resulting from a variable release at Ice House Reservoir.**

The summer temperature regime with natural flows (unregulated by Ice House Reservoir) were also modeled. For this model application, SMUD generated mean daily flows into Ice House Reservoir, which were used as the flow at the upper end of the model reach. The temperature record for SFSC6 (South Fork Silver Creek upstream of Ice House Reservoir) was used as the starting temperature. It was also necessary to modify the manning's n value and channel width coefficient for the most upstream node in the model network since the setup for existing conditions is configured to reflect the upstream near constant temperature of the hypolimnetic release from the reservoir. Figures 4.4-10 through 4.4-14 compare the predicted temperatures with natural flow to the calibrated model results for the regulated flow. The predicted temperatures were identical at the lower end of the model reach (SFSC1 South Fork Silver Creek just above Junciton Reservoir. The flow is in equilibrium with the surrounding conditions. Existing summer water temperatures at this point are the same as natural conditions. Just upstream at SFSC2, the maximum annual mean daily temperature under natural conditions is predicted to be 4°C warmer than the existing condition. The time of annual peak temperature is also later under natural conditions. Note that mean daily predicted temperature at SFSC3for natural conditions peaks at 16.5 °C, which is 3 °C cooler than upstream at SFSC2. The cooling effect of Peavine Creek is apparent in the predictions for natural conditions; however, this effect is masked for existing conditions since the hypolimnetic release from Ice House Reservoir is cool relative to Peavine Creek in the summer. The difference between natural condition and existing condition becomes more pronounce the closer to the outlet of Ice House Reservoir.

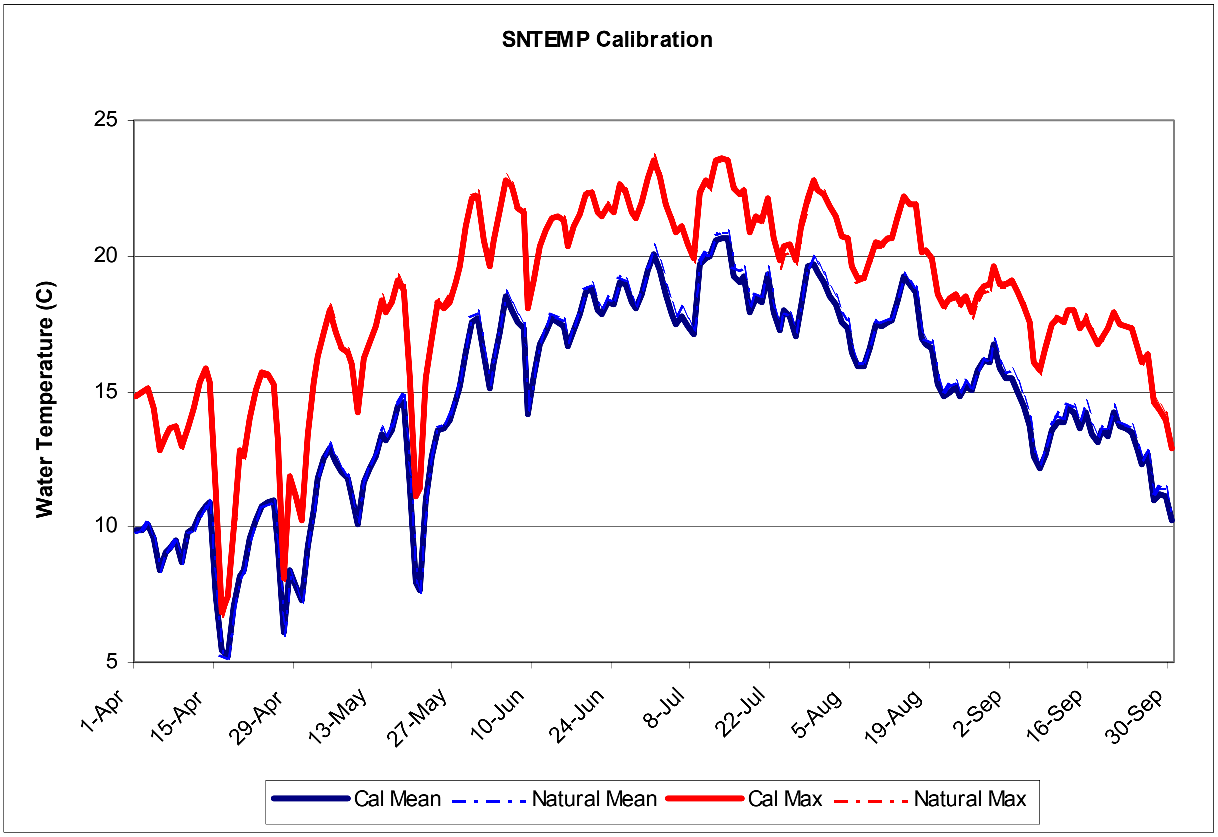


Figure 4.4-10. **SNTEMP results for South Fork Silver Creek just above Junction Reservoir (SFSC1) comparison of temperature for existing condition (calibrated) and natural flow.**

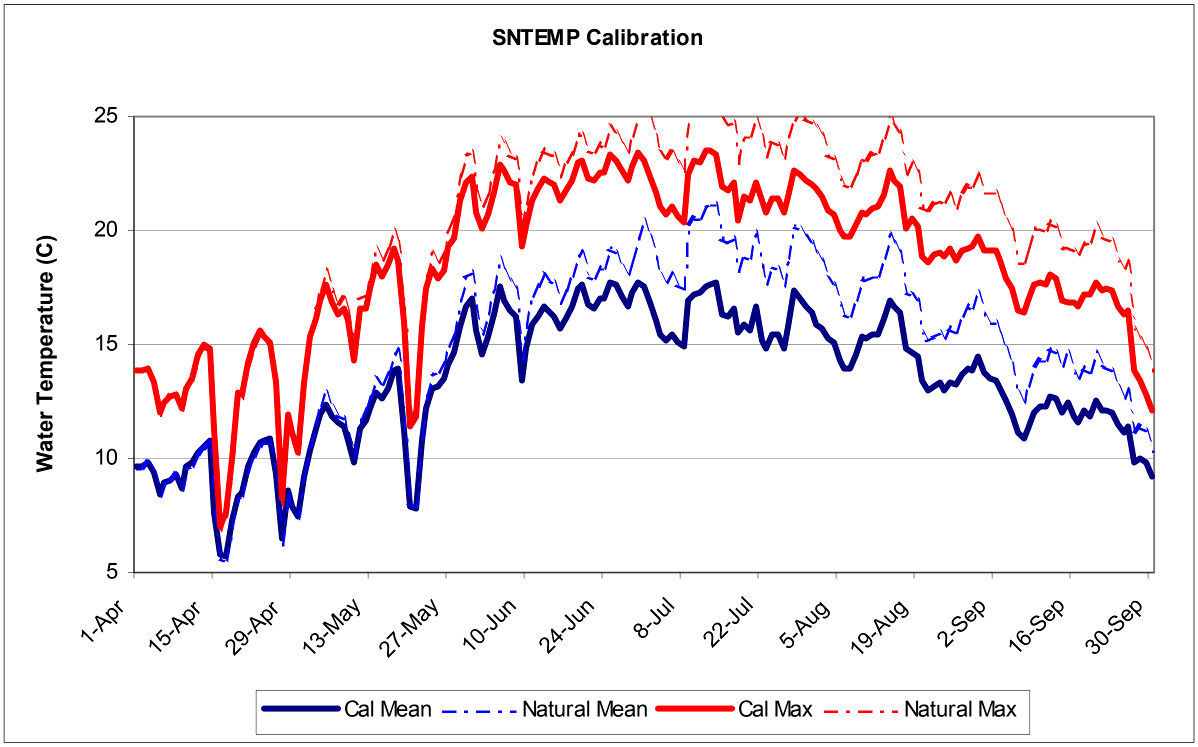


Figure 4.4-11. **SNTEMP results for South Fork Silver Creek (SFSC2 mid way burn area) comparison of temperature for existing condition (calibrated) and natural flow.**

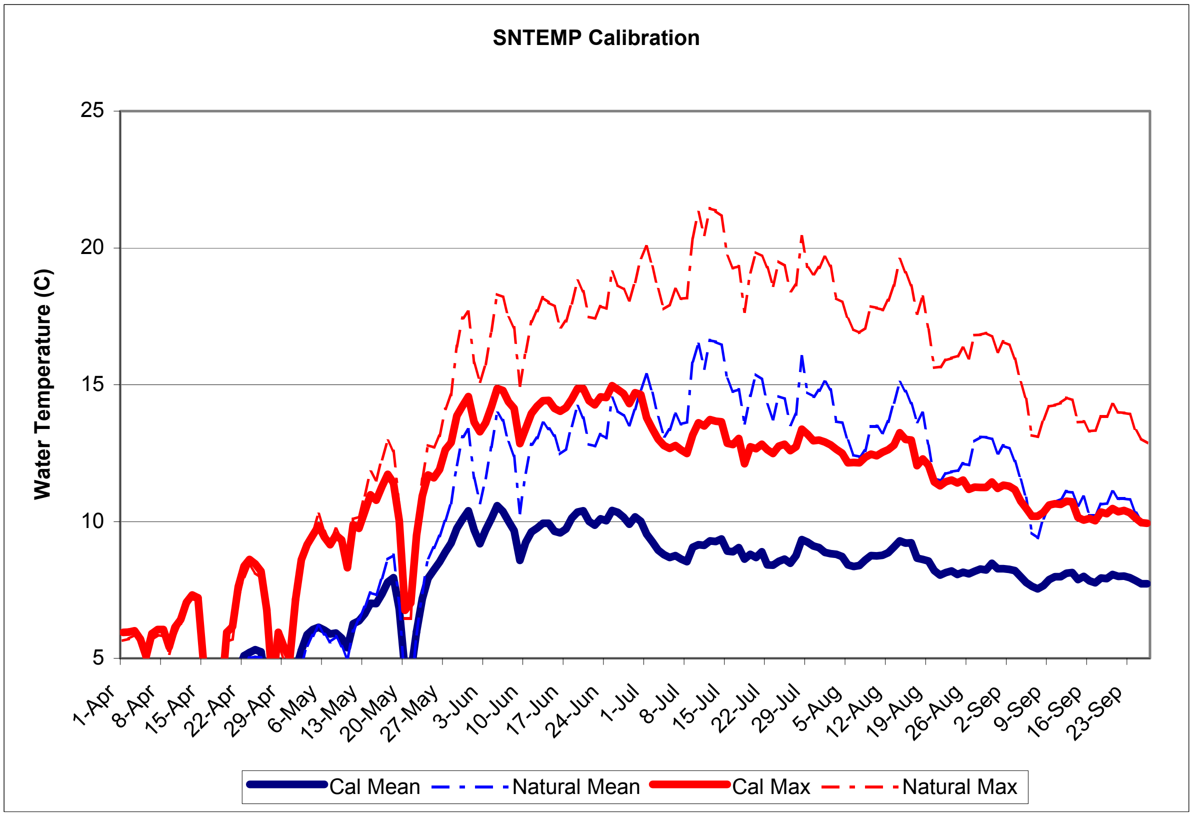


Figure 4.4-12. **SNTEMP results for South Fork Silver Creek (SFSC3 below Ice House Dam Road) comparison of temperature for existing condition (calibrated) and natural flow.**

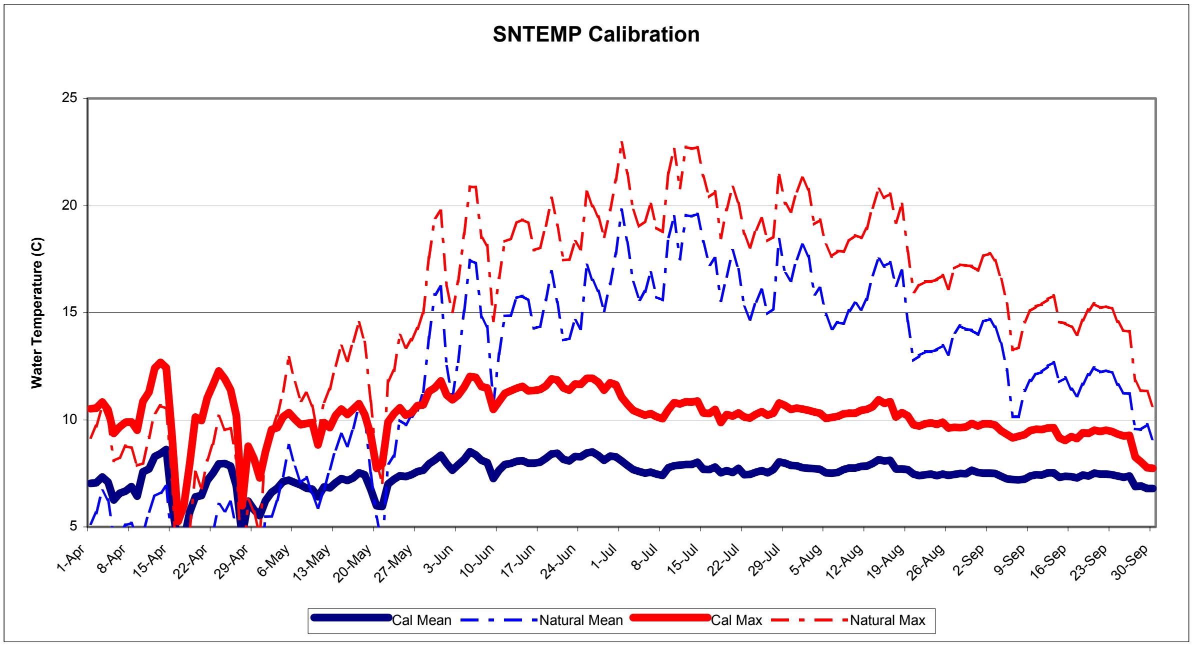


Figure 4.4-13. **SNTEMP results for South Fork Silver Creek (SFSC4 above Ice House Dam Road) comparison of temperature for existing condition (calibrated) and natural flow.**

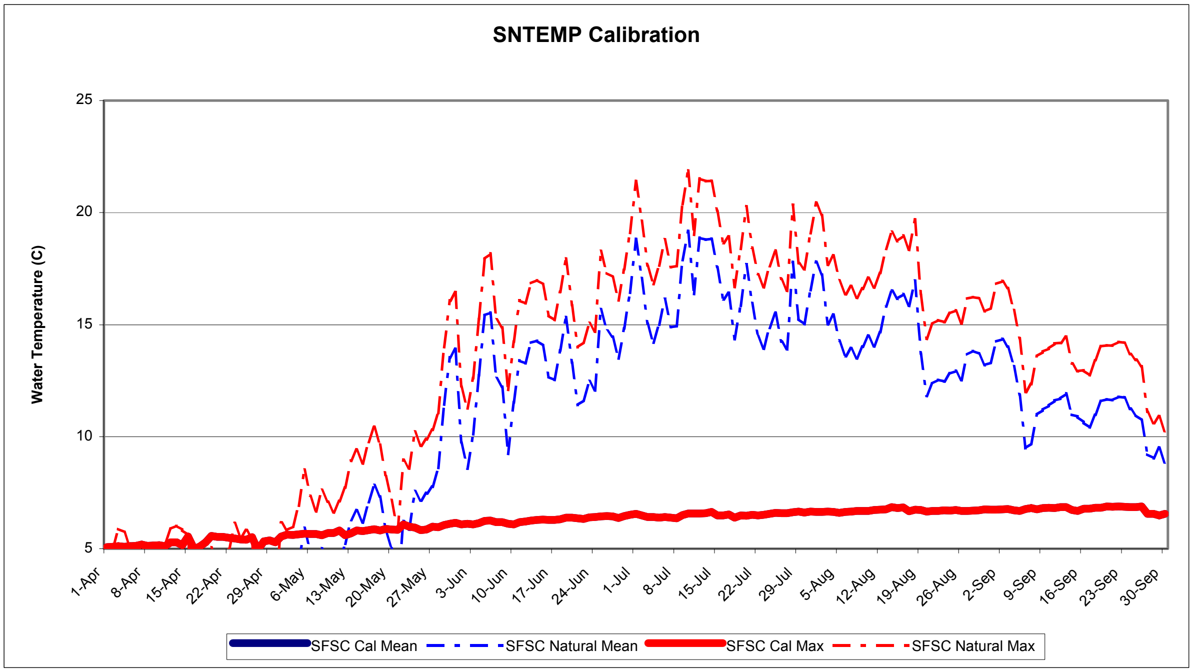


Figure 4.4-14. **SNTEMP results for South Fork Silver Creek (SFSC5 Below Ice House Dam) comparison of temperature for existing condition (calibrated) and natural flow.**

4.4.2 Camino Dam Reach Modeling

Silver Creek below Camino Reservoir to the junction with South Fork American River was partitioned into 24 nodes to account for topographic shading, channel geometry and basin drainage network. The SNTEMP files include the geometry, climate, shade, meteorology, and hydrology data used in this model. Concurrent thermograph data from Silver Creek just below Camino Reservoir (SC2) and just upstream of the confluence with South Fork American River (SC1) were used to calibrate the model. Climate data are from the NCDC Camino climate station (elevation 847.3 m).

Table 4.4-4 lists user-specified constants and calibration ranges for the Camino reach model.

Table 4.4-4. **Calibration constants and value ranges for the lower Silver Creek temperature model.**

Dust coefficient	0.04
Width exponent	0.0879
Width coefficient	34.08045
Ground reflectivity	Old snow = 0.6 Apr 01 – Jun 03; vegetation/rock = 0.22 (TVA 1972)
Evaporation factor (EFA)	40
Evaporation factor (EFB)	15
Evaporation factor (EFC)	0
Lateral Inflow temperature	10^{o}C
Mean daily air temperature (^{o}C)	Maximum adjustment ± 5% after adiabatic adjustment
Air calibration constant range	0 - 1.7
Air temperature calibration coefficient range	0 – 1.33
Wind speed (m/s)	Maximum adjustment ±1 m/s

Table 4.4-4. Calibration constants and value ranges for the lower Silver Creek temperature model.

Wind speed calibration constant range	1.0
Wind speed calibration coefficient range	0 - 2.0
Manning's n Silver Creek	20 for immediately below Camino Dam to force fit maximum thermograph data; 0.6 elsewhere
Travel time	Not used

The predicted daily mean and maximum temperatures for the calibrated model relative to observed temperatures are shown in Figures 4.4-15 through 4.4-16. Statistics on the accuracy and bias of the calibrated model for Silver below Camino Reservoir are shown in Table 4.4-5.

