State of California
The Resources Agency
Department of Water Resources

SPW6. PROJECT EFFECTS ON TEMPERATURE REGIME

Oroville Facilities Relicensing
FERC Project No. 2100

DRAFT FINAL REPORT

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REPORT SUMMARY

Operation of the Oroville Facilities affects water temperatures in the Feather River. Concern has been expressed at public meetings for project operation effects on temperature needs for fisheries, agriculture, and other beneficial uses; depletion of the cold water pool; effects from pump back; and effects of the hatchery in controlling temperatures in the Feather River. The Federal Energy Regulatory Commission (FERC) will require a water quality certification by the State Water Resources Control Board (SWRCB), which in turn must determine that the project complies with appropriate requirements of the Central Valley Regional Water Quality Control Board's (CVRWQCB) Basin Plan, including objectives for temperature.

The objectives of the study are to evaluate effects of project facilities and operations on the temperature regime of project waters and waters affected by the project, and the ability of the project to meet the temperature requirements for protection of beneficial uses, including agriculture, fish, and other aquatic resources. Information obtained from the study is used to determine the ability of the project to meet water temperature requirements, and the need for project modification or mitigation for impacts to water temperature from project operations. Water temperature data collected for this study provides information for assessing current baseline conditions of the Project. The data are also used to verify temperature models, and can be use to evaluate proposed project operation changes.

Water temperatures downstream from Oroville Dam are largely controlled by temperature requirements at the Feather River Fish Hatchery. Water is released from Oroville Dam to meet the hatchery temperature requirements, as well as those of the NOAA Fisheries at Robinson's Riffle, while also conserving the cold water pool in Lake Oroville. Water is released from Lake Oroville that is as close as possible to the maximum temperature allowable under the 1983 agreement with DFG to accommodate temperature requirements, as much as possible, for irrigation. However, due to conflicting temperature requirements for fisheries, it is not always possible to provide the temperatures desired by rice farmers.

During dryer years when reservoir levels are low, the cold water pool is diminished. In critically dry years, the cold water pool could be exhausted, resulting in water that is warmer than desired for the most critical needs (e.g., salmonid egg incubation). Deliveries from the reservoir are governed by the water year type. In dryer years, deliveries to water contractors are reduced so that carryover storage is increased and water may be conserved for critical in-stream needs.

Water released for power generation may be pumped back into the reservoir for re-use. While pump back operations can draw water that has warmed in the Thermalito Forebay or Afterbay back into the Diversion Pool and Lake Oroville, these activities are carefully monitored to insure that no adverse effects occur to other beneficial uses. Water temperatures at the hatchery, which receives water diverted from the Diversion

Pool, are monitored during pump back. Pump back is curtailed if water temperatures approach the limits of hatchery requirements. No effects from pump back to water column temperatures in the reservoir could be determined.

As specific temperature related issues are identified, data from this study can be used in their evaluation.

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1.0 INTRODUCTION

Existing and future operation of the Oroville Facilities may have effects on the temperature goals and objectives for the Feather River. Issues raised at public meetings include:

- effects of existing and future project facilities and operations on thermal stratification and other thermal processes on project waters, including availability of cold water for release in various water year types under current and future operational demands;
- effects of existing and future water releases and operations on water in the Diversion Pool, Forebay, Afterbay, Oroville Wildlife Area, low-flow section of the river, and downstream areas;
- at the hatchery;
- for agriculture;
- the quality and availability of habitat for salmonids and other aquatic resources;
- existing and future project compliance with temperature requirements of the SWP Feather River Flow Constraints and effectiveness of constraints for:
  a) protection of salmonids in the low-flow and high-flow sections of the Feather River,
  b) hatchery operation, and
  c) agricultural operations;
- effects of existing and future project facilities and operations on access to the cold water pool during below normal water years and multiple below normal water years under existing and future operational demands, and effectiveness of the Temperature Control Device in providing access;
- effects of existing and future hatchery operations on water quality and water temperatures in the Feather River and Afterbay; and
- effects of existing and future pump back operations on water quality and water temperatures in Lake Oroville, Diversion Pool, Thermalito Forebay, Thermalito Afterbay, and Oroville Wildlife Area, habitat suitability, and outmigration for salmonids.

Some temperature data have been collected from the North, Middle, and South forks of the Feather River near their confluences with Lake Oroville, from the reservoir itself, and downstream from Oroville Dam in the Feather River, Thermalito Power Canal, and Thermalito Afterbay. However, these data are not sufficient to determine compliance with all Basin Plan objectives, goals, and criteria for the designated beneficial uses. Additional temperature data and analyses are needed to demonstrate project compliance with Basin Plan objectives, commitments, and other requirements.

1.1 BACKGROUND INFORMATION

1.1.1 Statutory/Regulatory Requirements

Prior to issuance of a new license for the project, the Federal Energy Regulatory Commission (FERC) will require a water quality certification by the State Water Resources Control Board (SWRCB). The certification requires a determination by the SWRCB that the project complies with appropriate requirements of the Central Valley Regional Water Quality Control Board's (CVRWQCB) Basin Plan, which includes water quality objectives for protection of designated beneficial uses. The CVRWQCB has established surface water quality objectives for temperature. In addition, the California Department of Water Resources (DWR) has agreements with the Department of Fish and Game (DFG) for temperature objectives for the Feather River Fish Hatchery and with several water districts for temperature objectives for irrigation. The National Oceanic and Atmospheric Administration Fisheries (NOAA Fisheries - formerly National Marine Fisheries Service) has also identified temporary temperature goals in the Feather River downstream from Oroville Dam for salmonids that are listed under the federal Endangered Species Act.

1.1.2 Study Area

The study area is generally within the FERC project boundary, but also includes the Feather River downstream to the confluence with the Sacramento River. Specific water bodies included in the study plan are the North, Middle, and South Forks and West Branch of the Feather River, Concow Creek, Lake Oroville, Feather River downstream from Oroville Dam to the confluence with the Sacramento River, Thermalito Diversion Pool, Forebay, and Afterbay, and Oroville Wildlife Area ponds.

1.2 DESCRIPTION OF FACILITIES

The Oroville Facilities were developed as part of the State Water Project (SWP), a water storage and delivery system of reservoirs, aqueducts, power plants, and pumping plants. The main purpose of the SWP is to store and distribute water to supplement the needs of urban and agricultural water users in northern California, the San Francisco Bay area, the San Joaquin Valley, and southern California. The Oroville Facilities are also operated for flood management, power generation, to improve water quality in the Delta, provide recreation, and enhance fish and wildlife.

FERC Project No. 2100 encompasses 41,100 acres and includes Oroville Dam and Reservoir, three power plants (Hyatt Pumping-Generating Plant, Thermalito Diversion Dam Power Plant, and Thermalito Pumping-Generating Plant), Thermalito Diversion Dam, the Feather River Fish Hatchery and Fish Barrier Dam, Thermalito Power Canal, Oroville Wildlife Area (OWA), Thermalito Forebay and Forebay Dam, Thermalito

Afterbay and Afterbay Dam, and transmission lines, as well as a number of recreational facilities. An overview of these facilities is provided on Figure 1.2-1. The Oroville Dam, along with two small saddle dams, impounds Lake Oroville, a 3.5-million-acre-feet (maf) capacity storage reservoir with a surface area of 15,810 acres at its normal maximum operating level.

The hydroelectric facilities have a combined licensed generating capacity of approximately 762 megawatts (MW). The Hyatt Pumping-Generating Plant is the largest of the three power plants with a capacity of 645 MW. Water from the six-unit underground power plant (three conventional generating and three pumping-generating units) is discharged through two tunnels into the Feather River just downstream of Oroville Dam. The plant has a generating and pumping flow capacity of 16,950 and 5,610 cubic feet per second (cfs), respectively. Other generation facilities include the 3-MW Thermalito Diversion Dam Power Plant and the 114-MW Thermalito Pumping-Generating Plant.

Thermalito Diversion Dam, four miles downstream of the Oroville Dam creates a tail water pool for the Hyatt Pumping-Generating Plant and is used to divert water to the Thermalito Power Canal. The Thermalito Diversion Dam Power Plant is a 3-MW power plant located on the left abutment of the Diversion Dam. The power plant releases a maximum of 615 cfs of water into the river.