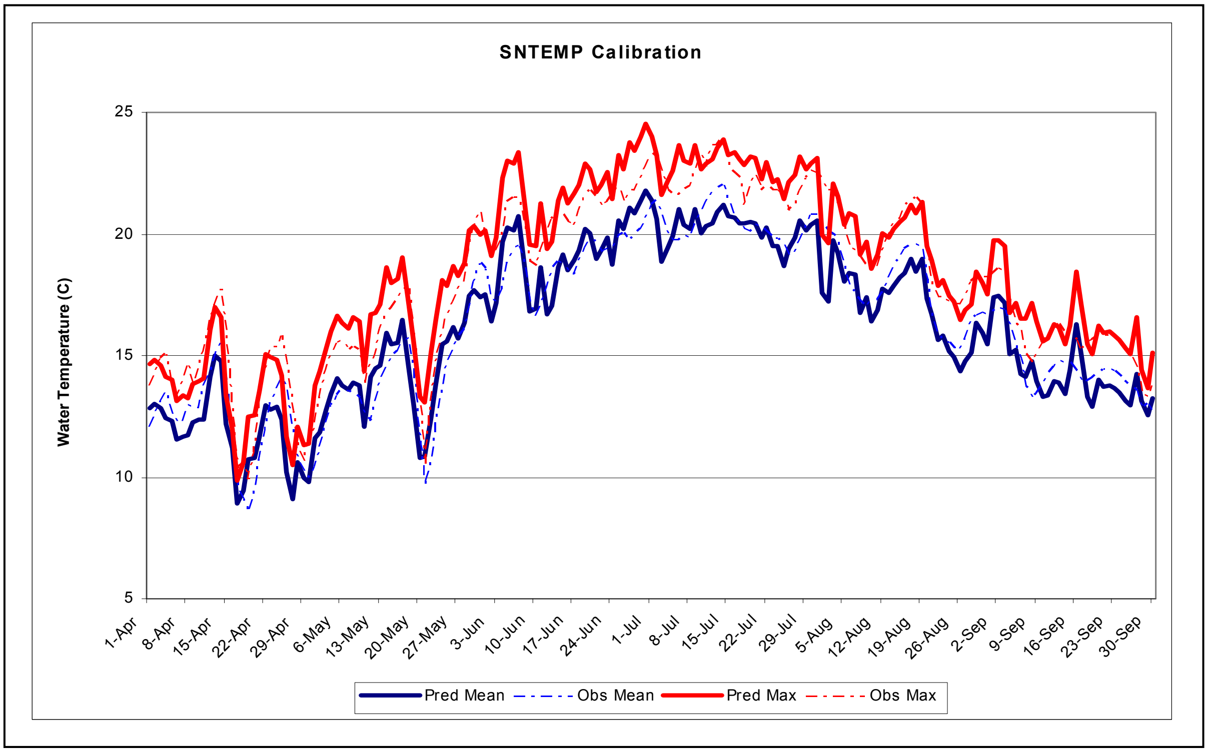


Figure 4.4-15. SNTEMP calibration results for Silver Creek below Camino Dam (SC2)

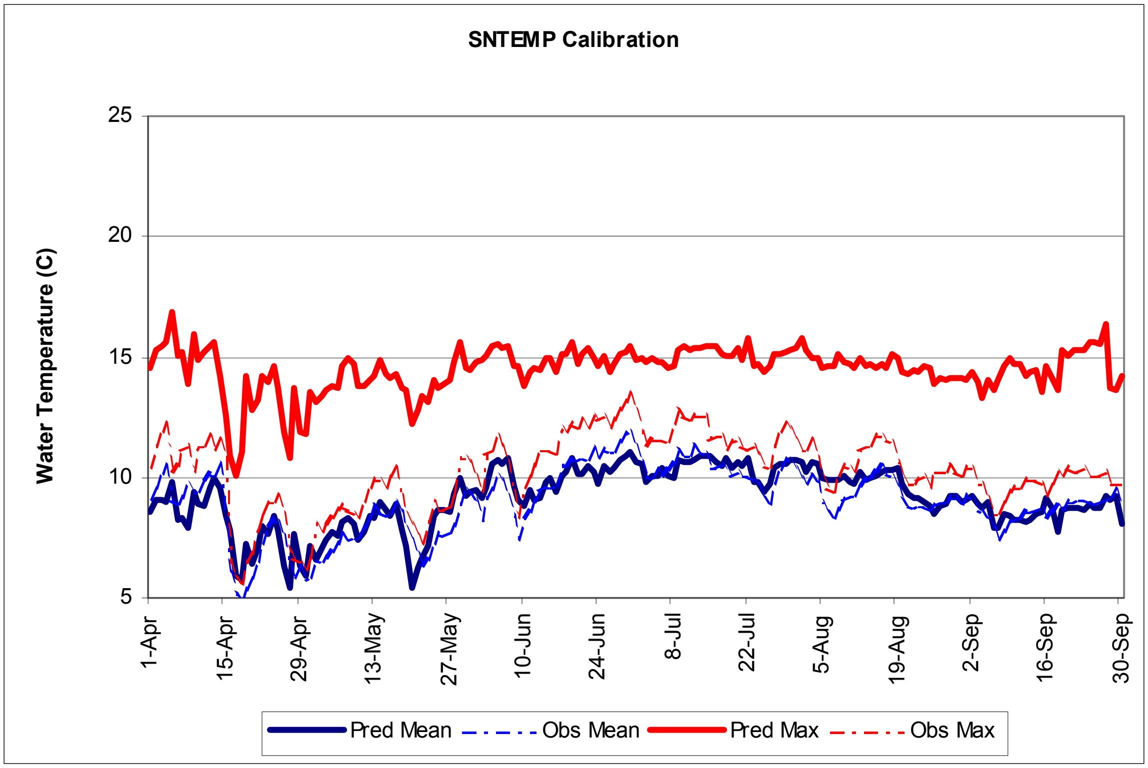


Figure 4.4-16. **SNTEMP calibration results for Silver Creek above confluence with S. F. American River (SC1).**

Table 4.4-5. Calibration statistics for lower Silver Creek below Camino Reservoir temperature model: predicted mean daily water temperatures.

Station		Absolute Mean Error (°C)	Bias (°C)	Maximum Error (°C)	Correlation R^2
SC1	April 1- Sept 30 2002	0.54	0.27	1.59	0.9445
	Jul 1 - Aug 31 2002	0.40	0.2	1.6	
SC2	April 1- Sept 30 2002	0.75	0.34	2.2	0.987
	Jul 1 - Aug 31 2002	.65	0.1	1.3	

The goodness-of-fit for the calibrated SNTEMP model for Silver Creek is considered good for mean daily water temperature. The absolute mean error (AME) is slightly higher than a desired target of 0.5 °C; however bias is low.

Table 4.4-6 lists the AME for predicted maximum daily water temperatures. Error bias for maximum was similar to mean temperatures. A large error for the maximum predicted temperature at SC1 (just below Camino Dam) is attributed to the effect of Camino Reservoir. The model is not capable of perceiving the reservoir. The SNTEMP predicts maximum daily temperatures by routing the water from solar noon to dusk (noon to 6pm). In the case of SC1, this travel distance exceeds the upstream reach length so poor predicted maximum temperatures are an artifact of the model at SC1

Table 4.4-6. Calibration statistics for Silver Creek below Camino Reservoir temperature model: predicted Maximum daily water temperatures

Station		Absolute Mean Error (°C)
SC1	April 1- Sept 30 2002	4.2
	Jul 1 - Aug 31 2002	3.7
SC2	April 1- Sept 30 2002	0.87
	Jul 1 - Aug 31 2002	0.66

Alternate flow releases from Camino Dam were modeled while keeping all other factors in the calibrated model unchanged. Accretion within the lower Silver Creek bypass reach was kept the same as in the calibrated model. Figures 4.4-17 shows the predicted temperature regimes in Silver Creek below Camino Dam associated with releases of 5 cfs, 15 cfs, 30 cfs and 60 cfs, respectively. A release of 60 cfs was necessary to maintain predicted mean daily water temperature below 20°C.

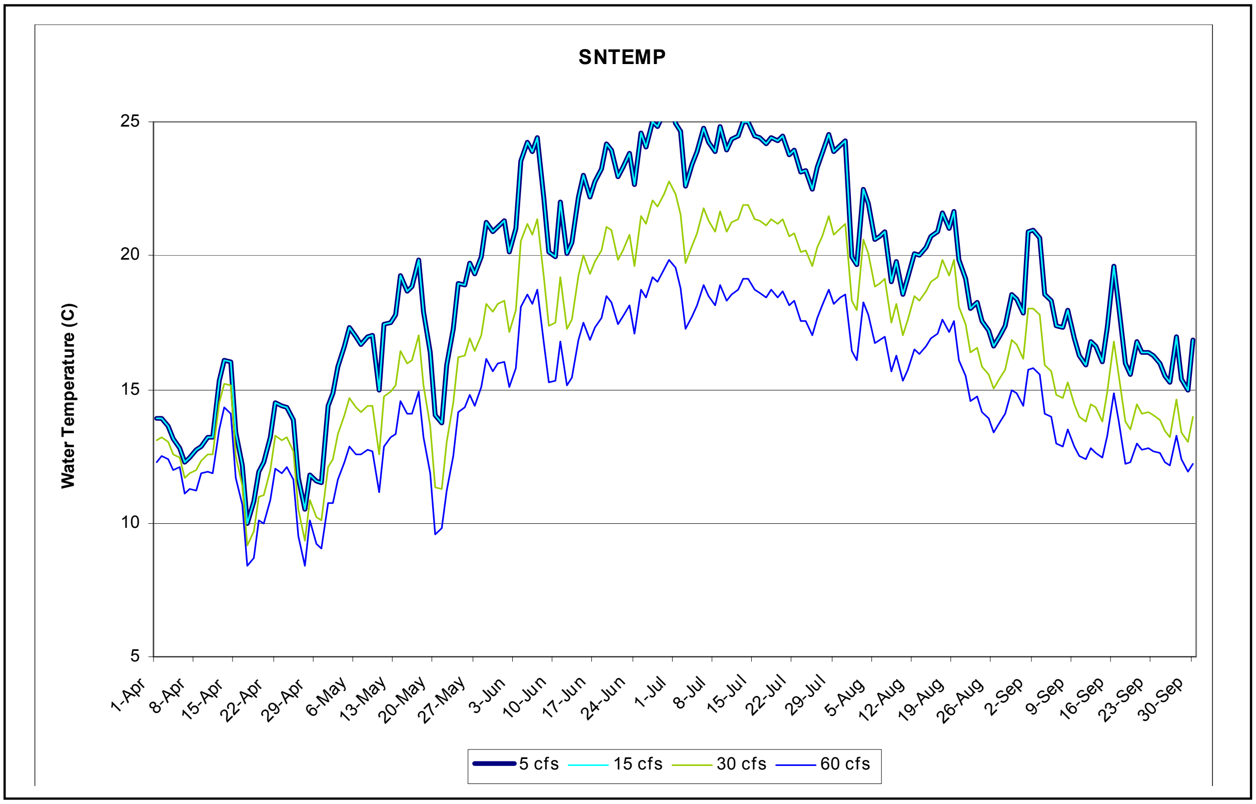


Figure 4.4-17. Predicted mean daily temperatures for Silver Creek upstream of confluence with S F American River (SC1) for variable flow release from Camino Dam.

4.4.3 Slab Creek Reach Modeling

The reach defined as South Fork American River downstream of Slab Reservoir to the White Rock powerhouse at the head of Chili Reservoir was partitioned into 24 nodes to account for topographic shading, channel geometry and basin drainage network. The SNTEMP calibrated model input files are provided in Appendix C. These files include the geometry, climate, shade, meteorology, and hydrology data used in this model. Climate data from the NCDC Camino climate station were used. Topographic shade data were derived from a GIS analysis of map data. Vegetation shade data used in the model are based on aerial photo interpretation. Stream width and depth relationships to flow are based on data from the instream flow study for this reach. Concurrent thermograph data from South Fork American River within the Slab Reservoir bypass reach were used to calibrate the model. These thermograph records include the following locations:

SFAR6	SF American River upstream of White Rock powerhouse (Rkm 0.62);
SFAR7	SF American River at Mosquito Road bridge (Rkm 7.08);
SFAR8	SF American River at walking bridge (Rkm 12.38); and
SFAR9	SF American River below Slab Reservoir dam (Rkm 12.38).

Table 4.4-7 lists user-specified constants and calibration ranges for the Slab reach model.

Table 4.4-7. Calibration constants and value ranges for the Slab diversion reach temperature model

Dust coefficient	0.04
Width exponent	0.676 –0.0461
Width coefficient	19.9 – 29.9 variable by segment
Ground reflectivity	0.15 rock (TVA 1972)
Evaporation factor (EFA)	40
Evaporation factor (EFB)	15
Evaporation factor (EFC)	0
Lateral Inflow temperature	10°C
Mean daily air temperature (°C)	Maximum adjustment 5% after adiabatic adjustment
Air calibration constant range	0.9 – 1.0
Air temperature calibration coefficient range	0.87 – 1.2
Wind speed (m/s)	Maximum adjustment ±1 m/s
Wind speed calibration constant range	0 - 1.0
Wind speed calibration coefficient range	0 – 1.5
Manning's n	0.28 for RkM 0.0 – 7.0; 0.9999 for RkM 7.04 – 12.94

An additional node was added to the revised model for the Slab Reach model at RkM 12.8, which forces the model to use the observed mean daily temperature data for SFAR9 as the starting water temperatures as released from the upstream reservoir. The Manning's n values for the upper segments were adjusted to 0.9999; this results in the mean daily and the maximum daily temperatures to be very similar for the upper calibration sites, which is consistent with the observed release temperatures from the reservoir. The predicted daily mean and maximum temperatures for the calibrated model relative to observed temperatures are shown in Figures 4.4-18 through 4.4-21. Statistics on the accuracy and bias of the calibrated model for the reach below Slab Reservoir are shown in Table 4.4-8.

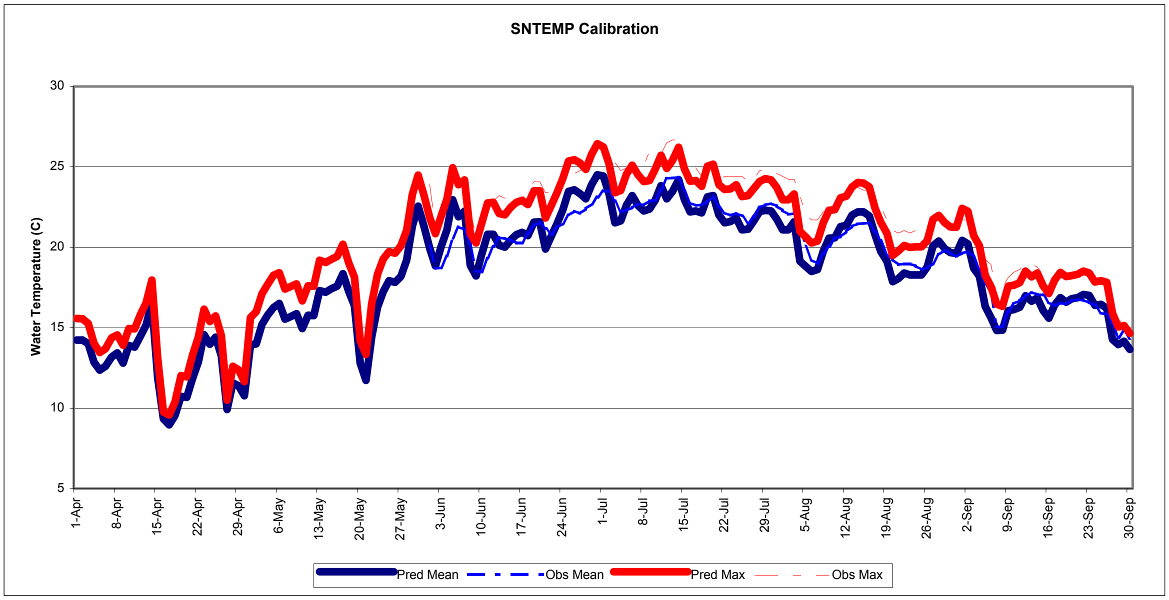


Figure 4.4-18. **SNTEMP calibration results for S F American above White Rock Powerhouse (SFAR6).**

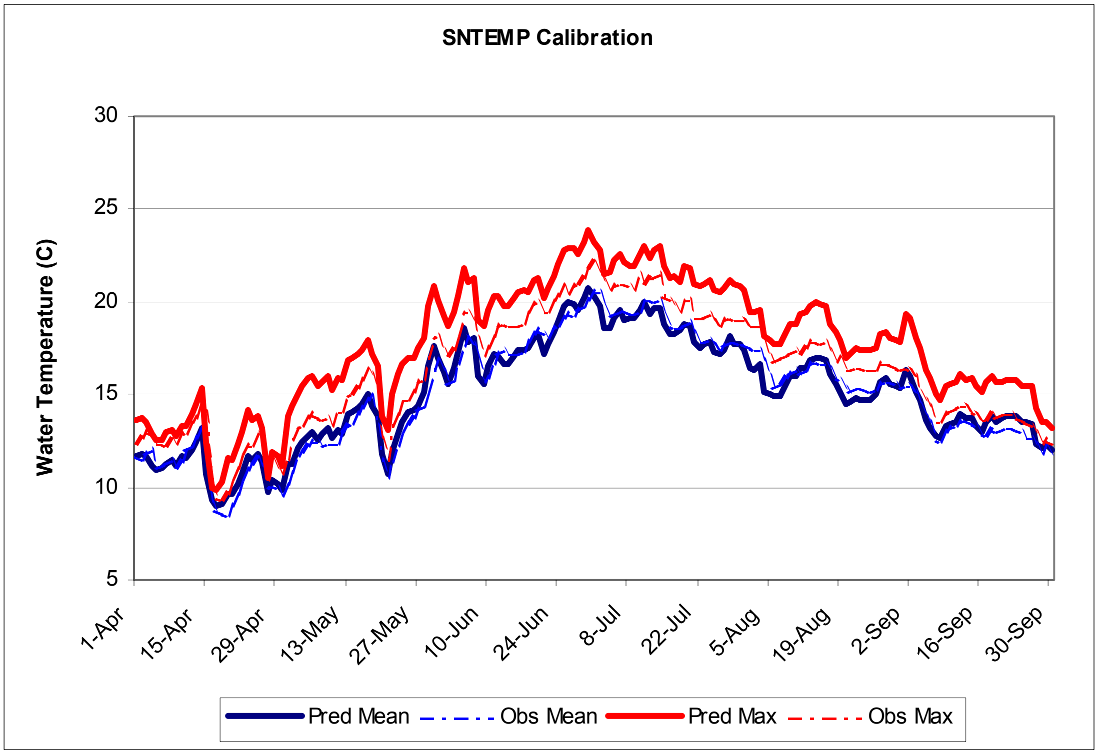


Figure 4.4-19. **SNTEMP calibration results for SF American River at Mosquito Bridge (SFAR7).**

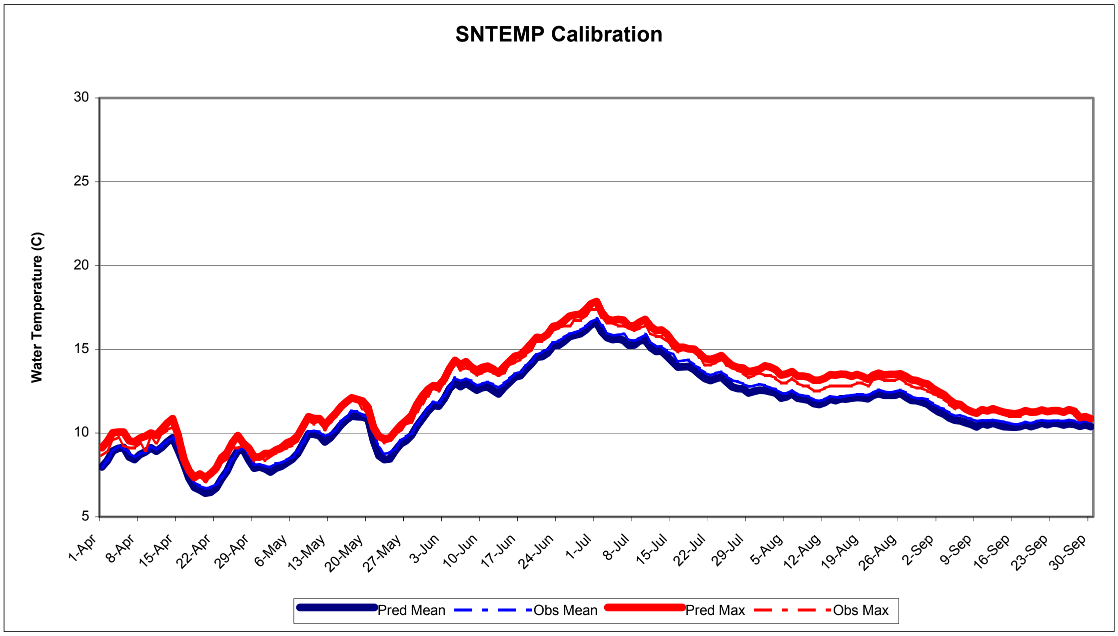


Figure 4.4-20. SNTEMP calibration results for SF American River at walking bridge (SFAR8).