The Power Canal is a 10,000 foot-long channel designed to convey generating flows of 16,900 cfs to the Thermalito Forebay and pump back flows to the Hyatt Pumping-Generating Plant. The Thermalito Forebay is an off-stream regulating reservoir for the 114-MW Thermalito Pumping-Generating Plant. The Thermalito Pumping-Generating Plant is designed to operate in tandem with the Hyatt Pumping-Generating Plant and has generating and pump back flow capacities of 17,400 and 9,120 cfs, respectively. When in generating mode, the Thermalito Pumping-Generating Plant discharges into the Thermalito Afterbay, which is contained by a 42,000 foot-long earth-fill dam. The Afterbay is used to release water into the Feather River downstream of the Oroville Facilities, helps regulate the power system, provides storage for pump back operations, and provides recreational opportunities. Several local irrigation districts receive water from the Afterbay.

The Feather River Fish Barrier Dam is downstream of the Thermalito Diversion Dam and immediately upstream of the Feather River Fish Hatchery. The flow over the dam maintains fish habitat in the low-flow channel of the Feather River between the dam and the Afterbay outlet, and provides attraction flow for the hatchery. The hatchery was intended to compensate for spawning grounds lost to returning salmon and steelhead trout from the construction of Oroville Dam. The hatchery can accommodate an average of 8,000 adult fish annually.

The Oroville Facilities support a wide variety of recreational opportunities. They include: boating (several types), fishing (several types), fully developed and primitive camping (including boat-in and floating sites), picnicking, swimming, horseback riding, hiking, off-road bicycle riding, wildlife watching, hunting, and visitor information sites with cultural and informational displays about the developed facilities and the natural environment. There are major recreation facilities at Loafer Creek, Bidwell Canyon, the Spillway, North and South Thermalito Forebay, and Lime Saddle. Lake Oroville has two full-service marinas, five car-top boat launch ramps, ten floating campsites, and seven dispersed floating toilets. There are also recreation facilities at the Visitor Center and the OWA.

The OWA comprises approximately 11,000 acres west of Oroville that is managed for wildlife habitat and recreational activities. It includes the Thermalito Afterbay and surrounding lands (approximately 6,000 acres) along with 5,000 acres adjoining the Feather River. The 5,000 acre area straddles 12 miles of the Feather River, which includes willow and cottonwood lined ponds, islands, and channels. Recreation areas include dispersed recreation (hunting, fishing, and bird watching), plus recreation at developed sites, including Monument Hill day use area, model airplane grounds, three boat launches on the Afterbay and two on the river, and two primitive camping areas. DFG's habitat enhancement program includes a wood duck nest-box program and dry land farming for nesting cover and improved wildlife forage. Limited gravel extraction also occurs in a number of locations.

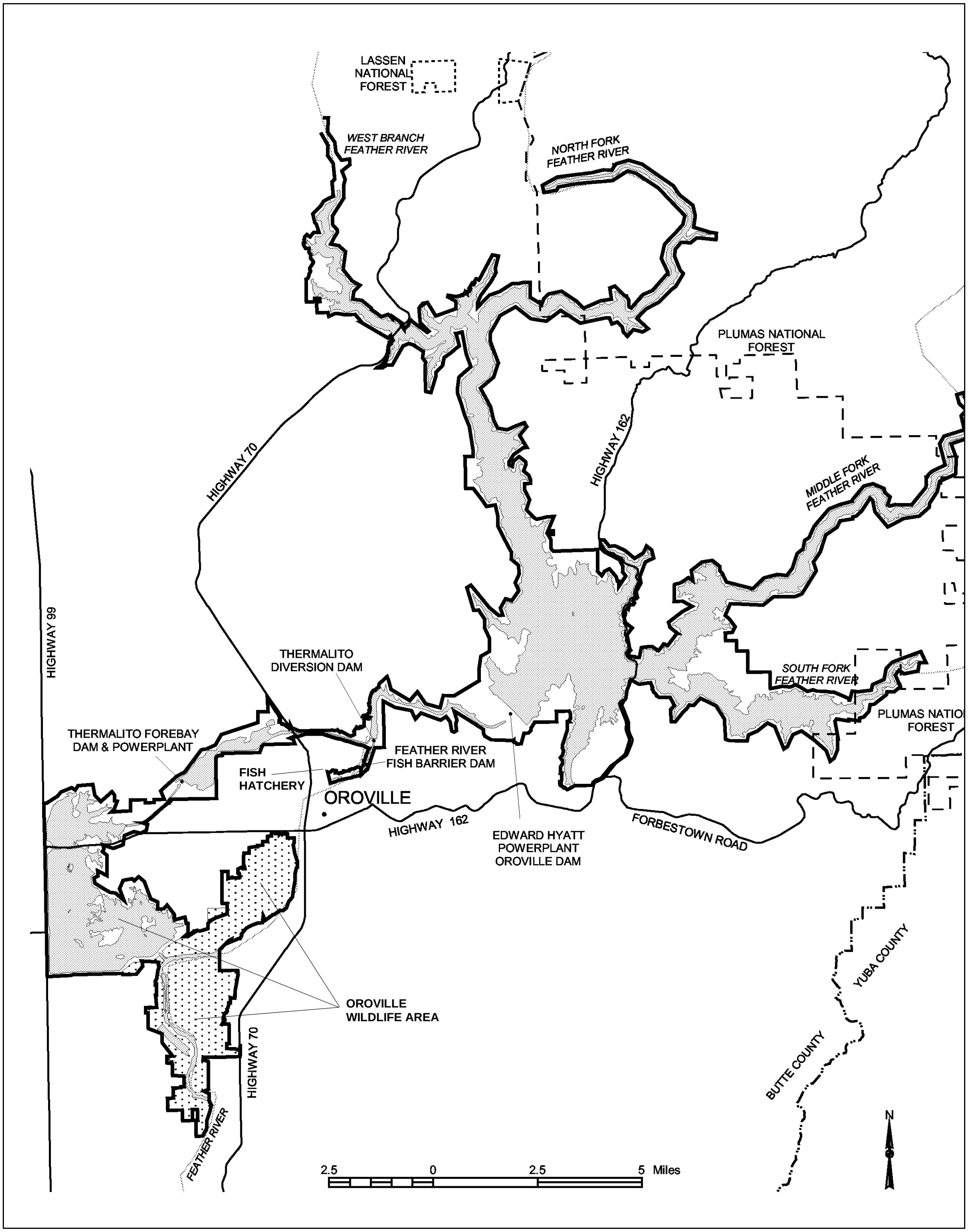


Figure 1.2-1. Oroville Facilities FERC Project Boundary.

1.3 CURRENT OPERATIONAL CONSTRAINTS

Operation of the Oroville Facilities varies seasonally, weekly and hourly, depending on hydrology and the objectives DWR is trying to meet. Typically, releases to the Feather River are managed to conserve water while meeting a variety of water delivery requirements, including flow, temperature, fisheries, recreation, diversion and water quality. Lake Oroville stores winter and spring runoff for release to the Feather River as necessary for project purposes. Meeting the water supply objectives of the SWP has always been the primary consideration for determining Oroville Facilities operation (within the regulatory constraints specified for flood control, in-stream fisheries, and downstream uses). Power production is scheduled within the boundaries specified by the water operations criteria noted above. Annual operations planning is conducted for multi-year carry over. The current methodology is to retain half of the Lake Oroville storage above a specific level for subsequent years. Currently, that level has been established at 1,000,000 acre-feet (af); however, this does not limit draw down of the reservoir below that level. If hydrology is drier than expected or requirements greater than expected, additional water would be released from Lake Oroville. The operations plan is updated regularly to reflect changes in hydrology and downstream operations. Typically, Lake Oroville is filled to its maximum annual level of up to 900 feet above mean sea level in June and then can be lowered as necessary to meet downstream requirements, to its minimum level in December or January. During drier years, the lake may be drawn down more and may not fill to the desired levels the following spring. Project operations are directly constrained by downstream operational constraints and flood management criteria as described below.

1.3.1 Downstream Operation

An August 1983 agreement between DWR and DFG entitled, “Agreement Concerning the Operation of the Oroville Division of the State Water Project for Management of Fish & Wildlife,” sets criteria and objectives for flow and temperatures in the low flow channel and the reach of the Feather River between Thermalito Afterbay and Verona. This agreement: (1) establishes minimum flows between Thermalito Afterbay Outlet and Verona which vary by water year type; (2) requires flow changes under 2,500 cfs to be reduced by no more than 200 cfs during any 24-hour period, except for flood management, failures, etc.; (3) requires flow stability during the peak of the fall-run Chinook spawning season; and (4) sets an objective of suitable temperature conditions during the fall months for salmon and during the later spring/summer for shad and striped bass.

1.3.1.1 Instream Flow Requirements

The Oroville Facilities are operated to meet minimum flows in the Lower Feather River as established by the 1983 agreement (see above). The agreement specifies that Oroville Facilities release a minimum of 600 cfs into the Feather River from the

Thermalito Diversion Dam for fisheries purposes. This is the total volume of flows from the diversion dam outlet, diversion dam power plant, and the Feather River Fish Hatchery pipeline.

Generally, the instream flow requirements below Thermalito Afterbay are 1,700 cfs from October through March, and 1,000 cfs from April through September. However, if runoff for the previous April through July period is less than 1,942,000 af (i.e., the 1911-1960 mean unimpaired runoff near Oroville), the minimum flow can be reduced to 1,200 cfs from October to February, and 1,000 cfs for March. A maximum flow of 2,500 cfs is maintained from October 15 through November 30 to prevent spawning in overbank areas that might become de-watered.

1.3.1.2 Temperature Requirements

The Diversion Pool provides the water supply for the Feather River Fish Hatchery. The hatchery objectives are 52 ºF for September, 51 ºF for October and November, 55 ºF for December through March, 51 ºF for April through May 15, 55 ºF for last half of May, 56 ºF for June 1-15, 60 ºF for June 16 through August 15, and 58 ºF for August 16-31. A temperature range of plus or minus 4 ºF is allowed for objectives, April through November.

There are several temperature objectives for the Feather River downstream of the Afterbay Outlet. During the fall months, after September 15, the temperatures must be suitable for fall-run Chinook. From May through August, they must be suitable for shad, striped bass, and other warmwater fish.

The NOAA Fisheries has also established an explicit criterion for steelhead trout and spring-run Chinook salmon. Memorialized in a biological opinion on the effects of the Central Valley Project and SWP on Central Valley spring-run Chinook and steelhead as a reasonable and prudent measure; DWR is required to control water temperature at Feather River mile 61.6 (Robinson's Riffle in the low-flow channel) from June 1 through September 30. This measure requires water temperatures less than or equal to 65 ºF on a daily average. The requirement is not intended to preclude pump back operations at the Oroville Facilities needed to assist the State of California with supplying energy during periods when the California ISO anticipates a Stage 2 or higher alert.

The hatchery and river water temperature objectives sometimes conflict with temperatures desired by agricultural diverters. Under existing agreements, DWR provides water for the Feather River Service Area (FRSA) contractors. The contractors claim a need for warmer water during spring and summer for rice germination and growth (i.e., 65 ºF from approximately April through mid May, and 59 ºF during the remainder of the growing season). There is no obligation for DWR to meet the rice water temperature goals. However, to the extent practical, DWR does use its operational flexibility to accommodate the FRSA contractor's temperature goals.

1.3.1.3 Water Diversions

Monthly irrigation diversions of up to 190,000 (July 2002) af are made from the Thermalito Complex during the May through August irrigation season. Total annual entitlement of the Butte and Sutter County agricultural users is approximately 1 maf. After meeting these local demands, flows into the lower Feather River continue into the Sacramento River and into the Sacramento-San Joaquin Delta. In the northwestern portion of the Delta, water is pumped into the North Bay Aqueduct. In the south Delta, water is diverted into Clifton Court Forebay where the water is stored until it is pumped into the California Aqueduct.

1.3.1.4 Water Quality

Flows through the Delta are maintained to meet Bay-Delta water quality standards arising from DWR's water rights permits. These standards are designed to meet several water quality objectives such as salinity, Delta outflow, river flows, and export limits. The purpose of these objectives is to attain the highest water quality, which is reasonable, considering all demands being made on the Bay-Delta waters. In particular, they protect a wide range of fish and wildlife including Chinook salmon, Delta smelt, striped bass, and the habitat of estuarine-dependent species.

1.3.2 Flood Management

The Oroville Facilities are an integral component of the flood management system for the Sacramento Valley. During the wintertime, the Oroville Facilities are operated under flood control requirements specified by the U.S. Army Corps of Engineers (USACE). Under these requirements, Lake Oroville is operated to maintain up to 750,000 af of storage space to allow for the capture of significant inflows. Flood control releases are based on the release schedule in the flood control diagram or the emergency spillway release diagram prepared by the USACE, whichever requires the greater release. Decisions regarding such releases are made in consultation with the USACE.

The flood control requirements are designed for multiple use of reservoir space. During times when flood management space is not required to accomplish flood management objectives, the reservoir space can be used for storing water. From October through March, the maximum allowable storage limit (point at which specific flood release would have to be made) varies from about 2.8 to 3.2 maf to ensure adequate space in Lake Oroville to handle flood flows. The actual encroachment demarcation is based on a wetness index, computed from accumulated basin precipitation. This allows higher levels in the reservoir when the prevailing hydrology is dry while maintaining adequate flood protection. When the wetness index is high in the basin (i.e., wetness in the watershed above Lake Oroville), the flood management space required is at its greatest amount to provide the necessary flood protection. From April through June, the maximum allowable storage limit is increased as the flooding potential decreases, which allows capture of the higher spring flows for use later in the year. During September, the maximum allowable storage decreases again to prepare for the next flood season. During flood events, actual storage may encroach into the flood reservation zone to prevent or minimize downstream flooding along the Feather River.

2.0 NEED FOR STUDY

Construction of Oroville Dam resulted in an altered thermal regime of waters within the project boundary and downstream in the Feather River. These temperature changes can affect the ecosystem and beneficial uses of water released downstream. In addition, large shallow water bodies such as the Thermalito Forebay and Afterbay may affect water quality by providing water temperatures that facilitate conversion of sediment-bound metals (e.g., mercury) to bioavailable forms (e.g., methylmercury), which can have effects on the aquatic food chain, wildlife, and humans. Temperature concerns include regulatory requirements for protection of fish habitat, effects of project operations to agriculture, and potential changes in future project operations.

3.0 STUDY OBJECTIVE(S)

The objectives of the study are to evaluate effects of project facilities and operations on the temperature regime of project waters and waters affected by the project, and the ability of the project to meet the temperature requirements for protection of beneficial uses, including agriculture, fish, and other aquatic resources.

3.1 APPLICATION OF STUDY INFORMATION

Information obtained from the study will be used to determine the ability of the project to meet water temperature requirements, and the need for project modification or mitigation for impacts to water temperature from project operations. This analysis is required for water quality certification by the SWRCB. The water quality certification is needed to file with the application for license renewal with FERC. In addition, water temperature data collected from this study will be used in other study plans for assessing habitat suitability and effects from the project to aquatic resources.

4.0 METHODOLOGY

The study is composed of several tasks that assess temperature conditions in project waters and downstream from the project boundaries, temperature compliance, access to the cold water pool in Lake Oroville, effects from the hatchery, and effects from pump back operations.

4.1 STUDY DESIGN

Determination of existing project effects on thermal processes in project waters involves empirical analysis of temperature data, while evaluation of future project effects requires development and calibration of a temperature model to simulate conditions. Where historic and current temperature data are not sufficient to evaluate project effects under various hydrologic conditions, the temperature model can be used to simulate temperature conditions for analysis. Output from the temperature model provides information for a greater range of operations than which may be empirically analyzed.

4.1.1 Task 1 — Thermal Regime of Project Waters

This study plan was responsible for collecting temperature data for empirical analyses of current conditions and providing data for calibration of the temperature models developed in Engineering and Operations study plans. This study provides information for calibration of the temperature models for the Oroville Reservoir, Thermalito Complex, Feather River, Oroville Reservoir cold water pool evaluation, and evaluation of pump back operations.

4.1.1.1 Task 1A — Existing Effects on the Thermal Regime of Project Waters

Some existing temperature data have been collected from the tributaries to the reservoir, Lake Oroville, Feather River downstream from Oroville Dam, and Thermalito Afterbay Outlet to the Feather River and Western Canal. These data have been compiled for access and evaluation.

Additional temperature data were collected at the existing monitoring sites as well as other sites to provide information needed for analyses of project effects on the thermal regime of project waters, document thermal conditions affecting salmonids (such as in spawning, rearing, or migration areas) or other aquatic life, identify sources of thermal change or stress, and provide information for calibration of temperature models. Continuously recording loggers (Onset Optic Stowaway) were used to record temperatures at 15-minute intervals at river or discharge (e.g., hatchery, Thermalito Afterbay Outlet) monitoring locations (Table 4.1.1.1-1, Figures 4.1.1.1-1 and 2). Temperature loggers were serviced and data downloaded to lap top computers at intervals not exceeding monthly.