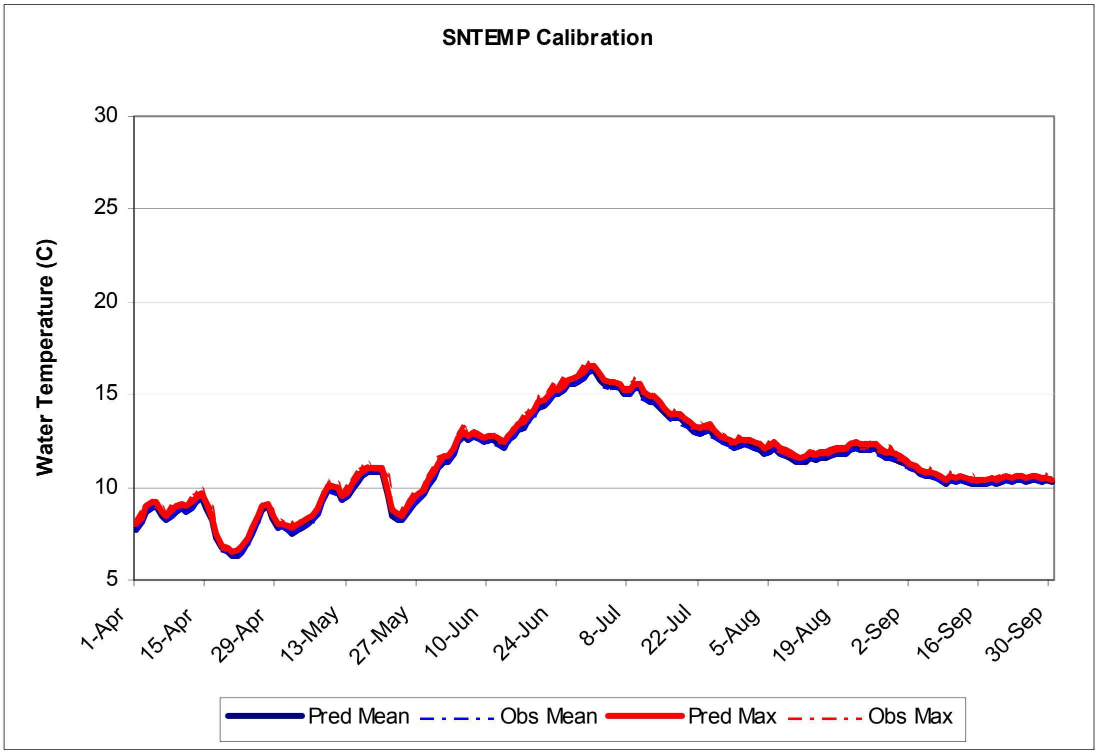


Figure 4.4-21. SNTEMP calibration results for SF American River below Slab Reservoir dam (SFAR9).

Table 4.4-8. Calibration statistics for temperature model SF American River below Slab Reservoir: predicted mean daily water temperatures

Station		Absolute Mean Error (°C)	Bias (°C)	Maximum Error (°C)	Correlation R^2
SFAR6	April 1- Sept 30 2002	0.61	0.03	2.4	0.9842
	Jul 1 - Aug 31 2002	0.56	0.03	-2.2	
SFAR7	April 1- Sept 30 2002	0.41	0.03	-1.7	0.9736
	Jul 1 - Aug 31 2002	0.38	0.03	-1.7	
SFAR8	April 1- Sept 30 2002	0.23	0.06	-0.4	0.9268
	Jul 1 - Aug 31 2002	0.27	0.06		
SFAR9	April 1- Sept 30 2002	0.03	0.06	0.1	0.999
	Jul 1 - Aug 31 2002	0.03	0.06	0.1	0.999

The goodness-of-fit for the calibrated SNTEMP model for the Slab reach temperature model predictions for mean daily temperature are considered excellent for all verification nodes. The absolute mean error (AME) is only slightly higher than a desired target of 0.5 °C at SFAR6; however bias is low.

Table 4.4-9 lists the AME for predicted maximum daily water temperatures. Error bias for maximum was similar to mean temperatures.

Table 4.4-9. Calibration statistics for the SF American River below Slab Reservoir temperature model: predicted Maximum daily water temperatures

Station		Absolute Mean Error (°C)
SFAR6	April 1- Sept 30 2002	0.67
	Jul 1 - Aug 31 2002	0.76
SFAR7	April 1- Sept 30 2002	1.49
	Jul 1 - Aug 31 2002	1.41
SFAR8	April 1- Sept 30 2002	0.3
	Jul 1 - Aug 31 2002	0.38
SFAR9	April 1- Sept 30 2002	0.12
	Jul 1 - Aug 31 2002	0.09

Alternate flow releases from Slab Reservoir were modeled while keeping all other factors in the calibrated model unchanged. Accretion within the bypass reach was kept the same as in the calibrated model. Figure 4.4-22 shows the predicted temperature regimes for SF American River above White Rock Powerhouse (SFAR6) associated with releases of 15 cfs, 30 cfs, 60 cfs and 90 cfs, respectively. A release of 90 cfs maintained predicted mean daily water temperature below 20°C for all but a few days and the exceedence was within model error.

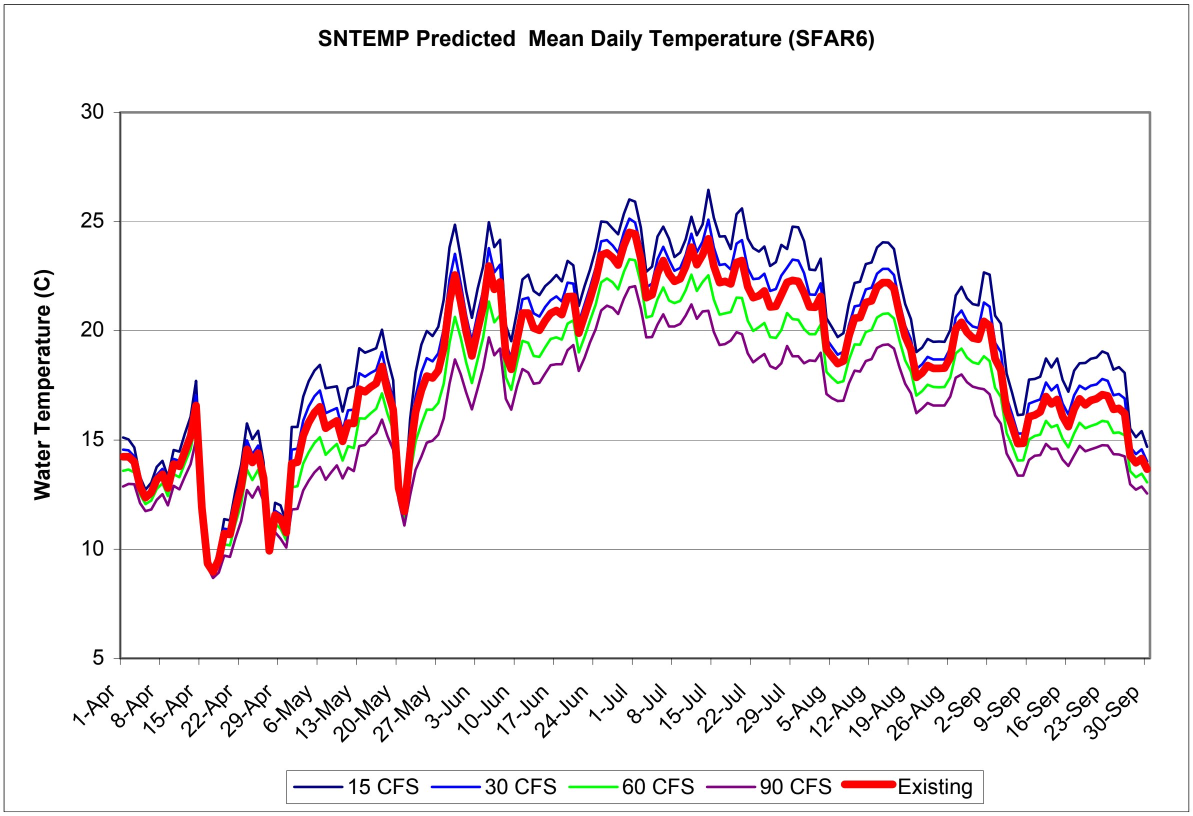


Figure 4.4-22. **Predicted mean daily temperatures for Silver Creek upstream of White Rock Powerhouse (SFAR6).**

5.0 LITERATURE CITED

Bartholow, J. 1987. Temperature model technical note no. 6: Stream Reach Solar Model (SRSOLAR) ver. 1.4. USFWS. Ft. Collins, CO.

Bartholow, J. M. 2000. The Stream Segment and Stream Network Temperature Models: A Self-Study Course. Ver. 2.0. U.S. Fish & Wildlife Service. Open File Report 99-112. Fort Collins, CO.

Cole, T. and Buchak, E. (1995) "CE-QUAL-W2: A Two-Dimensional, Laterally Averaged, Hydrodynamic and Water Quality Model, Version 2.0," Tech. Rpt. EL-95-May 1995, Waterways Experiments Station, Vicksburg, MS

Ecological Analysts, Inc. 1980. Field studies of Ice House Reservoir and Union Valley Reservoir, El Dorado County, California. Prepared for Sacramento Municipal Utility District, Sacramento, CA.

Ecological Analysts, Inc. 1982. Draft Environmental Impact Report, South Fork Rubicon River Diversion. Prepared for Sacramento Municipal Utility District, Sacramento, CA.

Livesay, R.D. 1972. Summer water temperature observations, South Fork American River, 1960-1969. USGS Pub. 6212-02, Menlo Park, CA.

Lutgens, F.K. and E.J. Tarbuck. 1992. The atmosphere, an Introduction to Meteorology. 5th ed. Prentice Hall. New Jersey.

Pacific Gas and Electric Company (PG&E) 2003. First Stage Consultation Document, Chili Bar Project, FERC No. 2155. Pacific Gas and Electric Company, San Francisco, CA.

SMUD (Sacramento Municipal Utility District). 2001. Initial Information Package for Relicensing of the Upper American River Project (FERC Project No. 2101). Sacramento, CA.

Satterlund, D.R., R.C. Chapman, and R. D. Beach. 1983. Modeling the daily temperature cycle. Northwest Science: Vol. 57, No. 1.

Sullivan, K., J. Tooley, K. Doughty, J.E. Caldwell, and P. Knudsen, 1990. Evaluation of Prediction Models and Characterization of Stream Temperature Regimes in Washington. TFW-WQ-90-006. Olympia, WA.

Tennessee Valley Authority. 1972. Heat and mass transfer between a water surface and the atmosphere. Water Res. Lab. Rep. No. 14. Norris TN.

Tetra Tech. 2000a. Water quality monitoring report for the Upper American River Project. Prepared for the Sacramento Municipal Utility District, Sacramento, CA.

Tetra Tech. 2000b. Water quality monitoring report for the Upper American River Project. (Final Report). Prepared for the Sacramento Municipal Utility District, Sacramento, CA.

Theurer, F.D., K.A. Voos, and W.J. Miller. 1984. Instream Water Temperature Model Instream Flow Information Paper 16. U.S. Fish & Wildlife Service. Fort Collins, CO

United States Geological Survey (USGS). STORET Data retrieved from, USGS webpage.

Wells, S. A. (1997) "Theoretical Basis for the CE-QUAL-W2 River Basin Model," Dept. of Civil Engr., Tech. Rpt. EWR-6-97, Portland St. Univ., Portland, OR, 1997.

Wetzel, R.G., 1975. Limnology. W.B. Saunders Company, Philadelphia, PA.

APPENDIX A

RESERVOIR THERMAL PROFILE GRAPHS RELICENSING AND HISTORICAL STUDIES

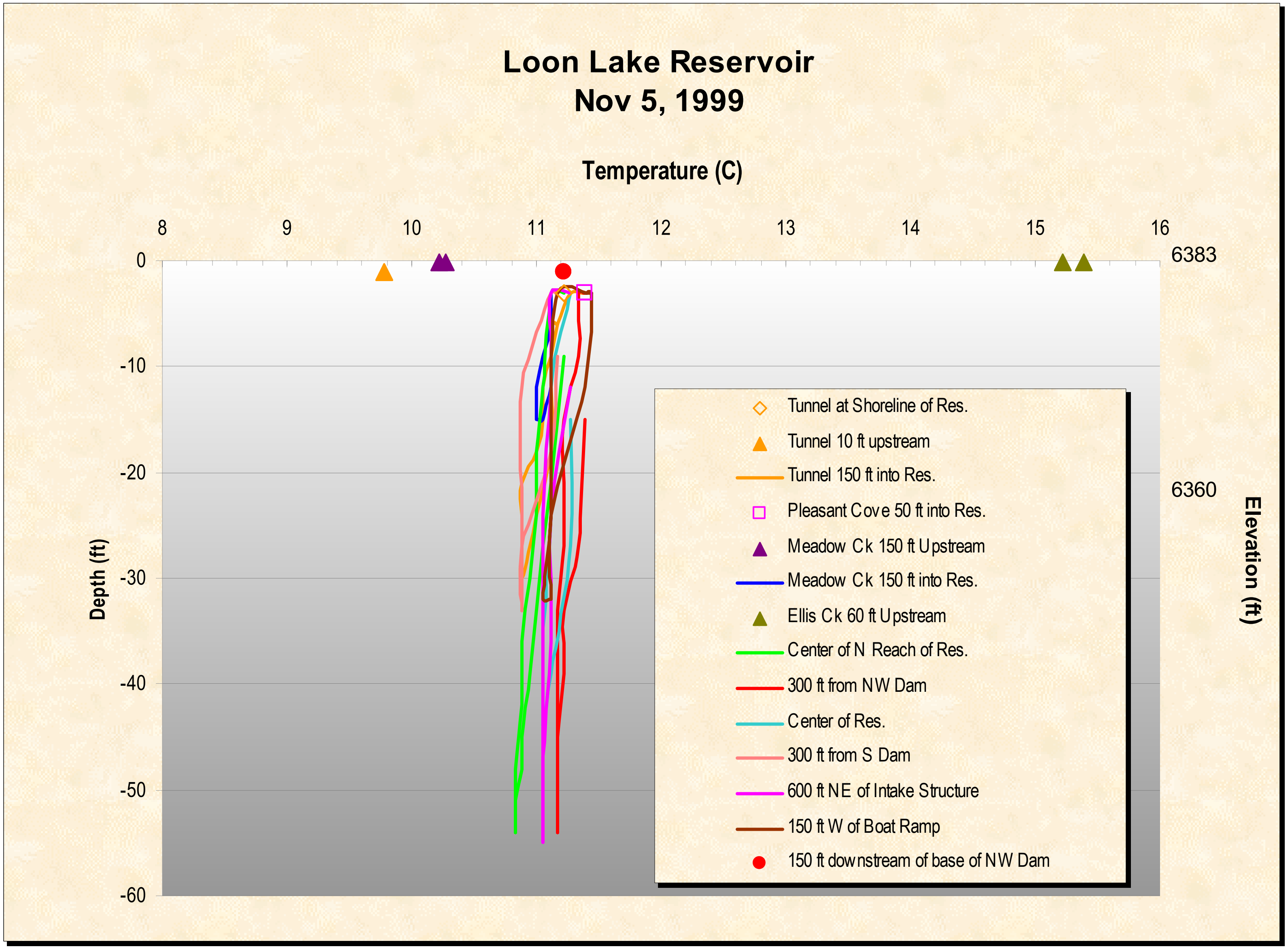
Section 1

2002 - 2004 Relicensing Profile Data

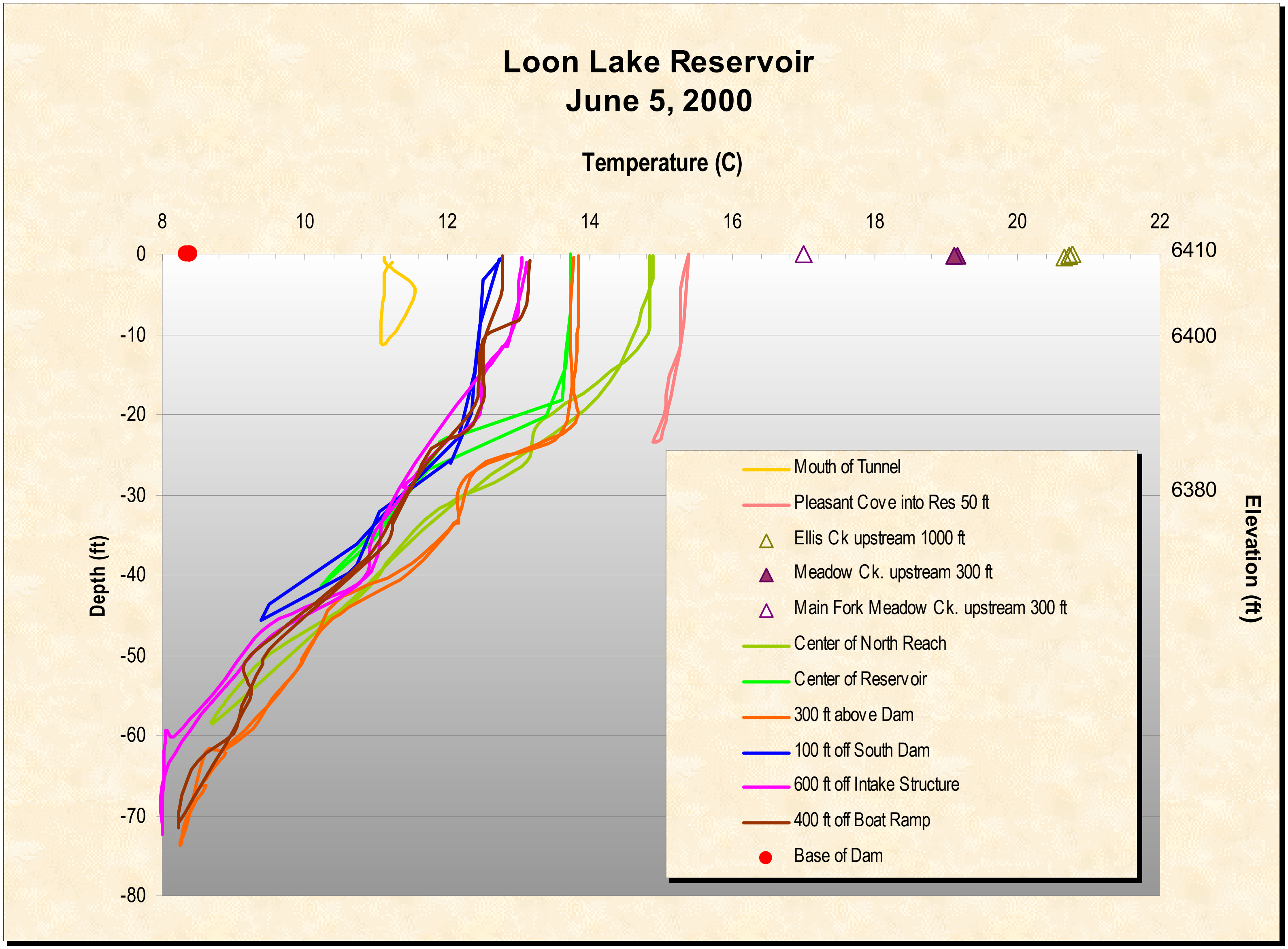
- Water Temperature
- Dissolved Oxygen
- PH
- Specific Conductance

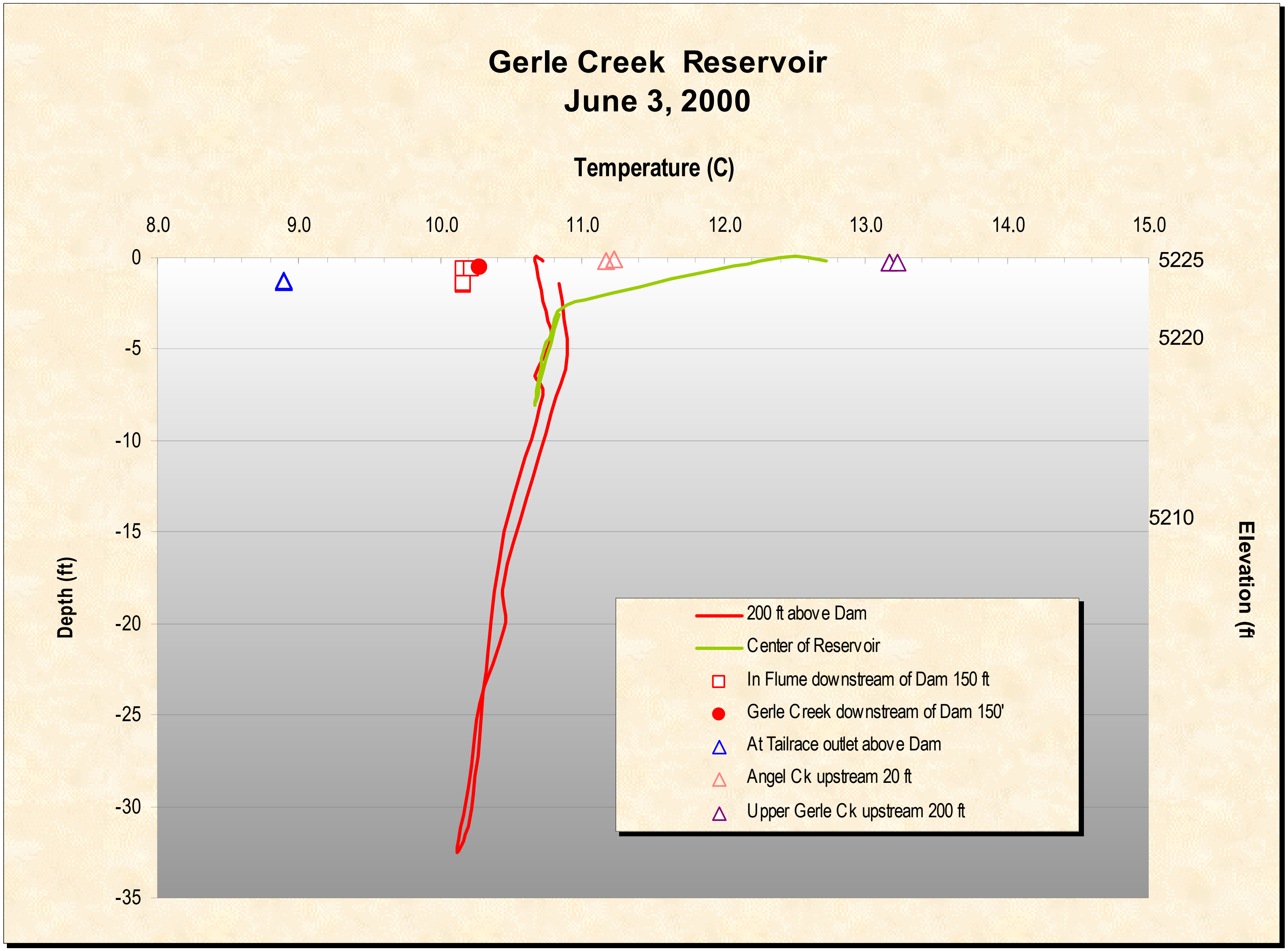
SECTION 2

1999 AND 2000 TETRA TECH DATA

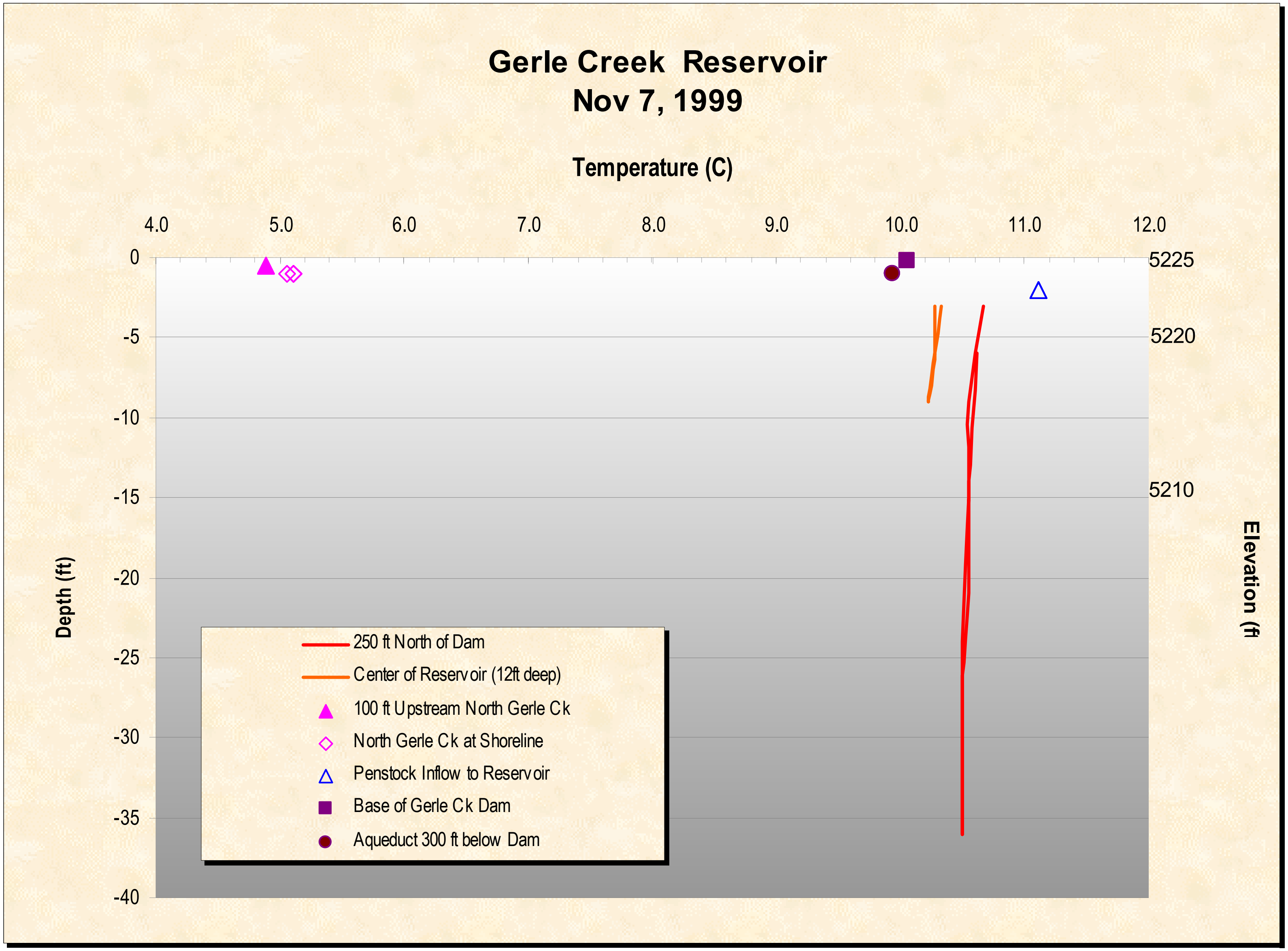


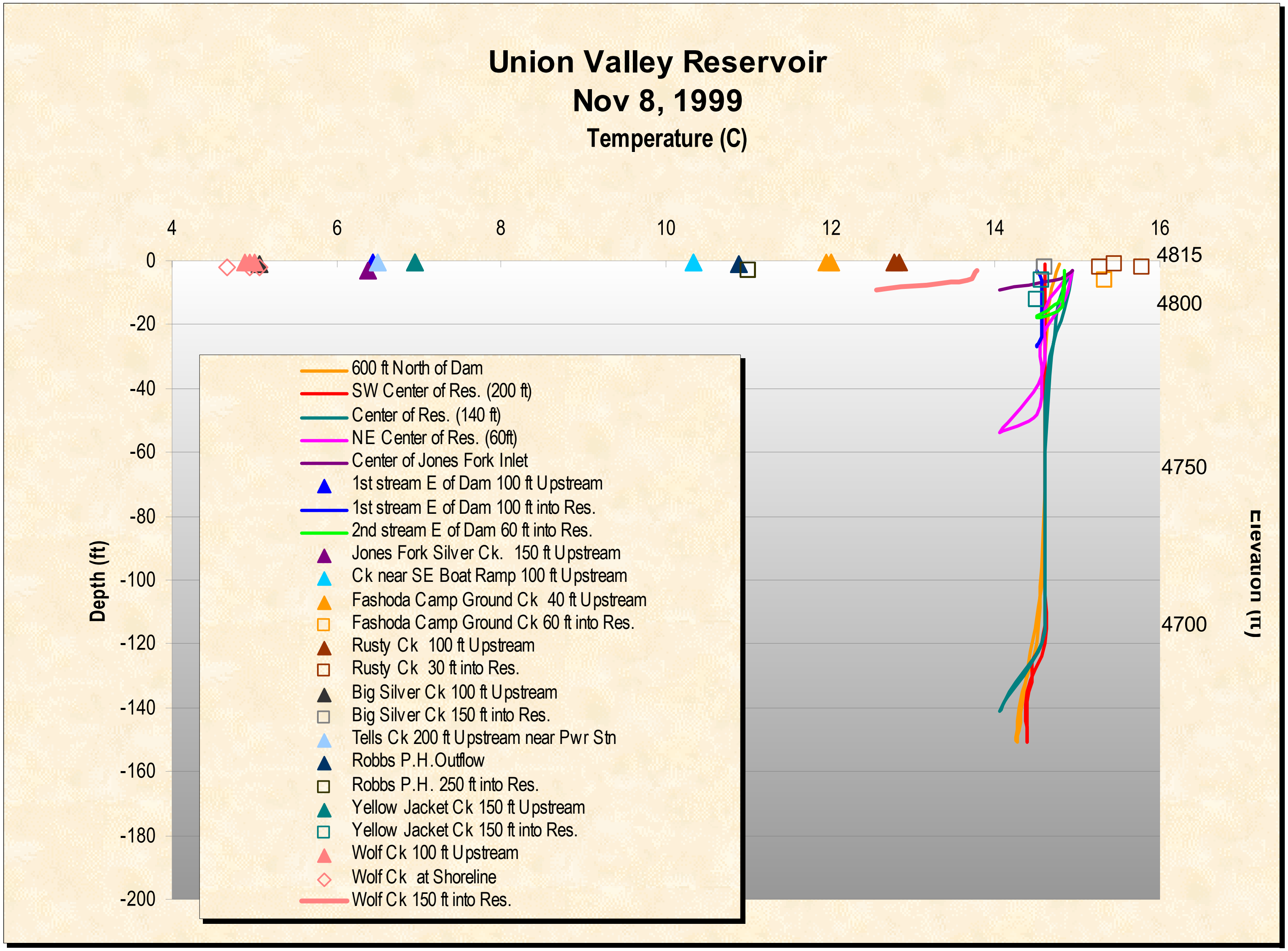
Loon Lake Reservoir
Nov 5, 1999


Loon Lake Reservoir
June 5, 2000
Temperature (C)
8
10
12
14
16
18
20
22
0
-10
-20
-30
-40
-50
-60
-70
-80
Depth (ft)
6410
6400
6380
Elevation (ft)
Mouth of Tunnel
Pleasant Cove into Res 50 ft
Ellis Ck upstream 1000 ft
Meadow Ck. upstream 300 ft
Main Fork Meadow Ck. upstream 300 ft
Center of North Reach
Center of Reservoir
300 ft above Dam
100 ft off South Dam
600 ft off Intake Structure
400 ft off Boat Ramp
Base of Dam

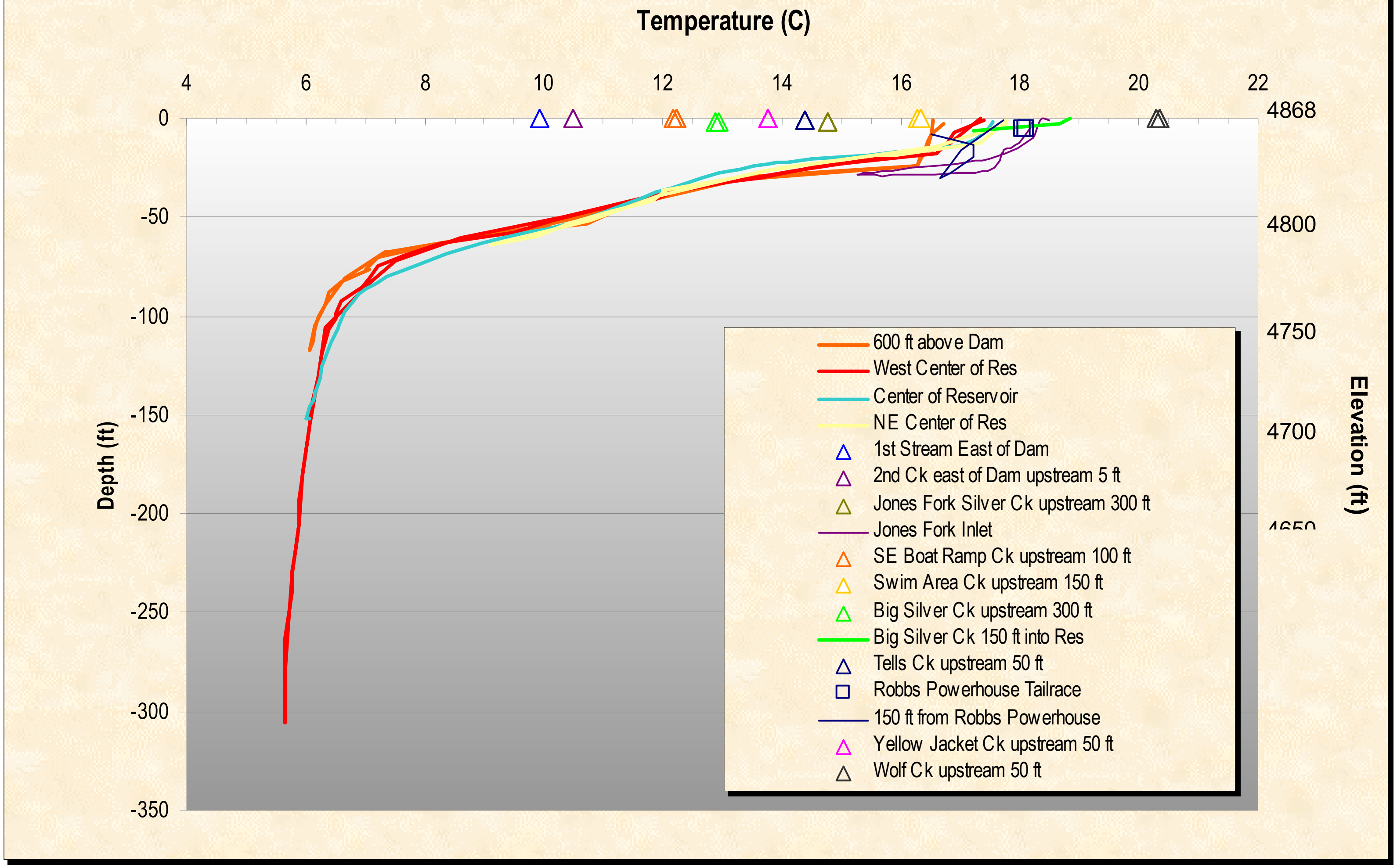


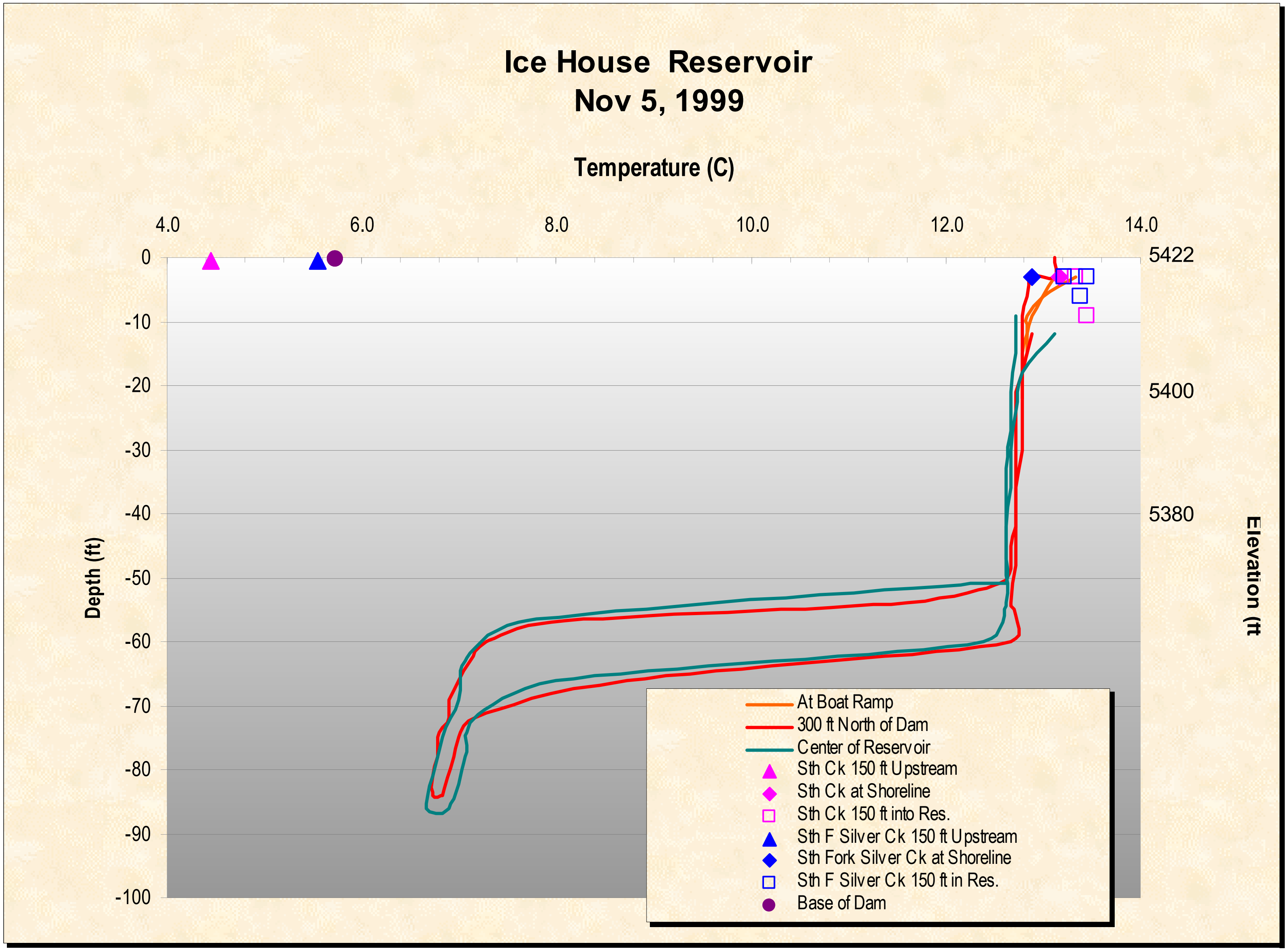
Gerle Creek Reservoir
June 3, 2000


Gerle Creek Reservoir
Nov 7, 1999
Temperature (C)
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
0
-5
-10
-15
-20
-25
-30
-35
-40
Depth (ft)
5225
5220
5210
Elevation (f
250 ft North of Dam
Center of Reservoir (12ft deep)
100 ft Upstream North Gerle Ck
North Gerle Ck at Shoreline
Penstock Inflow to Reservoir
Base of Gerle Ck Dam
Aqueduct 300 ft below Dam