Table 4.1.1.1-1. Temperature measurement sites in project and downstream waters.

	Location	Measurement Method	Rationale
1	West Branch NR Paradise	Recorder	a,b
2	West Branch US LK Oroville	Recorder	a,b,c
3	Concow Cr A Jordan Hill Rd	Recorder	a,b
4	Concow Creek NR mouth	Recorder	a,b,c
5	North Fork A Pulga	Recorder	a,b
6	North Fork US Poe PH	Recorder	a,b
7	Poe PH Discharge	Grab	k
8	North Fork DS Poe PH	Recorder	a,b,c
9	French Creek NR mouth	Recorder	a,b,c,d
10	Middle Fork NR Merrimac	Recorder	a,b,c
11	Fall River US Feather Falls	Recorder	c
12	South Fork US Ponderosa Res	Recorder	c
13	Ponderosa Dam Outlet	Grab	c
14	Sucker Run NR Forbestown	Recorder	a,b,c,d
15	North Fork Lake Oroville	Profile	b,e
16	Middle Fork Lake Oroville	Profile	b,e
17	South Fork Lake Oroville	Profile	b,e
18	Lake Oroville Main Body	Profile	b,e
19	Lake Oroville near Dam	Profile	b,e
20	Lake Oroville Intake Structure	Sensors/SCADA	e,f
21	Hyatt tailrace	Sensor/SCADA	e
22	Diversion Pool US Kelly Ridge PH	Profile, Recorder	e
23	Diversion Pool A Kelly Ridge PH	Recorder	e
24	Diversion Pool DS Kelly Ridge PH	Profile, Recorder	e
25	Glen Pond	Profile	a, b
26	Glen Creek US Glen Pond	Recorder	a, b
27	Diversion Pool US Diversion Dam	Profile	e
28	Diversion Dam Power Plant	Sensor/SCADA	e
29	Thermalito Power Canal at Diversion Pool	Sensor/SCADA	e
30	Thermalito Power Canal at Hwy 70	Sensor/SCADA	e
31	Thermalito North Forebay	Profile	e,g
32	Thermalito North Forebay Transect	Transect profiles	
33	Thermalito South Forebay	Profile	e,g
34	Thermalito South Forebay Transect	Transect profiles	
35	Thermalito Pumping-Generating Plant	Sensor/SCADA	e
36	Thermalito North Afterbay	Profile	e,g
37	Thermalito North Afterbay Transect	Transect profiles	
38	Thermalito South Afterbay	Profile	e,g

39	Thermalito South Afterbay Transect A	Transect profiles	
40	Thermalito South Afterbay Transect B	Transect profiles	
41	Thermalito South Afterbay Transect C	Transect profiles	
42	Western Canal A Afterbay Outlet	Sensor/SCADA	e,h
43	Sutter Buttes Canal A Afterbay Outlet	Sensor/SCADA	e,h
44	Afterbay Outlet to PGE	Sensor/SCADA	e,h
45	Afterbay Outlet A Feather River	Sensor/SCADA/recorder	d,e,g,h,k
46	Mile Long Pond	Profile	b
47	Robinson Riffle Pond	Profile	
48	Oroville Fishing Pond	Profile	
49	Upper Pacific Heights Pond	Profile	
50	Lower Pacific Heights Pond	Profile	
51	Feather R DS Diversion Dam	Recorder	
40	Feather R A Oroville (USGS Gage)	Recorder	b,e
41	Fish Barrier Dam	Sensor/SCADA	e,I,j
42	Feather River US Hatchery	Recorder	d,e,I
43	Feather River A Hatchery Aerator Outfall	Sensor/SCADA	e,j
44	Hatchery Settling Pond	Recorder	k
45	Feather R Spawning Channel	Recorder	k
46	Feather R A Auditorium Riffle	Recorder	d,e,I,k
47	Feather River DS Hatchery	Recorder	d,e,I,h
48	Feather River DS Hwy 162	Recorder	d,e,I,h
49	Feather River A Robinson Riffle	Recorder	d,e,I,h
50	Feather River A Eye Riffle	Recorder	d,e,I,h
51	Feather River US Afterbay Outlet	Recorder	d,e,I,h
52	Feather River A Afterbay Outlet Outfall	Profile	
53	Feather River DS Afterbay Outlet	Recorder	d,e,h,k,L
54	Feather R US SCOR Outfall	Recorder	
55	Feather River DS SCOR Outfall	Recorder	k
56	Feather River NR Mile Long Pond	Recorder	d,e,h,L
57	Feather River NR Gridley	Recorder	d,e,h,L
58	Feather River A Singh AB Riviera RD (US Honcut Creek)	Recorder	d,e,h,L
59	Honcut Creek A Pacific Ranch NR Palermo	Recorder	e,k
60	Feather River A Archer Ave (NR Live Oak)	Recorder	d,e,h,L
61	Feather River US Yuba River	Recorder	d,e,h,L
62	Yuba River A mouth	Recorder	e,k
63	Feather River A Shanghai Bend	Recorder	d,e,h,L
64	Feather River A Star Bend	Recorder	d,e,h,L
65	Bear River NR mouth	Recorder	e,k
66	Feather River A Nicolaus	Recorder	d,e,h,L

67 Feather River NR Verona	Recorder	d,e,h,L
68 Sacramento River US Feather River	Recorder	d,e,h,L
69 Sacramento River A Verona	Recorder	d,e,h,L

a. Fisheries access, passage
b. Habitat quality, evaluation
c. Inflow effects to reservoir temperatures
d. Endangered species concern
e. Temperature model calibration
f. Effects to stratification
g. Temperature effects to water quality
h. Effects to agricultural beneficial uses
i. Biological Opinion temperature compliance
j. Fish hatchery temperature agreement
k. Discharge effects to river temperature
l. Basin Plan standards compliance

Temperatures were measured with a thermistor at half-meter intervals in deeper pools in the Feather River downstream from the dam for determination of effects of project flows on thermal conditions including stratification. Temperatures were measured bi-weekly from late spring (May) to the fall (October), and monthly from late fall (November) though early spring (April). Additional profiles were obtained at several sites upstream, within, and downstream from the pool formed in the Feather River by discharges from the Afterbay Outlet. These additional measurements were obtained monthly from late spring to the fall. Both temperature and dissolved oxygen were measured at intervals from the surface to the bottom at these sites.

Water temperatures were also measured at close intervals along the edge of the river upstream and downstream from the hatchery from the spring through the fall to help determine whether water leaches to the river from the hatchery and whether any hatchery leakage affects river temperatures.

Water temperatures were measured from the surface to the bottom at monthly intervals during the winter and biweekly from spring to fall in impounded waters (Lake Oroville, Thermalito Diversion Pool, Forebay, and Afterbay, and Fish Barrier Pool) and ponds in the Oroville Wildlife Area. Temperature profiles were measured in Lake Oroville with a thermistor at meter intervals when temperature differences are observed between successive depth measurements, and at three to five meter intervals when temperatures are uniform between depths. Temperature profiles were measured at half to one-meter intervals in the other water bodies from the surface to the bottom using a thermistor. Cross section measurements were also conducted at the Forebay and Afterbay to determine variation in temperatures in shallower and deeper areas, arms, and bays.

Existing and newly collected data were evaluated to determine thermal processes in Lake Oroville, Thermalito Diversion Pool, Forebay, and Afterbay, Fish Barrier Pool, and Oroville Wildlife Area ponds. Temperature data and the depth-capacity curve for the reservoir were used to evaluate the extent of the cold water pool under existing project operations.

Figure 4.1.1.1-1. Temperature monitoring sites for Project waters.

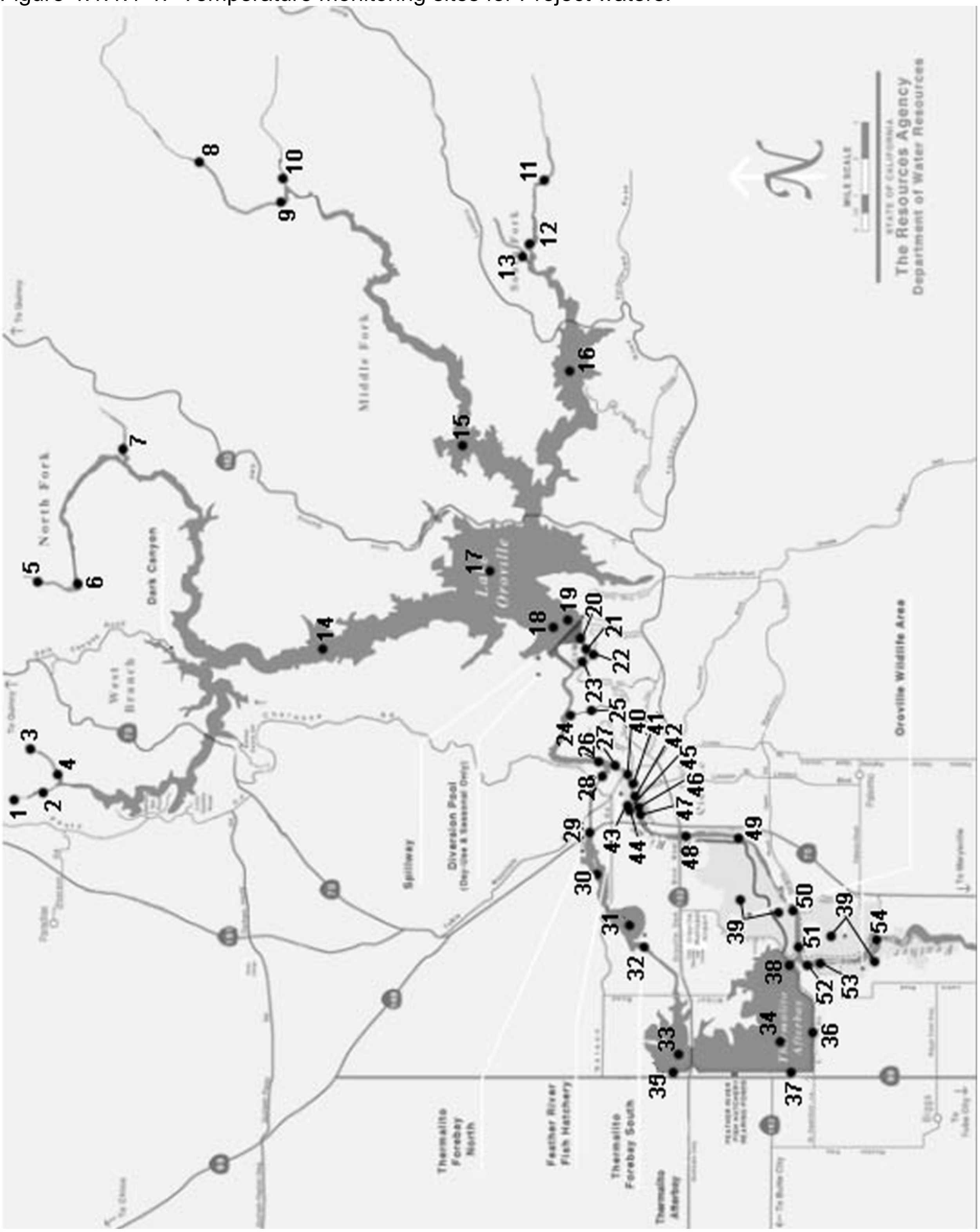
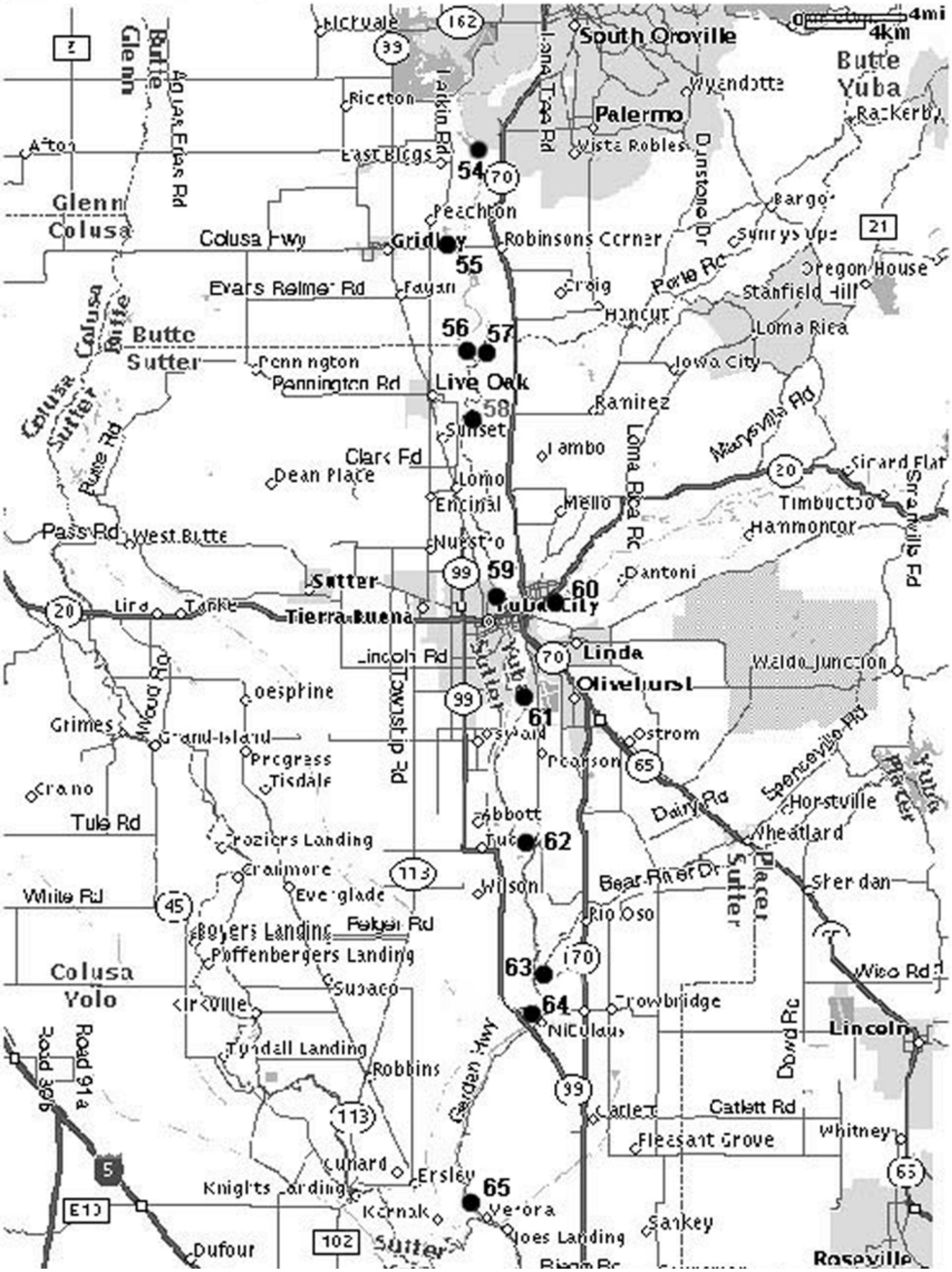


Figure 4.1.1.1-2. Temperature monitoring sites in the lower Feather River.



4.1.1.2. Task 1B — Future Project Effects on Thermal Regime of Project Waters

The Engineering and Operations Work Group has developed tools to simulate the physical attributes of Oroville Facilities operations in support of studies involving changes or impacts to flow, water temperature, sediment transport, and power generation. The study plans have developed models to simulate expected temperature conditions from potential future project operations. Model calibration and verification is dependent on use of existing and additional temperature data collected under Task 1A of this study.

The temperature model will be used to evaluate effects from potential future project operations on the cold water pool in Lake Oroville, and daily water temperatures in the Thermalito Diversion Pool, Forebay, and Afterbay, and Fish Barrier Pool. The model will also be used to simulate hourly temperatures at designated control points in the project area of the Feather River due to potential future project operations. The temperature models for the Oroville Reservoir (study plan SP-E1.3), Thermalito Complex (study plan SP-E1.4), and Feather River (study plan SP-E1.5) relies on data collected in this study plan for calibration and verification.