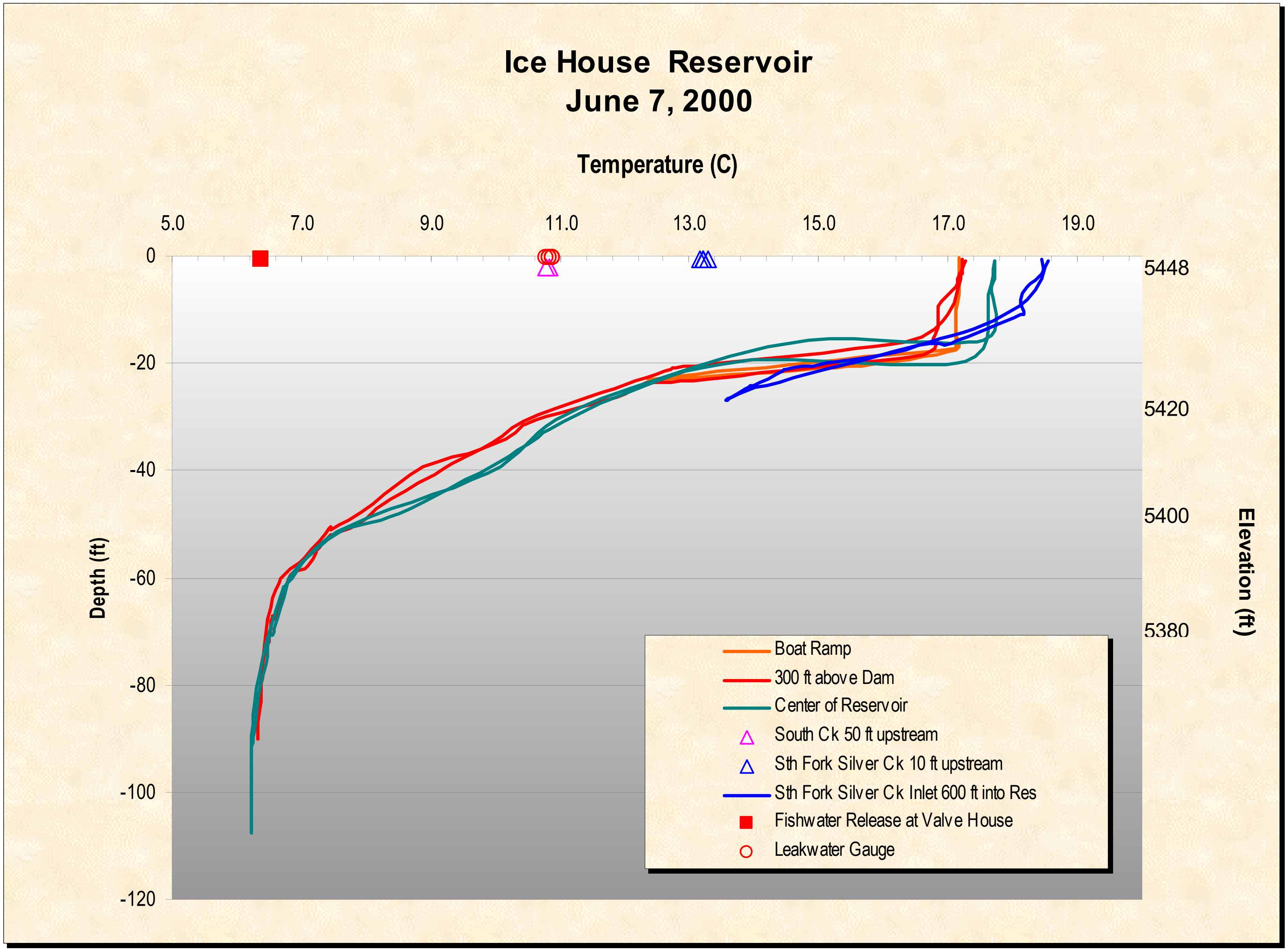

Union Valley Reservoir
Nov 8, 1999
Temperature (C)
4
6
8
10
12
14
16
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
Depth (ft)
4815
4800
4750
4700
Elevation (ft)
600 ft North of Dam
SW Center of Res. (200 ft)
Center of Res. (140 ft)
NE Center of Res. (60ft)
Center of Jones Fork Inlet
1st stream E of Dam 100 ft Upstream
1st stream E of Dam 100 ft into Res.
2nd stream E of Dam 60 ft into Res.
Jones Fork Silver Ck. 150 ft Upstream
Ck near SE Boat Ramp 100 ft Upstream
Fashoda Camp Ground Ck 40 ft Upstream
Fashoda Camp Ground Ck 60 ft into Res.
Rusty Ck 100 ft Upstream
Rusty Ck 30 ft into Res.
Big Silver Ck 100 ft Upstream
Big Silver Ck 150 ft into Res.
Tells Ck 200 ft Upstream near Pwr Stn
Robbs P.H. Outflow
Robbs P.H. 250 ft into Res.
Yellow Jacket Ck 150 ft Upstream
Yellow Jacket Ck 150 ft into Res.
Wolf Ck 100 ft Upstream
Wolf Ck at Shoreline
Wolf Ck 150 ft into Res.

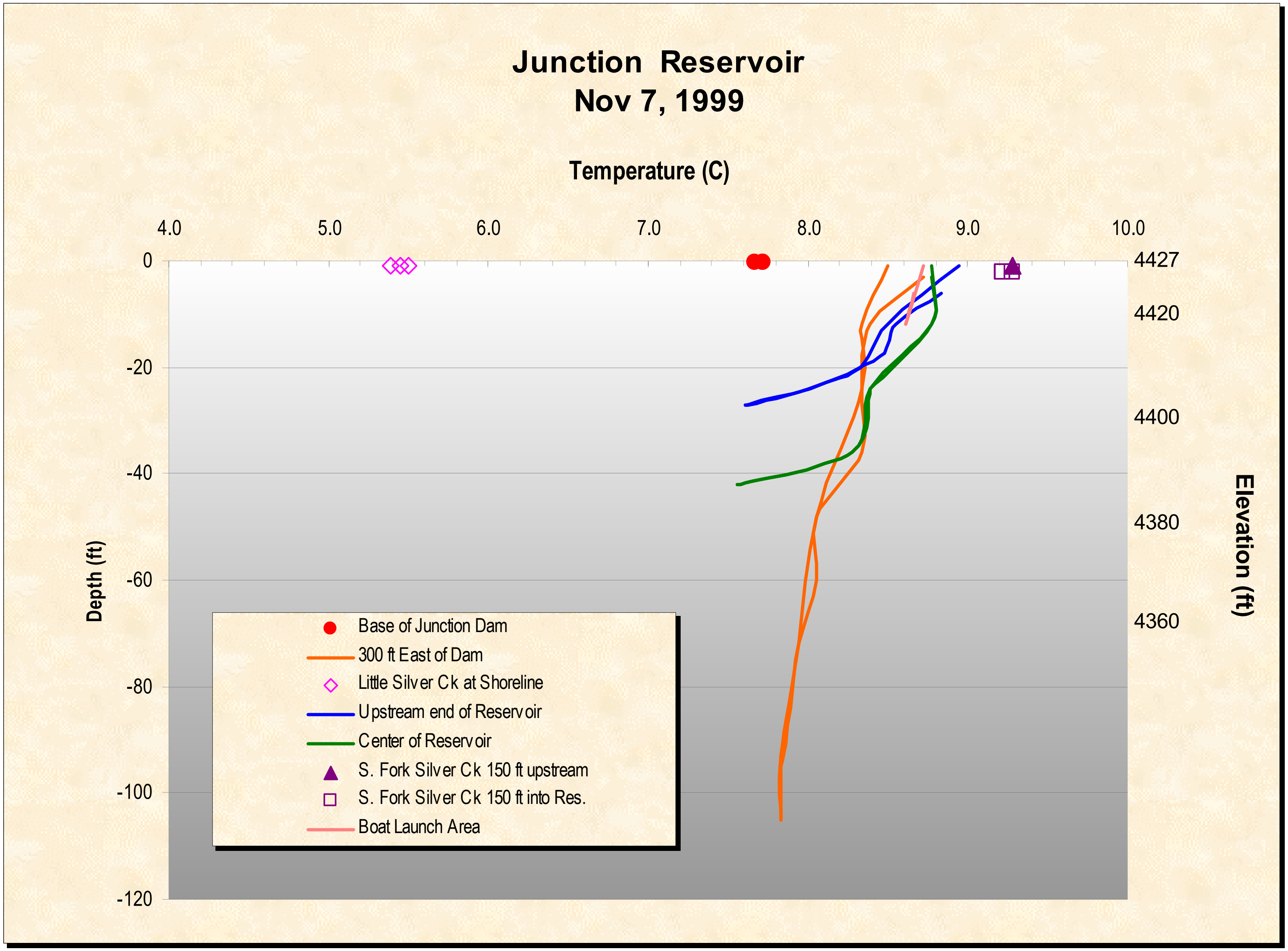
Union Valley Reservoir
June 6, 2000

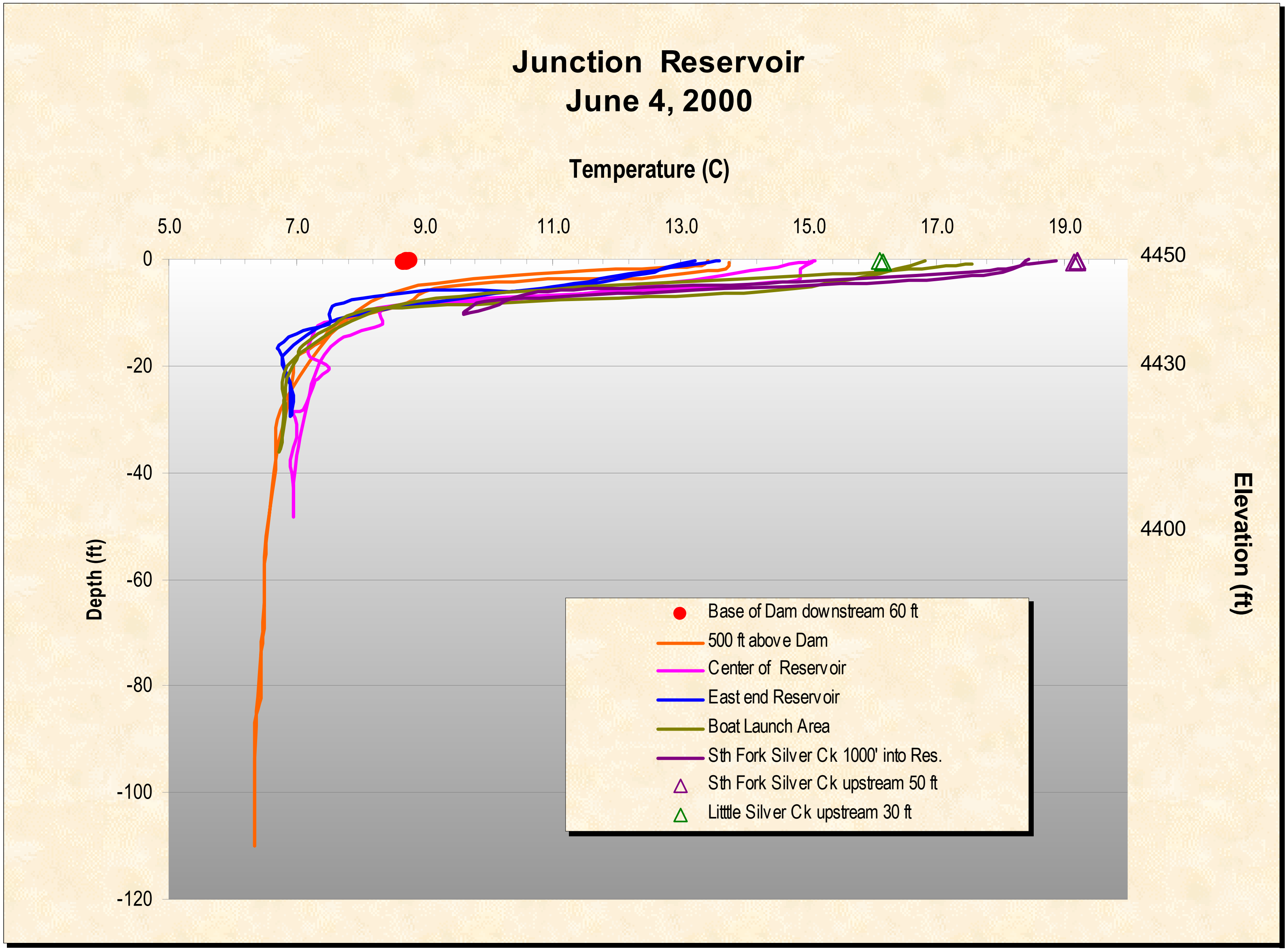


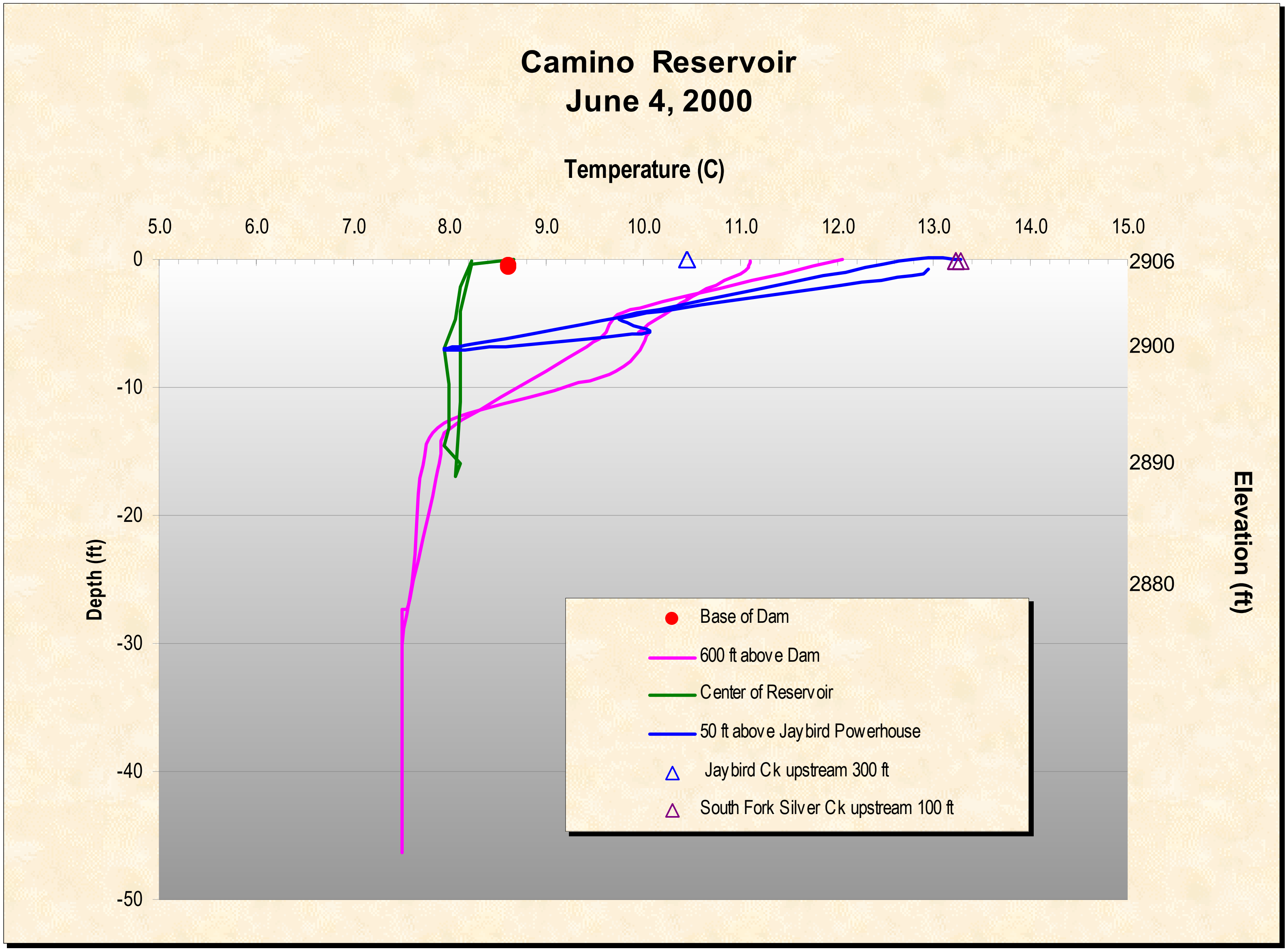


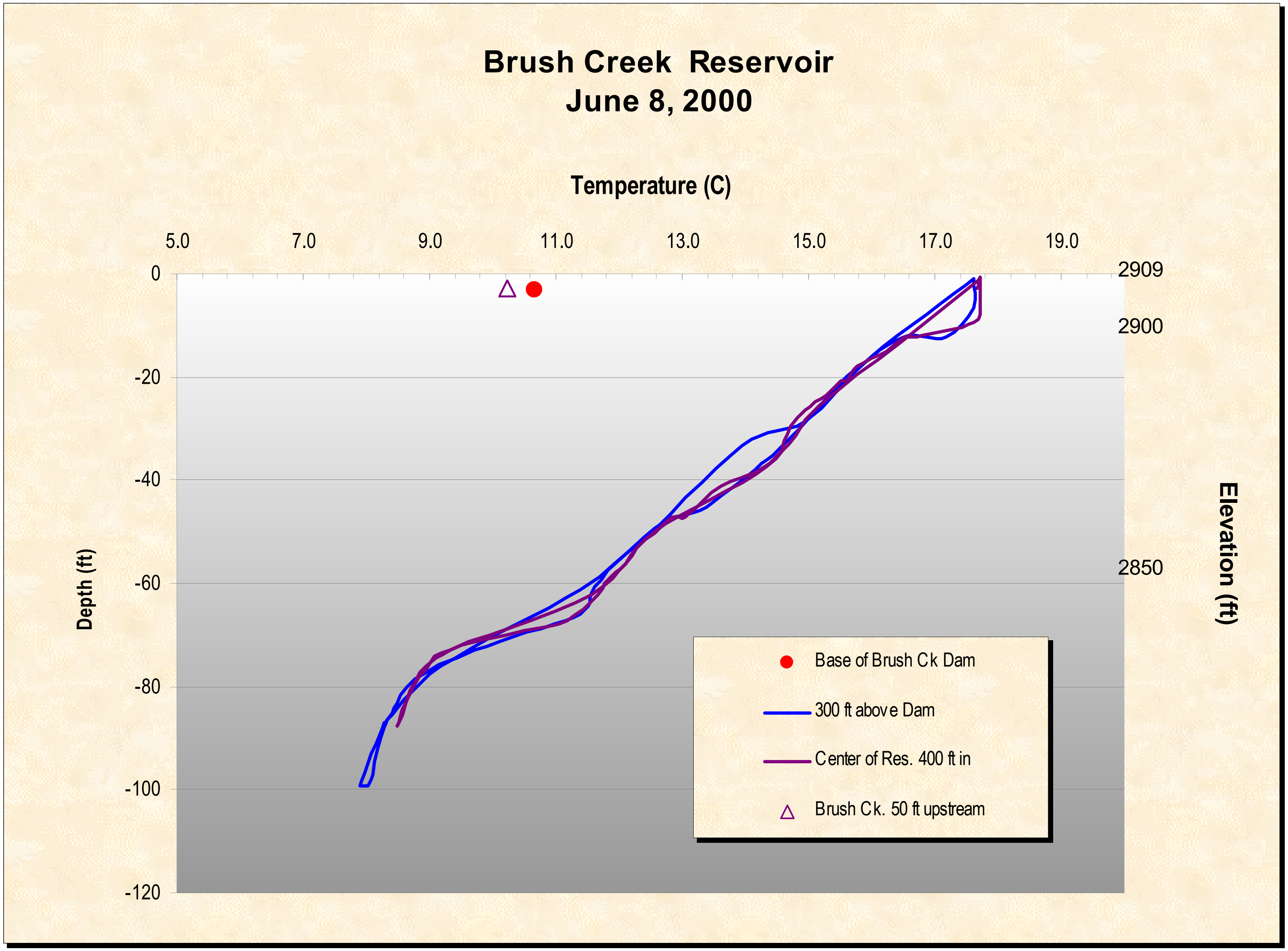
Ice House Reservoir
Nov 5, 1999
Temperature (C)
4.0
6.0
8.0
10.0
12.0
14.0
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
Depth (ft)
5422
5400
5380
Elevation (ft
At Boat Ramp
300 ft North of Dam
Center of Reservoir
▲ Sth Ck 150 ft Upstream
◆ Sth Ck at Shoreline
□ Sth Ck 150 ft into Res.
▲ Sth F Silver Ck 150 ft Upstream
◆ Sth Fork Silver Ck at Shoreline
□ Sth F Silver Ck 150 ft in Res.
● Base of Dam