4.1.2. Task 2 — Project Effects on Water Temperatures Downstream from Oroville Dam

Effects of existing and future project operations, including water releases, on temperatures in the Thermalito Diversion Pool, Forebay, and Afterbay, Fish Barrier Pool, and Oroville Wildlife Area ponds are assessed in Task 1. Effects of existing and future project operations on water temperatures in the Feather River downstream from the Fish Barrier Dam are assessed in this task. This assessment includes water temperatures in the agricultural canals fed by the Thermalito Afterbay.

4.1.2.1. Task 2A — Existing Project Effects on the Thermal Regime Downstream from the Thermalito Afterbay

Temperature data were collected at existing and additional monitoring sites downstream from the Fish Barrier Dam (Figures 4.1.1.1-1 and 4.1.1.1-2) to provide information for analyses of existing project effects on the thermal regime in the Feather River and agricultural diversions. Continuously recording loggers (Onset Optic Stowaway) were used to record temperatures at 15-minute intervals at the monitoring locations. Temperature loggers were serviced and data downloaded to lap top computers at intervals not exceeding monthly, but more frequently at sites where recorder loss was prevalent. Temperature data from the river and diversions were used to evaluate existing effects due to project releases from the dam and the Thermalito Afterbay.

4.1.2.2. Task 2B— Future Project Effects on the Thermal Regime Downstream from the Thermalito Afterbay

The Engineering and Operations Work Group developed a temperature model to simulate temperature conditions due to potential future project operations in the Feather River downstream from the Fish Barrier Dam and in agricultural diversions from the Afterbay and river. Model calibration and verification was dependent on temperature data collected under Task 2A. The temperature model can be used to simulate hourly temperatures due to potential future project operations at designated control points in the Feather River and agricultural diversions. Output from the temperature models for the Feather River (study plan SP-E1.5) can be used to determine compliance with applicable goals, criteria, or standards.

4.1.3. Task 3 — Project Effects on Temperature Compliance

Various agreements have established temperature requirements downstream from Oroville Dam. A 1983 agreement with the DFG specifies water temperatures at the Feather River Hatchery for raising Chinook salmon and steelhead, and between the Thermalito Afterbay Outlet and Verona to provide suitable temperatures during the fall for fall-run Chinook salmon and from May through August for shad and striped bass. The temperature objectives for the hatchery are:

April 1 to May 15	51 ºF
May 16 to May 31	55 ºF
June 1 to June 15	56 ºF
June 16 to August 15	60 ºF
August 16 to August 31	58 ºF
September 1 to September 30	52 ºF
October 1 to November 30	51 ºF
December 1 to March 31	no more than 55 ºF.

NOAA Fisheries issued a Biological Opinion in 2001 that included a temporary temperature objective to avoid or minimize project effects to spring-run Chinook salmon and steelhead. This temporary objective was to maintain water temperatures in the low flow channel, measured at river mile 61.6 (Robinson's Riffle), from June 1 through September 30 to a daily average temperature of no more than 65 ºF to protect over-summering steelhead. DWR and NOAA Fisheries expect to develop a long-term Biological Opinion that would likely include temperature objectives after March 2004.

An additional agreement with several irrigation districts provides a water supply for maintaining agricultural production with water diverted from the Thermalito Afterbay and Feather River (DWR 1969). In addition, the CVRWQCB Basin Plan has designated beneficial uses for the Feather River from the Fish Barrier Dam to the Sacramento River as cold freshwater habitat, salmon and steelhead migration, and salmon and steelhead spawning.

4.1.3.1. Task 3A—Existing Project Effects on Temperature Compliance

Effects of existing project operations on fisheries and agriculture temperature compliance were evaluated with data obtained in Tasks 1 and 2. Data obtained from these tasks were compared to the temperature requirements in the various agreements, Biological Opinions, and Basin Plan to determine project compliance.

4.1.3.2. Task 3B — Future Project Effects on Temperature Compliance

The temperature model developed in Task 1 can be used to simulate temperature conditions due to potential future project operations in the Feather River. This simulation can be used to determine compliance of future project operations with the temperature agreements, Biological Opinions, and Basin Plan.

4.1.4. Task 4—Access to Cold Water Pool

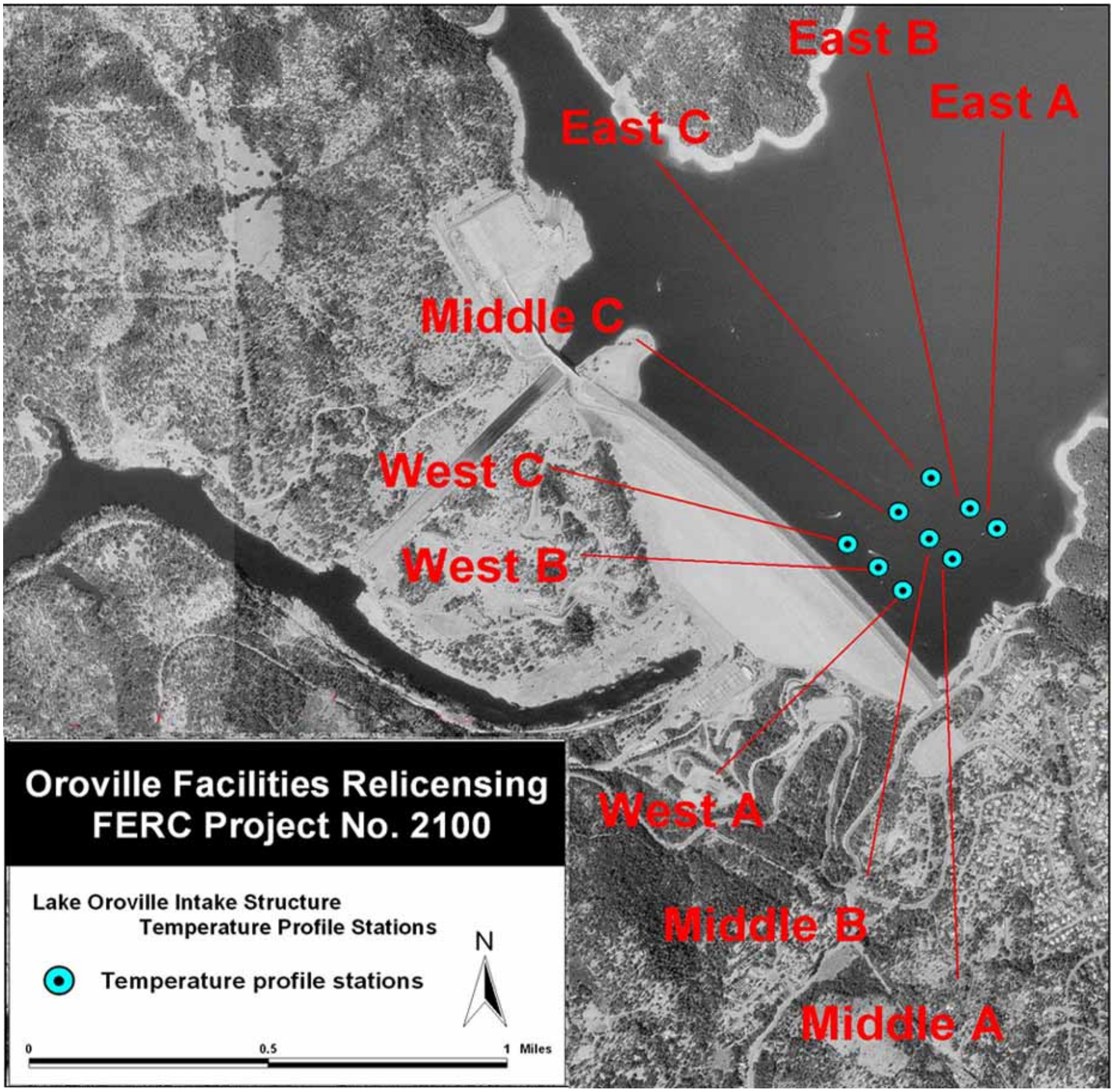
Water temperatures in the Feather River downstream from Oroville Dam are regulated by a temperature control intake structure. This structure consists of a series of shutters that are removed to withdraw water down to a specific depth in the reservoir. As the reservoir level decreases, additional shutters are opened to maintain downstream temperatures. Drought years reduce the cold water pool available for downstream release. The intake structure controls the lake level from which water is withdrawn to supply water to the hatchery and low-flow channel for temperature maintenance. Since all controlled water releases from the reservoir pass through the intake structure, water released for downstream water supply and power generation is obtained from the same depths as that for temperature maintenance at the hatchery and low flow channel, which further reduces the cold water pool.