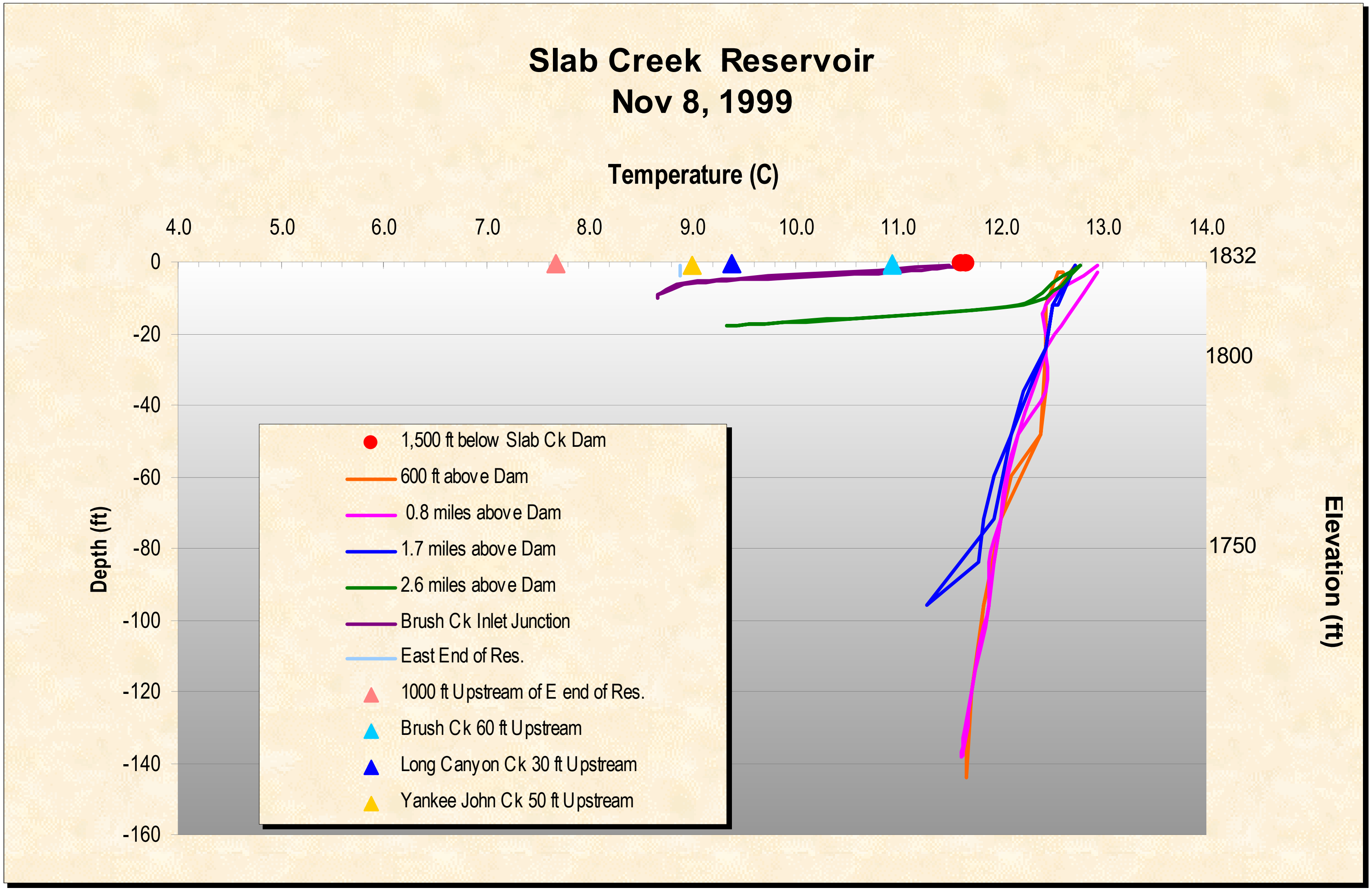

Ice House Reservoir
June 7, 2000
Temperature (C)
5.0
7.0
9.0
11.0
13.0
15.0
17.0
19.0
0
-20
-40
-60
-80
-100
-120
Depth (ft)
5448
5420
5400
5380
Elevation (ft)
Boat Ramp
300 ft above Dam
Center of Reservoir
△ South Ck 50 ft upstream
△ Sth Fork Silver Ck 10 ft upstream
Sth Fork Silver Ck Inlet 600 ft into Res
■ Fishwater Release at Valve House
○ Leakwater Gauge


Junction Reservoir
Nov 7, 1999
Temperature (C)
4.0
5.0
6.0
7.0
8.0
9.0
10.0
0
-20
-40
-60
-80
-100
-120
Depth (ft)
4427
4420
4400
4380
4360
Elevation (ft)
● Base of Junction Dam
300 ft East of Dam
◇ Little Silver Ck at Shoreline
Upstream end of Reservoir
Center of Reservoir
▲ S. Fork Silver Ck 150 ft upstream
☐ S. Fork Silver Ck 150 ft into Res.
Boat Launch Area

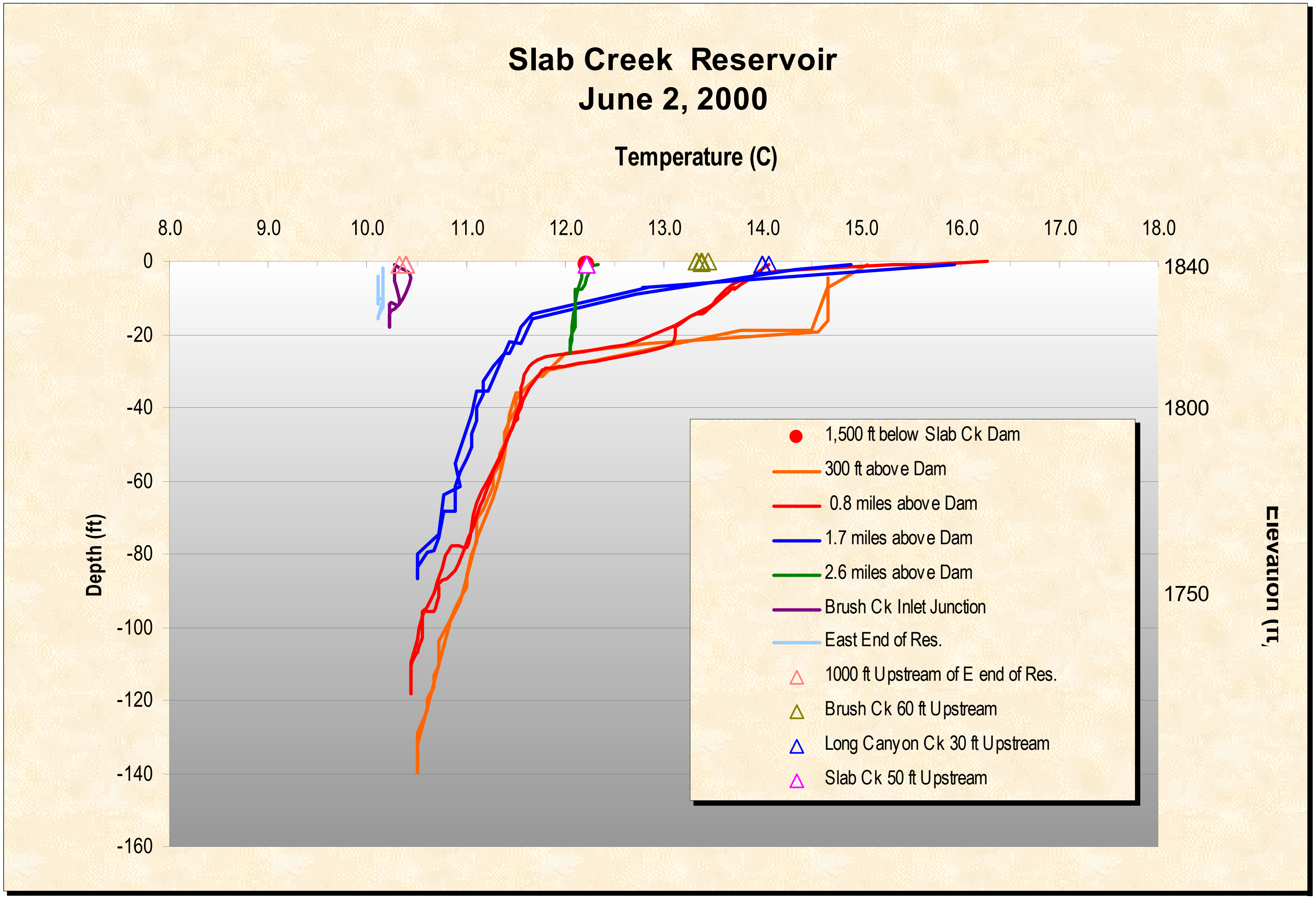

Junction Reservoir
June 4, 2000
Temperature (C)
5.0
7.0
9.0
11.0
13.0
15.0
17.0
19.0
0
-20
-40
-60
-80
-100
-120
Depth (ft)
4450
4430
4400
Elevation (ft)
Base of Dam downstream 60 ft
500 ft above Dam
Center of Reservoir
East end Reservoir
Boat Launch Area
Sth Fork Silver Ck 1000' into Res.
Sth Fork Silver Ck upstream 50 ft
Little Silver Ck upstream 30 ft


Camino Reservoir
June 4, 2000


Brush Creek Reservoir
June 8, 2000
Temperature (C)
5.0
7.0
9.0
11.0
13.0
15.0
17.0
19.0
0
-20
-40
-60
-80
-100
-120
Depth (ft)
2909
2900
2850
Elevation (ft)
● Base of Brush Ck Dam
300 ft above Dam
Center of Res. 400 ft in
△ Brush Ck. 50 ft upstream

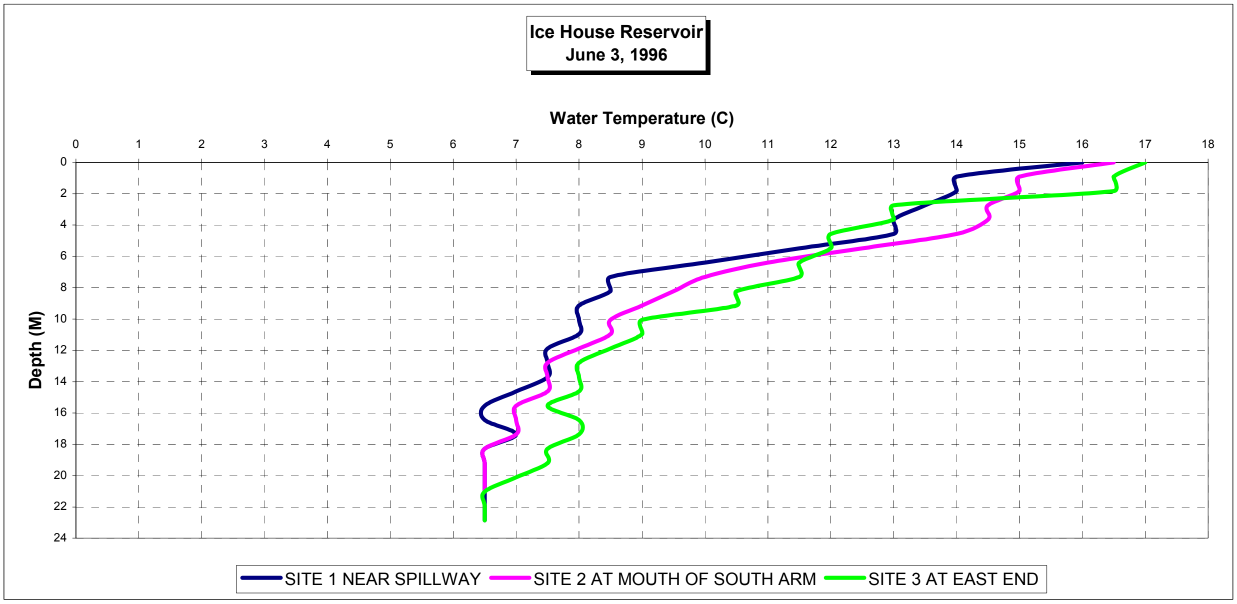


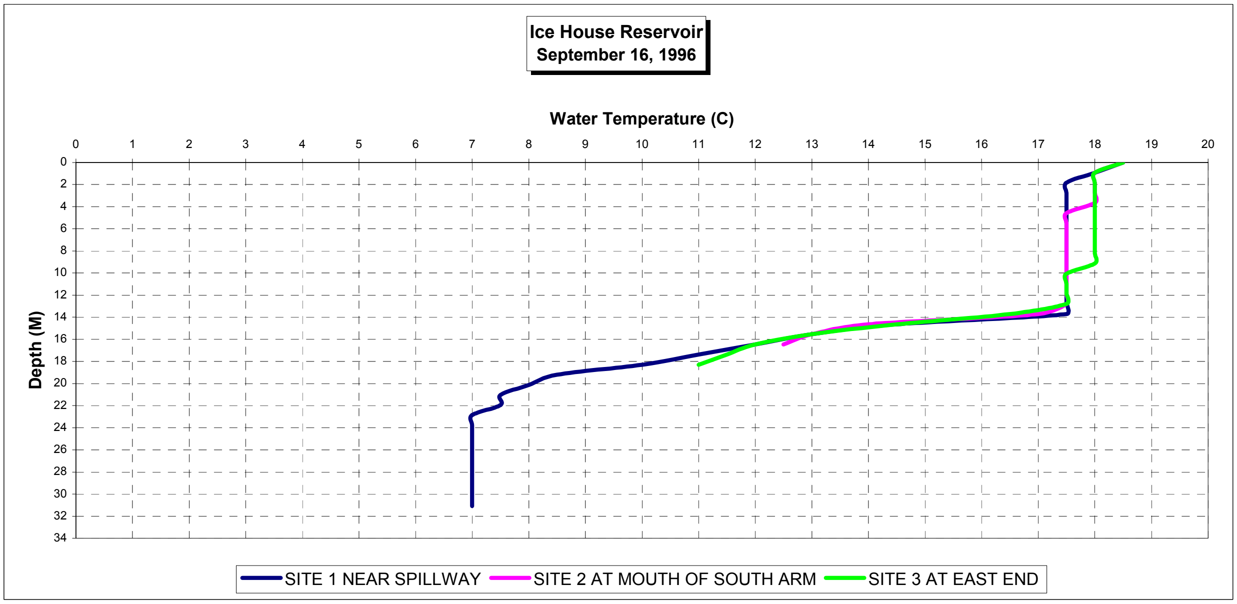
Slab Creek Reservoir
Nov 8, 1999

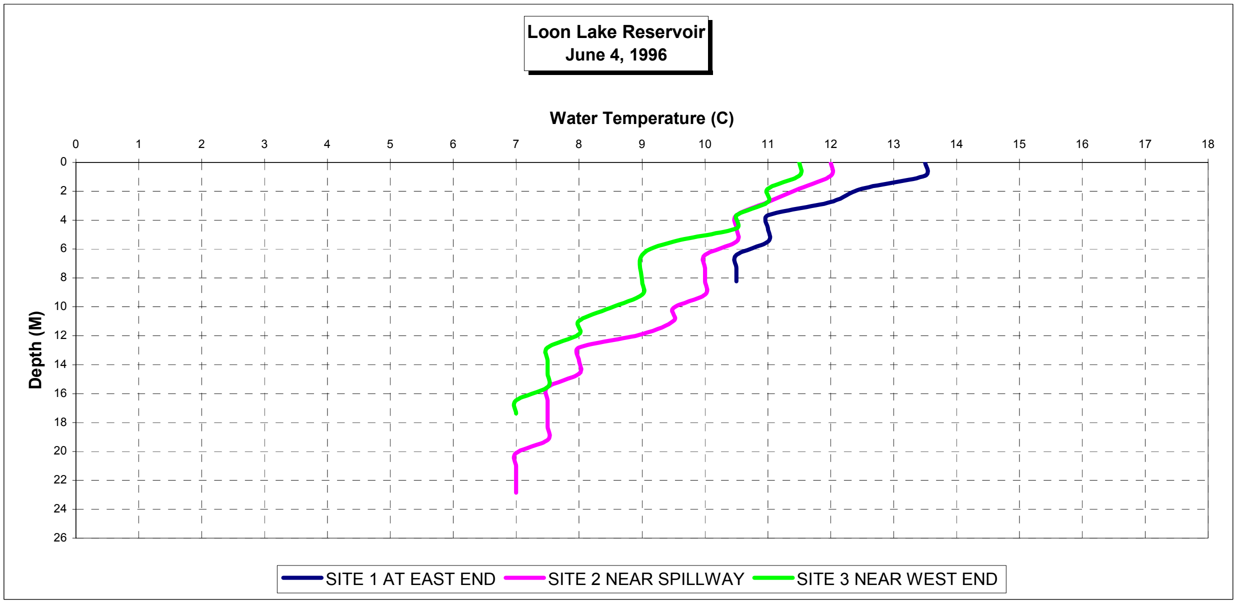

Slab Creek Reservoir
June 2, 2000
Temperature (C)
8.0
9.0
10.0
11.0
12.0
13.0
14.0
15.0
16.0
17.0
18.0
0
-20
-40
-60
-80
-100
-120
-140
-160
Depth (ft)
1840
1800
1750
Elevation (ft
● 1,500 ft below Slab Ck Dam
300 ft above Dam
0.8 miles above Dam
1.7 miles above Dam
2.6 miles above Dam
Brush Ck Inlet Junction
East End of Res.
△ 1000 ft Upstream of E end of Res.
△ Brush Ck 60 ft Upstream
△ Long Canyon Ck 30 ft Upstream
△ Slab Ck 50 ft Upstream