4.1.4.1. Task 4A — Existing Project Effects on Cold Water Pool

Current data collection activities include monthly temperature profiles in the reservoir near the intake structure, daily reservoir water levels, daily reservoir releases, and data loggers at several sites in the Feather River downstream from the dam to the Sacramento River. Thermistors positioned on the intake structure every 18 to 19 feet from the 612 to 819 foot elevation record water temperatures.

Additional monthly temperature profiles were obtained near the intake structure (Figure 4.1.4.1-1) and other areas of the reservoir from Task 1A (Figure 4.1.1.1-2) to determine whether intake structure withdrawals produce local or wider ranging effects to water column temperatures. Water column effects from intake structure operations were determined by comparing temperature profiles near the intake structure with those obtained further away. Temperature profiles were also obtained at the profile monitoring locations preceding and following pump back operations to determine effects to water column temperatures.

Figure 4.1.4.1-1. Temperature monitoring sites at the Intake Structure.



Previous reservoir temperature data, additional reservoir temperature data collected during this study, reservoir water level data, reservoir release data, and downstream temperature data were used to evaluate the effects of the project on the cold water pool and the effectiveness of the project in meeting temperature requirements during various water year types. Information collected in this task can be used by the Engineering and Operations Work Group in evaluating the availability of the cold-water pool in Oroville

Reservoir to control downstream temperatures under a variety of operational and climatic conditions.

4.1.4.2 Task 4B — Future Project Effects on Cold Water Pool

Water temperature data collected in Task 4A can be used to calibrate a temperature model for the reservoir developed in the Engineering and Operations Work Group study plan SP-E1. The reservoir temperature model can be used to evaluate effects from a variety of potential operational and climatic conditions and future project operations on the cold water pool in Lake Oroville and temperature of water released from the reservoir. The river temperature model developed in study plan SP-E1.5 can be used to simulate hourly temperatures at designated control points in the Feather River resulting from reservoir release temperatures. The river temperature simulations can be used to develop a water temperature management plan and determine the ability of the project to comply with the various temperature goals, criteria, or standards.

4.1.5   Task 5 — Hatchery Effects on Temperature

The depth at which water is released from the reservoir to provide suitable temperatures at the fish hatchery also controls the temperature of the water in the low flow section of the Feather River and water diverted to the Thermalito Afterbay for release to agricultural users.

4.1.5.1 Task 5A — Existing Hatchery Effects on Temperature

This study plan evaluates the existing effects to beneficial uses of water released from Oroville Dam to maintain water temperatures at the hatchery, and effects to water temperatures in the Feather River from hatchery discharges. Evaluation of the existing effects to beneficial uses of water released for maintenance of temperatures at the hatchery uses data collected in Tasks 1 and 2. The data are compared to temperature agreements for fisheries and agriculture, Basin Plan Standards, and Biological Opinions.

The fish hatchery does not directly discharge to the Feather River. However, water leaching to the Feather River from percolation in the wastewater holding ponds could affect water temperatures in the river. Evaluation of the effects of hatchery discharges through percolation of wastewater on temperatures in the Feather River uses data collected in Task 1. Additional temperature data along the Feather River adjacent to the hatchery were collected with a thermistor to help determine locations of hatchery water leaching to the river. Upstream and downstream water temperatures were compared to determine effects from the hatchery.

4.1.5.2 Task 5B — Future Hatchery Effects on Temperature

Hatchery operations are undergoing review. Evaluation of proposed hatchery operation changes will determine whether water temperatures are affected. The temperature model developed in study plan SP-E1.5 can be used to simulate the effects of any future altered hatchery operation on water temperatures in the Feather River. Model simulation results can be used to determine effects to beneficial uses as described in the Basin Plan, temperature agreements, and Biological Opinions.

4.1.6 Task 6 — Effects of Pump Back Operations

Water can be pumped back from the Thermalito Afterbay, Forebay, and Diversion Pool for reuse in power generation based on power economics. Water from the Diversion Pool is discharged into the reservoir through the temperature control intake structure. Potentially warmer water from the Diversion Pool can disrupt the reservoir temperature profile near the intake structure. In addition, potentially warmer water pumped back into the Diversion Pool can be released to the low flow section of the Feather River and affect hatchery operations and fisheries in the river.

4.1.6.1 Task 6A — Existing Effects of Pump Back Operations

Water temperature data for evaluation of existing effects of pump back operations in the reservoir and river were obtained from Tasks 1 and 4. In addition, water profile temperatures were measured in the Thermalito Diversion Pool, Power Canal, Forebay, and Afterbay immediately preceding and following pump back operations to determine the effects on the temperature regime in these impoundments. The data are compared with the various temperature agreements, Basin Plan Standards, and Biological Opinions to evaluate effects from pump back operations on beneficial uses.

Effects from pump back operations on water temperatures at the hatchery are evaluated using temperature and pump back records from historic operations, as well as data obtained during this study. Water temperatures at the hatchery are compared prior to and following pump back operations to determine whether any changes in temperatures occurred. These records are compared for a range of pump back operations and temperature conditions.

4.1.6.2 Task 6B — Future Effects of Pump Back Operations

A temperature model developed by the Engineering and Operations Work Group in study plan SP-E8 can be used to evaluate impacts of pump back operations on the coldwater pool in Oroville Reservoir under various climatic and hydrologic conditions if data from Task 6A indicates an impact to reservoir temperatures.

5.0 STUDY RESULTS

Results from this study evaluate effects of the project on water temperatures both within and downstream from Project boundaries. Data from upstream of the Project are also evaluated. Data obtained from the study can be used to develop a water temperature management plan and determine the ability of the project to meet temperature requirements for protection of beneficial uses, including agriculture, fish, and other aquatic resources.

Thermograph data collected during the course of this study are stored on the Bay Delta and Tributaries Project database, which has electronic access (http://bdat.ca.gov).

5.1 EFFECTS OF EXISTING PROJECT OPERATIONS TO WATER TEMPERATURES

This phase of the study describes the water temperature regime of Project facilities, tributaries, and the Feather River based on the collected data. The data are also used to determine compliance with the various temperature agreements, Basin Plan standards, and Biological Opinions to evaluate existing effects of the Project to water temperatures. This analysis is not intended to address all issues related to water temperatures, but to generally describe the temperature regime of Project waters. As specific issues are identified, the water temperature data collected during this study can be used to provide appropriate evaluations.

5.1.1 Thermal Regime of Project Waters

Water quality, including temperature, of Project waters can be affected by tributaries to the Project facilities. In addition, water temperatures downstream from the Project boundary are influenced by Project operations. Therefore, water temperatures of streams tributary to Project waters as well as the Feather River downstream from the Project boundary were included in the analyses of data from Project waters.

5.1.1.1 Thermal Regime of Tributaries to Lake Oroville

Water temperatures collected from the West Branch and North, Middle, and South forks of the Feather River, including tributaries to these streams such as Concow Creek, Fall River, and Sucker Run Creek, all follow similar patterns. Water temperatures in these tributaries to Lake Oroville begin to warm in May and June, reaching maximum temperatures ranging from 70 to 80 °F in late July and early August (Appendix 1). These waters begin cooling in late September, with water temperatures ranging from 40 to 50 °F in November through March. Mean summer water temperatures range from a low of 68 °F at Fall River upstream of Feather Falls, to a high of 75 °F at West Branch near Paradise.

Water temperatures within the North Fork Feather River are influenced by upstream hydroelectric operations. Water temperatures downstream of the Poe Powerhouse Outflow reflect this effect (Appendix 1). The water temperature of this reach follows a similar diurnal pattern as the other tributaries, but minimum temperatures are much cooler due to releases from the Poe Powerhouse. This is also illustrated by the cooler temperatures of monthly grab samples taken from the Poe Powerhouse outflow (Appendix 1).