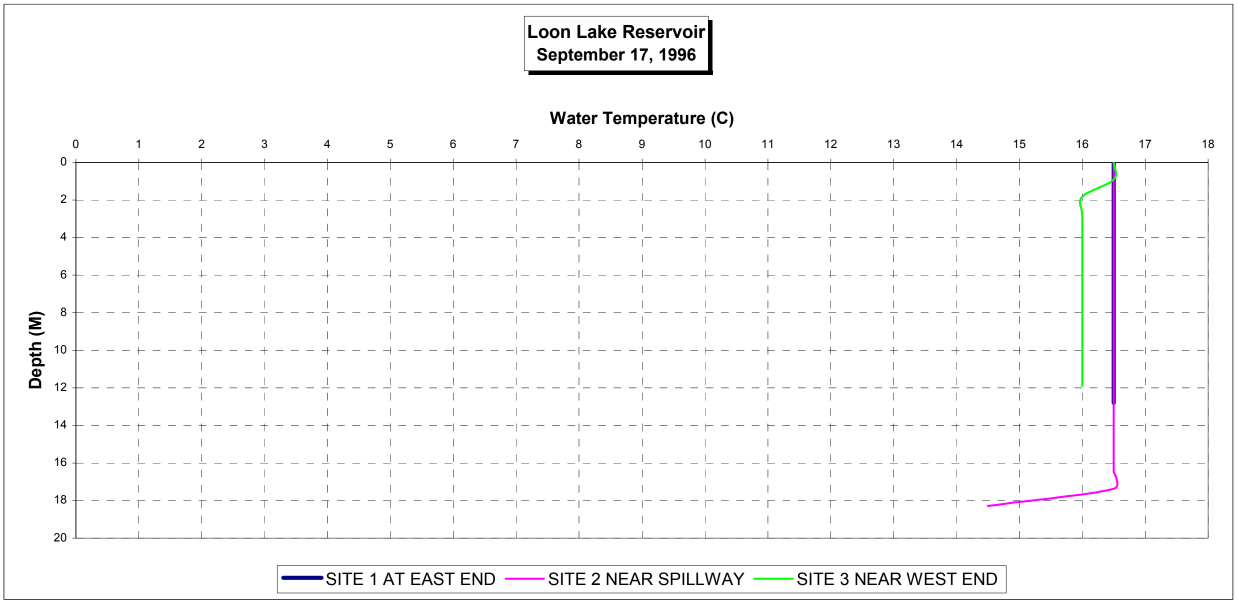
SECTION 3

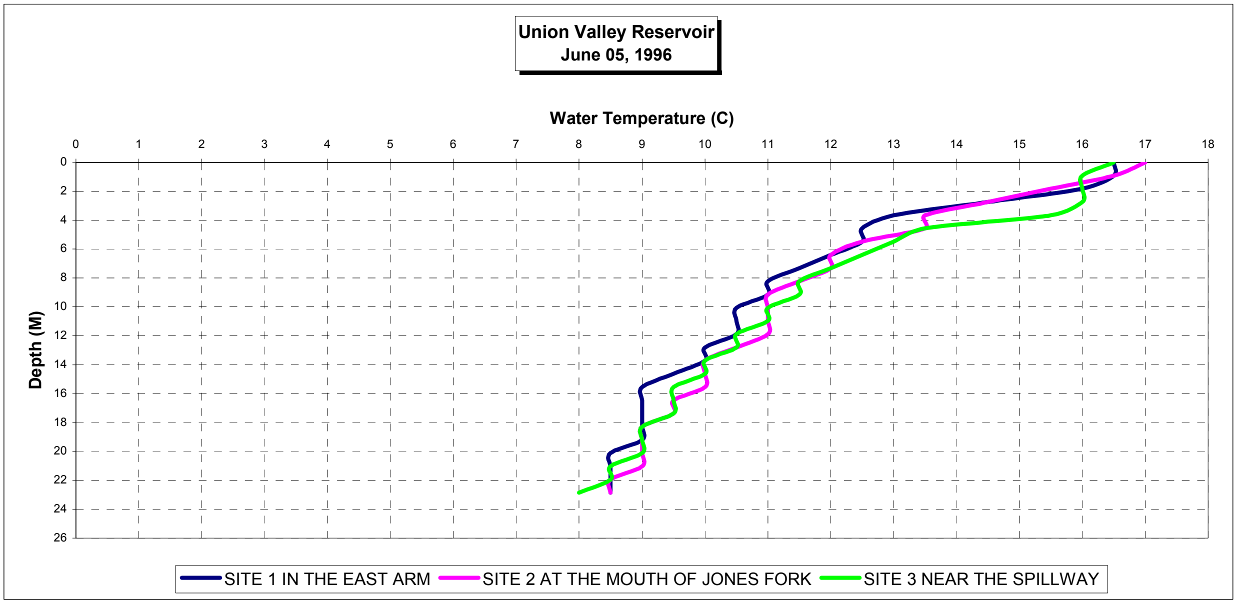
1996 USGS PROFILE DATA


Ice House Reservoir
June 3, 1996
Water Temperature (C)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Depth (M)
0 2 4 6 8 10 12 14 16 18 20 22 24
SITE 1 NEAR SPILLWAY
SITE 2 AT MOUTH OF SOUTH ARM
SITE 3 AT EAST END

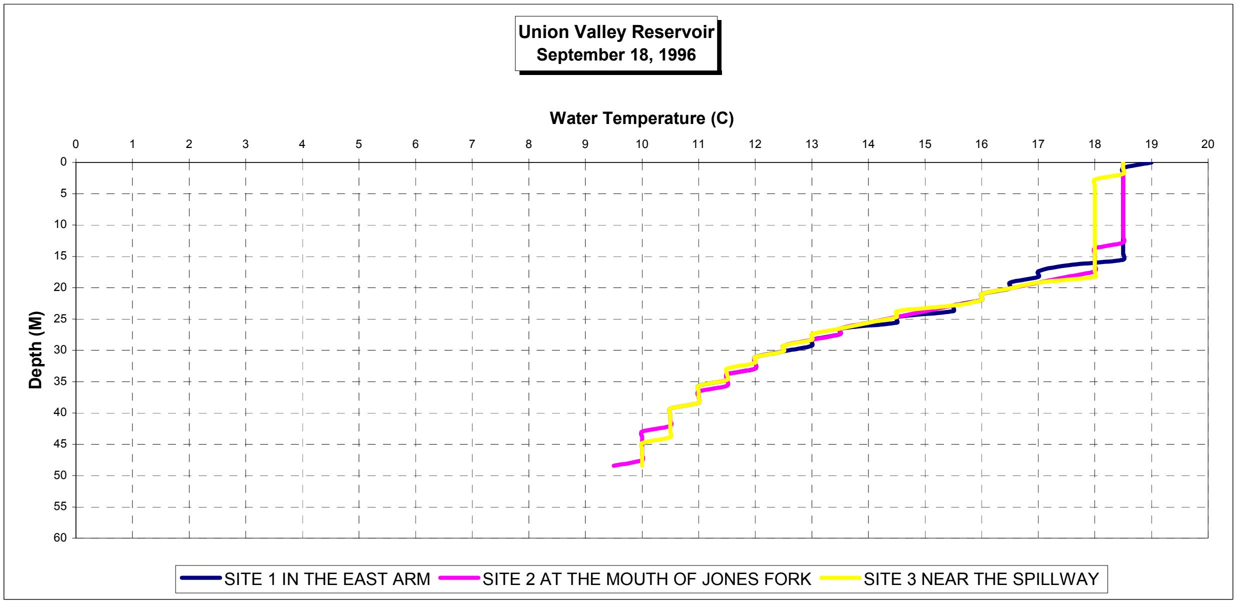

Ice House Reservoir
September 16, 1996
Water Temperature (C)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Depth (M)
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34
SITE 1 NEAR SPILLWAY
SITE 2 AT MOUTH OF SOUTH ARM
SITE 3 AT EAST END


Loon Lake Reservoir
June 4, 1996
Water Temperature (C)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Depth (M)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
SITE 1 AT EAST END
SITE 2 NEAR SPILLWAY
SITE 3 NEAR WEST END


Loon Lake Reservoir
September 17, 1996
Water Temperature (C)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Depth (M)
0
2
4
6
8
10
12
14
16
18
20
SITE 1 AT EAST END
SITE 2 NEAR SPILLWAY
SITE 3 NEAR WEST END



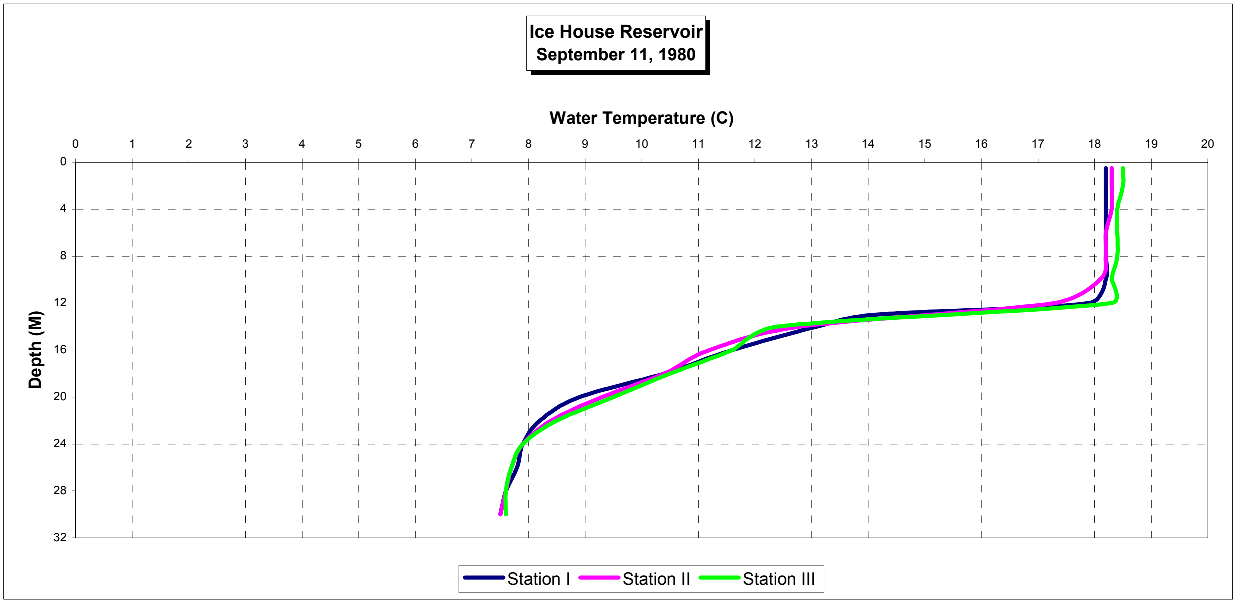
Union Valley Reservoir
June 05, 1996
Water Temperature (C)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Depth (M)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
SITE 1 IN THE EAST ARM
SITE 2 AT THE MOUTH OF JONES FORK
SITE 3 NEAR THE SPILLWAY

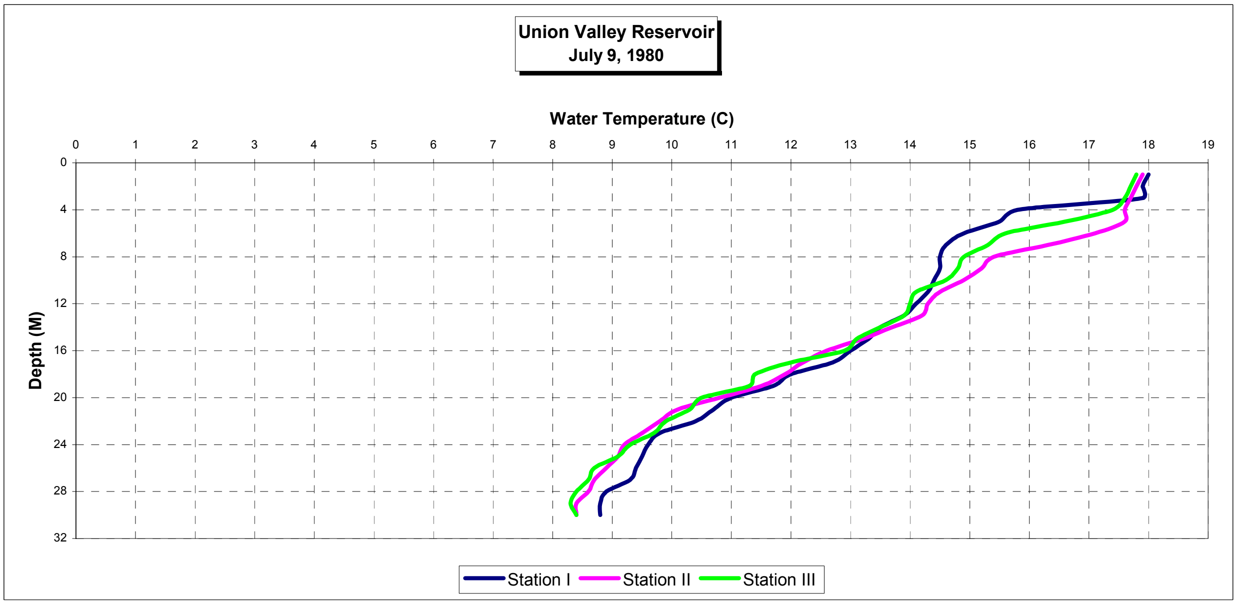


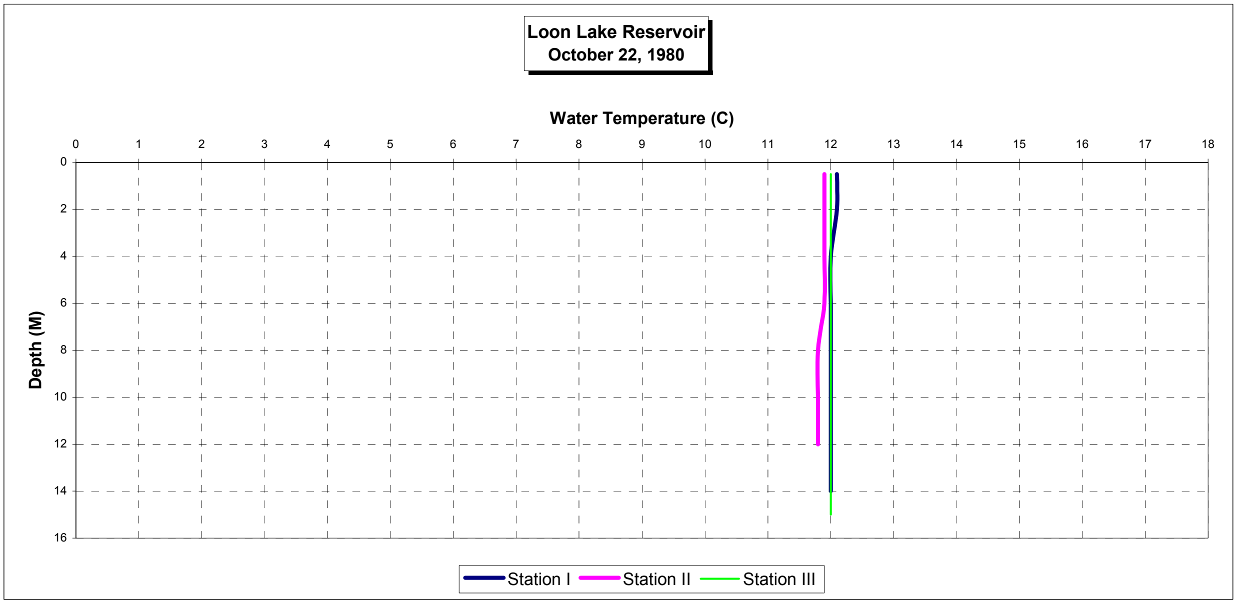
Union Valley Reservoir
September 18, 1996
Water Temperature (C)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Depth (M)
0
5
10
15
20
25
30
35
40
45
50
55
60
SITE 1 IN THE EAST ARM
SITE 2 AT THE MOUTH OF JONES FORK
SITE 3 NEAR THE SPILLWAY

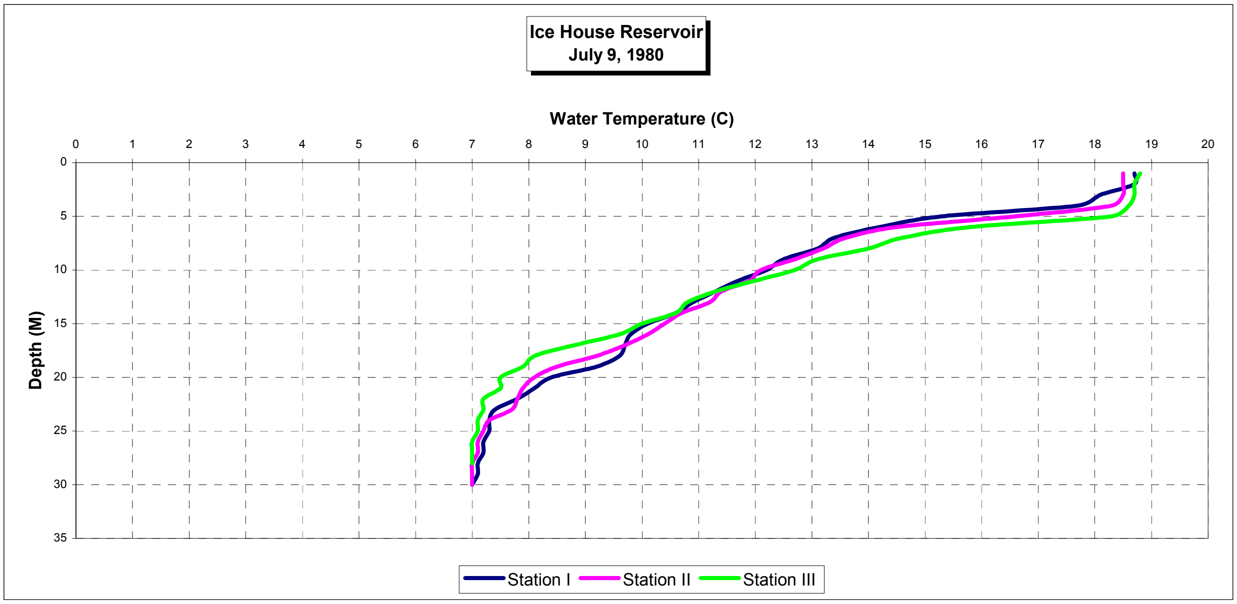
SECTION 4

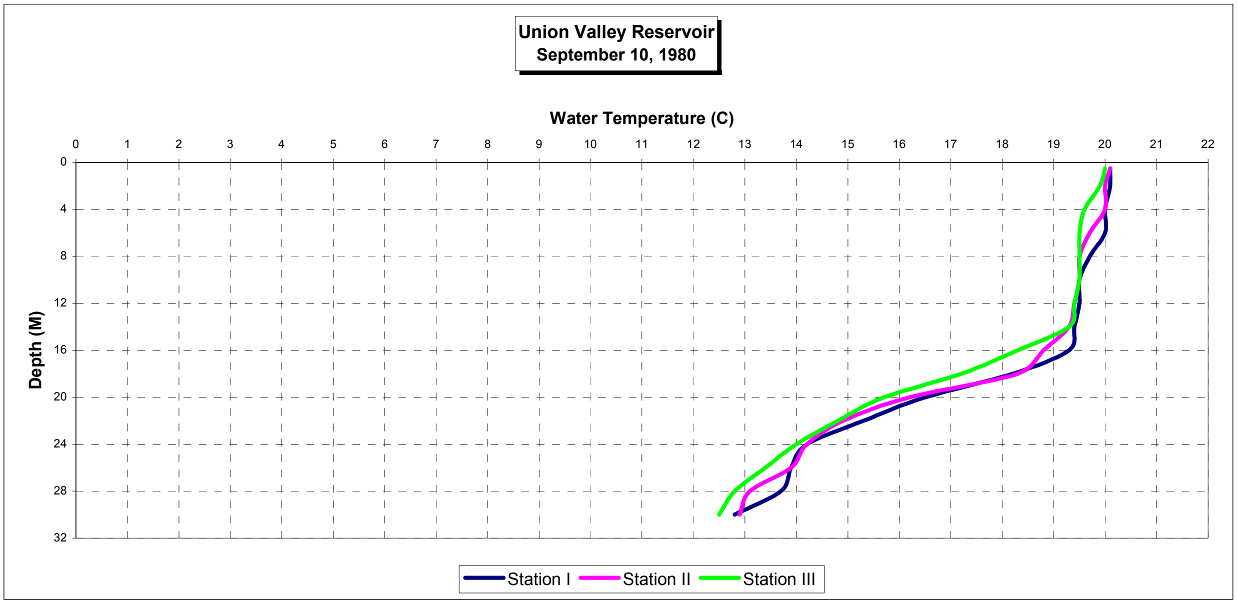
1980 ECOLOGICAL ANALYSTS PROFILE DATA


Ice House Reservoir
September 11, 1980
Water Temperature (C)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Depth (M)
0
4
8
12
16
20
24
28
32
Station I
Station II
Station III


Union Valley Reservoir
July 9, 1980
Water Temperature (C)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Depth (M)
0
4
8
12
16
20
24
28
32
Station I
Station II
Station III


Loon Lake Reservoir
October 22, 1980


Ice House Reservoir
July 9, 1980


Union Valley Reservoir
September 10, 1980
Water Temperature (C)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
Depth (M)
0
4
8
12
16
20
24
28
32
Station I
Station II
Station III

APPENDIX B

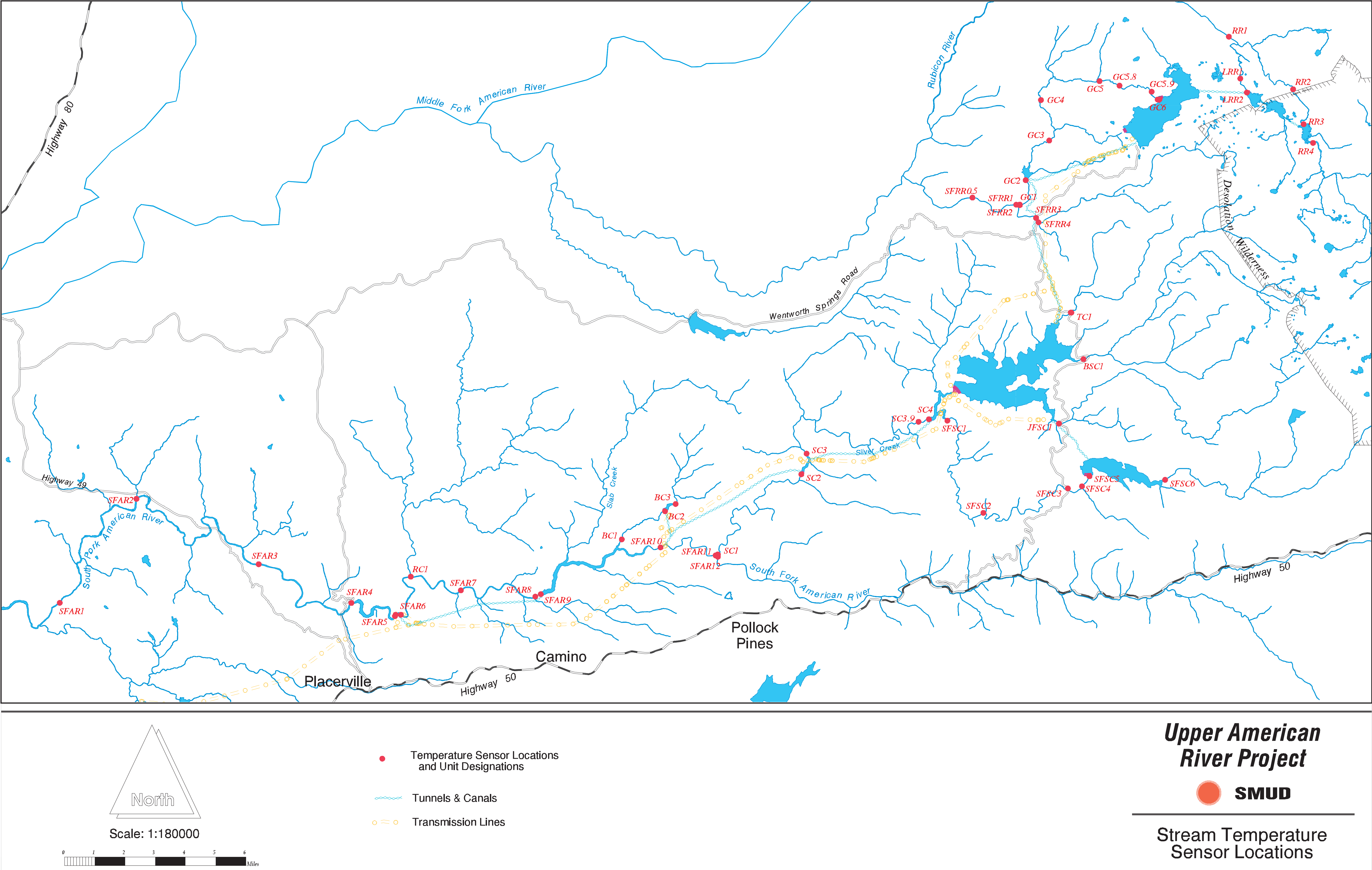
MAP OF CONTINUOUS WATER TEMPERATURE MONITORING LOCATIONS AND WATER TEMPERATURE MONITORING GRAPHS

Included in the stream temperature times series plots of this appendix are overlay plots of stream flow for the same time period. The source of stream flow data differs among the temperature sampling locations. For sampling locations that are near existing USGS gage stations (usually below a dam), gage data are used directly for the stream flow overlay. For sampling locations that are not in the vicinity of a gage station (such as inflow to reservoirs), the stream flow overlay data are estimated values derived from historic gage records, accretion estimates and watershed data. These sampling locations include:

- Rubicon River below Little Rubicon (RR1)
- Rubicon River above Rubicon Reservoir (RR4)
- Gerle Creek above Gerle Creek Reservoir (GC3)
- Gerle Creek below Barts Creek (GC4)
- Gerle Creek above Jerrett Creek (GC5)
- Gerle Creek above SF Rubicon River (GC1)
- SF Rubicon River above Gerle Creek (SFRR2)
- SF Rubicon River above Robbs Forebay (SFRR4)
- SF Silver Creek above Junction Reservoir (SFSC1)
- SF Silver Creek midway between burn area (SFSC2)
- SF Silver Creek above Ice House Reservoir (SFSC6)
- SF Silver Creek above Jaybird powerhouse (SC3)
- Tells Creek above Union Valley Reservoir (TC1)
- Big Silver Creek above Union Valley Reservoir (BSC1)
- Jones Fork Silver Creek above Union Valley Reservoir (JFSC1)
- SF American River above White Rock powerhouse (SFAR6)
- SF American River at Mosquito Bridge (SFAR7)

As of the preparation of these appendix materials, official gage data for water year 2004 have not yet been released by USGS. Nevertheless, SMUD was able to create a stream flow overlap plot using the 2004 preliminary gage data. These data are preliminary and may be adjusted once USGS releases the official data set.

The time series plots of air temperature provided in this appendix are estimated values that have been derived from air temperature data from the Pacific House meteorological station, modified by an adiabatic correction factor.



Scale: 1:180000

● Temperature Sensor Locations and Unit Designations

Tunnels & Canals

Transmission Lines

Upper American River Project

SMUD

Stream Temperature Sensor Locations

Map prepared by VESTRA Resources, Redding CA February 09, 2005

SECTION 1

Water Temperature Station Map, Water Temperature Monitor Stations Sensor Table & Accretion Site Table

Sensor Table

Reach	Station Name	Station Description	GPS location	Flow Data USGS Site #	Unit Number	Show / No Show	Elevation (Ft)
Brush Creek	BC1	Brush Creek Above Slab Creek Reservoir	N 38° 47.824' W 120° 40.987'		74	1	1860
Brush Creek	BC2	Brush Creek At Brush Creek Dam	N 38° 48.574' W 120° 37.307'	11442700	26	1	2720
Brush Creek	BC3	Brush Creek Above Brush Creek Dam	N 38° 48.880' W 120° 60.800'		70	1	2920
Camino	SC1	Silver Creek Above SF American River	N 38° 47.403' W 120° 35.392'	11441900+CR4+CR5	25	1	2060
Camino	SC2	Silver Creek At Camino Dam	N 38° 50.232' W 120° 32.041'	11441900	9	1	2800
Chili Bar	SFAR1	SF American River Above Weber Creek	N 38° 46.465' W 120° 59.677'		67	1	480
Chili Bar	SFAR2	SF American River Below Greenwood Creek	N 38° 49.417' W 120° 56.765'		63	1	640
Chili Bar	SFAR3	SF American River Above Dutch Creek	N 38° 47.450' W 120° 52.316'		61	1	800
Chili Bar	SFAR4	SF American River At Chilli Bar Dam	N 38° 46.269' W 120° 48.937'	11444500	64	1	900
Gerle Creek	GC1	Gerle Creek Above SF Rubicon River	N 38° 57.255' W 120° 23.905'	Gerle Ck Bl Gerle Res+GR4	54	1	5040
Gerle Creek	GC2	Gerle Creek At Gerle Creek Dam	N 38° 57.952' W 120° 23.661'	Gerle Ck Bl Gerle Res	33	1	5170
Ice House	SFSC1	SF Silver Creek Above Junction Reservoir	N 38° 51.082' W 120° 26.800'	11441500+IH4+IH5+IH6+IH7	24	1	4450
Ice House	SFSC2	SF Silver Creek Midway Between Burn Area	N 38° 48.393' W 120° 25.570'	11441500+IH4+IH5	4	1	4800
Ice House	SFSC3	SF Silver Creek Below Ice House Dam Road	N 38° 49.027' W 120° 22.431'	11441500+IH4	52	1	5200
Ice House	SFSC4	SF Silver Creek Above Ice House Dam Road	N 38° 49.071' W 120° 21.919'	11441500+IH4	32	1	5200
Ice House	SFSC5	SF Silver Creek At Ice House Dam	N 38° 49.364' W 120° 21.622'	11441500	28	1	5300
Ice House	SFSC6	SF Silver Creek Above Ice House Reservoir	N 38° 49.195' W 120° 18.839'	Unimp SFSC	41	1	5450
Junction	BSC1	Big Silver Creek Above Union Valley Reservoir	N 38° 52.743' W 120° 21.719'	Big Silver	11	1	4870
Junction	JFSC1	Jones Fork Silver Creek Above Union Valley Reservoir	N 38° 50.908' W 120° 22.674'	JF Silver	17	1	4870
Junction	SC3	Silver Creek Above Jaybird Powerhouse	N 38° 49.663' W 120° 32.072'	11441800+JR4+JR5+JR6+JR7	20	1	2920
Junction	SC4	Silver Creek At Junction Dam	N 38° 51.137' W 120° 27.480'	11441800	19	1	4280
Junction	SC3.9	Silver Creek About 0.5 mi. Below Junction dam	N 38° 51.060' W 120° 27.861'		73	1	4230
Junction	TC1	Tells Creek Above Union Valley Reservoir	N 38° 54.097' W 120° 22.137'	Tells Ck	1	1	4870
Little Rubicon	LRR1	Little Rubicon River Above Rubicon River	N 39° 00.702' W 120° 15.624'		68	1	6000
Little Rubicon	LRR2	Little Rubicon At Buck Island Dam	N 39° 00.294' W 120° 15.399'	11428400	18	1	6410
Loon Lake	GC3	Gerle Creek Above Gerle Creek Reservoir	N 38° 59.071' W 120° 22.766'	11429500+LL4+LL5+LL5+LL6	3	1	5230
Loon Lake	GC4	Gerle Creek Below Barts Creek	N 38° 00.252' W 120° 23.011'	11429500+LL4+LL5	44	1	5800
Loon Lake	GC5	Gerle Creek Above Jerrett Creek	N 39° 00.748' W 120° 20.827'	11429500+LL4	42	1	5920
Loon Lake	GC5.8	Gerle Ck. About 1.5 mi. Below Loon Lake Dam	N 39° 00.399' W 120° 18.915'		71	1	6030
Loon Lake	GC5.9	Gerle Ck. About 0.5 mi. Below Loon Lake Dam	N 39° 00.399' W 120° 18.915'		72	1	6150
Loon Lake	GC6	Gerle Creek At Loon Lake Dam	N 38° 59.881' W 120° 18.477'	11429500	5	1	6300
Loon Lake	JC1	Jerrett Ck above Gerle Ck	N 39° 00.800' W 120° 20.916'		56	1	5920
Rubicon River	RR1	Rubicon River Below Little Rubicon	N 39° 01.919' W 120° 16.000'	11427960+RR4+RR5+RR6	12	1	6000
Rubicon River	RR2	Rubicon River Above Rubicon Springs	N 39° 00.347' W 120° 13.685'	11427960+RR4	45	1	6040
Rubicon River	RR3	Rubicon River At Rubicon Dam		11427960	6	1	6510
Rubicon River	RR4	Rubicon River Above Rubicon Reservoir	N 38° 58.783' W 120° 13.008'	Unimp RR	43	1	6550
SF American River	SFAR10	SF American River At Camino Powerhouse	N 38° 47.662' W 120° 37.509'		27	1	1860
SF American River	SFAR11	SF American River Below Silver Creek	N 38° 47.376' W 120° 35.475'		15	1	2060
SF American River	SFAR12	SF American River Above Silver Creek	N 38° 47.334' W 120° 35.394'		37	1	2060
SF Rubicon	SFRR.5	SF Rubicon River 2 mi. Below Gerle Creek	N 38° 57.577' W 120° 24.808'		75	1	4800
SF Rubicon	SFRR1	SF Rubicon River Below Gerle Creek	N 38° 57.252' W 120° 24.035'	11430000	10	1	5020
SF Rubicon	SFRR2	SF Rubicon River Above Gerle Creek	N 38° 57.241' W 120° 23.917'	SF Rubicon Bl Robbs+GR4	53	1	5040
SF Rubicon	SFRR3	SF Rubicon River At Robbs Forebay Dam	N 38° 56.853' W 120° 23.304'	SF Rubicon Bl Robbs	34	1	5180
SF Rubicon	SFRR4	SF Rubicon River Above Robbs Forebay	N 38° 56.739' W 120° 23.212'	Unimp SFRR	13	1	5230
Slab Creek	RC1	Rock Creek Above SF American River	N 38° 46.986' W 120° 46.725'		57	1	1150
Slab Creek	SFAR5	SF American River At White Rock Powerhouse	N 38° 45.901' W 120° 47.315'		2	1	1000
Slab Creek	SFAR6	SF American River Above White Rock Powerhouse	N 38° 45.894' W 120° 47.121'	11443500+SR4+SR5+SR6+SR7	55	1	1010
Slab Creek	SFAR7	SF American River At Mosquito Bridge	N 38° 46.555' W 120° 44.893'	11443500+SR4+SR5	14	1	1240
Slab Creek	SFAR8	SF American River Below Walking Bridge	N 38° 46.322' W 120° 42.156'	11443500	30	1	1640
Slab Creek	SFAR9	SF American River At Slab Creek Dam	N 38° 46.389' W 120° 41.951'	11443500	31	1	1640

Accretions Table

RR4	Rubicon River at Rubicon Springs
RR5	Rubicon River blw Miller Creek excluding above Rubicon Springs
RR6	Rubicon River below Little Rubicon
LL4	Gerle Creek below Jerret Creek excl inflow Loon
LL5	Gerle Creek below Barts & Deller Creek
LL6	Gerle Creek below above Basin Creek
LL7	Gerle Creek below Rocky Basin Creek
GR4	Gerle Creek above SF Rubicon excl Gerle Creek abv Gerle Res.
GR5	SF Rubicon u/s of Rubicon River
IH4	SF Silver Creek Below Peavine Ridge
IH5	SF Silver Creek Below Windmiller Ridge
IH6	SF Silver Creek Below Big Hill Canyon
IH7	SF Silver Creek at Junction Reservoir
JR4	Silver Creek below Grey Horse Creek
JR5	Silver Creek below Onion Creek
JR6	Silver Creek below Sugar Pine Creek
JR7	Silver Creek above Camino Reservoir
CR4	Silver Creek (half way below no name creek)
CR5	Mouth of SFAR
BR4	Brush Creek Above Slab Creek Reservoir
SR4	SF American River below Iowa Canyon Creek
SR5	SF American River below MosquiRd Bridge
SR6	SF American River below Rock Creek
SR7	SF American River above Chili Bar R

SECTION 2

Daily AIR Water flow
Processed data*

*Additional information provided:

(1) Mean daily air temperature from CDWR’s Pacific House weather station adjusted to monitoring site elevation.

(2) Mean daily flows for USGS gage locations below UARP dams. All other sites based on accretion or unimpaired flow estimates. Gage locations include:

Rubicon River at Rubicon Dam – RR3
Little Rubicon River at Buck Island Dam – LRR2
Gerle Creek at Loon Lake Dam – GC6
South Fork Rubicon River below Gerle Creek – SFRR1
South Fork Silver Creek at Ice House Dam – SFSC5
Silver Creek at Junction Dam – SC4
Silver Creek at Camino Dam – SC2
South Fork American River at Slab Creek Dam – SFAR9
South Fork American River at Chili Bar Dam

(Due to the volume of information contained in this Appendix it is provided for review on CD)

SECTION 3

Daily Air Temperature
Organized By River Reach

(Due to the volume of information contained in this Appendix it is provided for review on CD)

APPENDIX C

STREAM WATER TEMPERATURE SNTEMP MODELING INFORMATION CALIBRATED INPUT FILES

- Ice House Dam Reach
- Camino Dam Reach
- Slab Creek Dam Reach

(Due to the volume of information contained in this Appendix it is provided for review on CD)

APPENDIX D

HOURLY TEMPERATURE DATA

(Due to the volume of information contained in this Appendix it is provided for review on CD)

APPENDIX E

DAILY MEAN DATA

(Due to the volume of information contained in this
Appendix it is provided for review on CD)

APPENDIX F

UARP AND CHILI BAR PROJECT AREA MAP

- Map (NE) of the SMUD Upper American River Project
- Map (SE) of the SMUD Upper American River Project
- Map (West) of the SMUD Upper American River Project
- Map (SW) of the SMUD Upper American River Project