5.1.1.2 Thermal Regime of Project Facilities

Oroville Reservoir

Water temperatures in Lake Oroville from the North, Middle, and South Fork arms, main body, and near the dam follow similar patterns. Water temperatures at all of the monitoring sites begin to warm in the early spring to reach maximum temperatures in the upper portion of the water column during late July, after which temperatures in the epilimnion gradually decline to minimum levels in late winter (Appendix 2a through e). Surface waters approached mid-80 ºF temperatures during the summers of both 2002 and 2003. The transition zone between the upper warmer and lower colder waters, or metalimnion, during mid-summer extends from about 30 to 50 feet below the surface. The cooler lower waters comprising the hypolimnion extend below the metalimnion to a minimum of about 44 ºF near the reservoir bottom. Drawdown of reservoir water levels and gradual cooling through the fall extends the depth of the epilimnion, which diminishes the extent of the transistion zone between the epilimnion and hypolimnion, and decreases the volume of the hypolimnion until relatively uniform temperatures from surface to bottom are achieved in late winter at all the reservoir monitoring sites. Winter stratification, in which near-freezing less dense water forms the surface layer, does not occur due to the large mass of relatively warm water in Lake Oroville during the winter.

Thermalito Diversion Pool

Water temperatures in the Diversion Pool near Oroville Dam are controlled by the temperatures of the water released from the dam as well as water released through the Kelly Ridge Powerhouse. Early in the year, water temperatures in the upper Diversion Pool are similar both upstream and downstream from the Powerhouse (Figures 5.1.1.2-1 and 2). However, by late summer and continuing into early fall, water temperatures downstream from the Powerhouse can be several degrees warmer than the upstream water temperatures as a result of warmer water discharged through the Powerhouse. Water temperatures upstream from the Powerhouse discharge ranged from 43.8 to 59.3 ºF, while temperatures downstream from the discharge were slightly warmer and ranged from 44.1 to 59.7 ºF.

Figure 5.1.1.2-1. Diversion Pool temperatures near the Kelly Ridge Powerhouse in 2002.

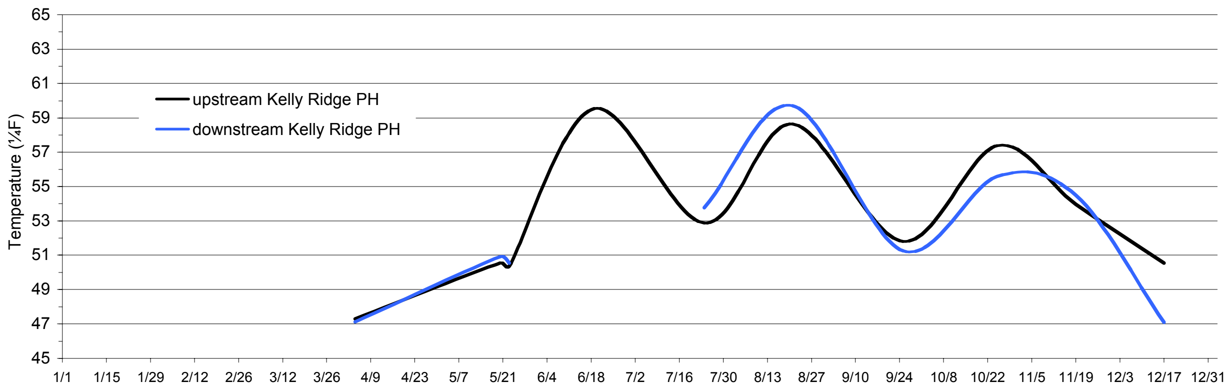
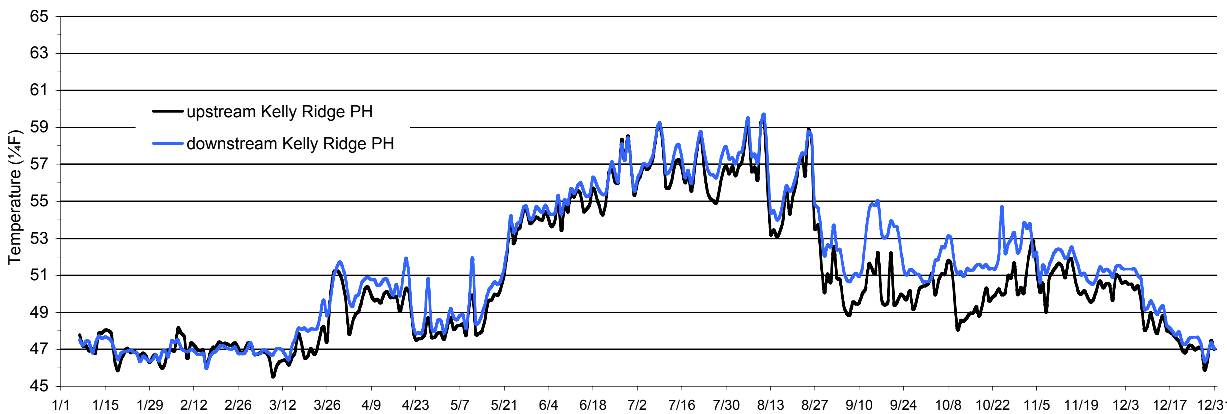


Figure 5.1.1.2-2. Diversion Pool temperatures near the Kelly Ridge Powerhouse in 2003.



As water flows from Oroville Dam to the Diversion Dam, some additional warming may occur, especially at the surface. The upper 10 to 15 feet or so of water in the Diversion Pool near the Diversion Dam can experience several degrees of surface warming, even during the cooler months of the year (Figures 5.1.1.2-3 and 4). Water temperatures below this upper warmer water layer also can experience significant warming during the warmer portion of the year. However, warming of the water column below the shallow upper warmer layer is controlled by temperatures of water released from Oroville Dam as modified by releases from the Kelly Ridge Powerhouse. Progressively warmer water through the summer measured in the Diversion Pool just downstream from the Kelly Ridge Powerhouse is reflected by progressively warmer water column temperatures at the Diversion Dam. Little, if any, summer stratification is found in the water column at the Diversion Dam, except for the shallow surface layer, with most temperature profiles differing by no more than a degree below the surface layer to the bottom. As water temperatures downstream from the Kelly Ridge Powerhouse cool beginning in the late summer, water temperatures at the Diversion Dam also cool, which follows a pattern similar to that of water temperatures in Lake Oroville.

Figure 5.1.1.2-3. Diversion Pool water column temperatures near the dam in 2002.

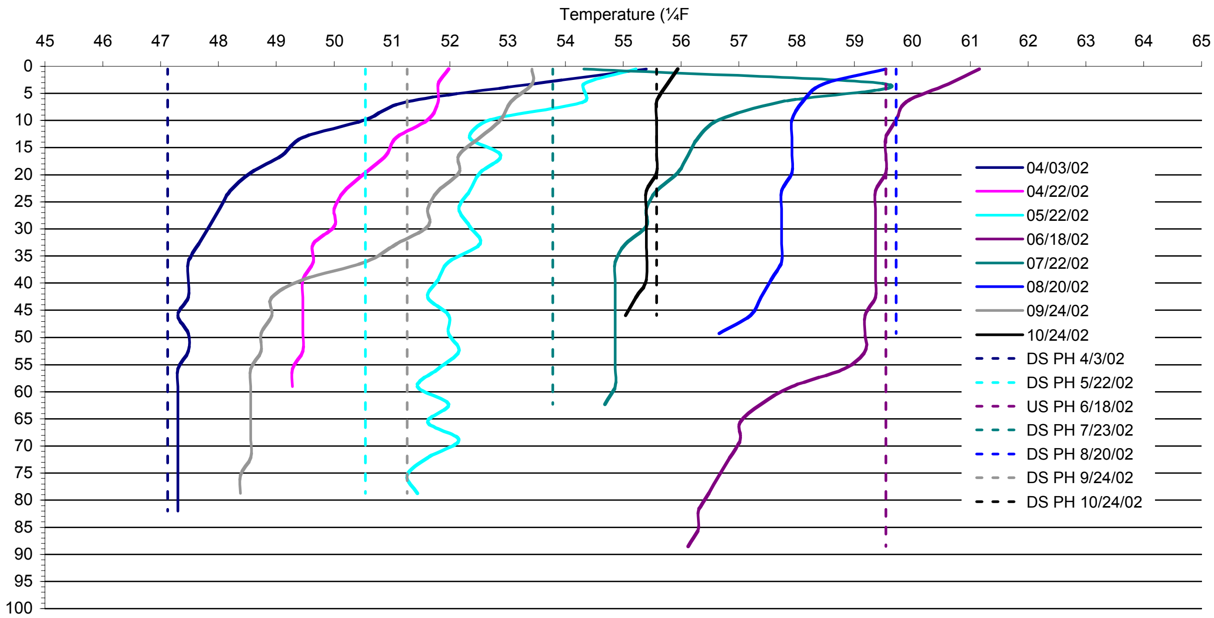
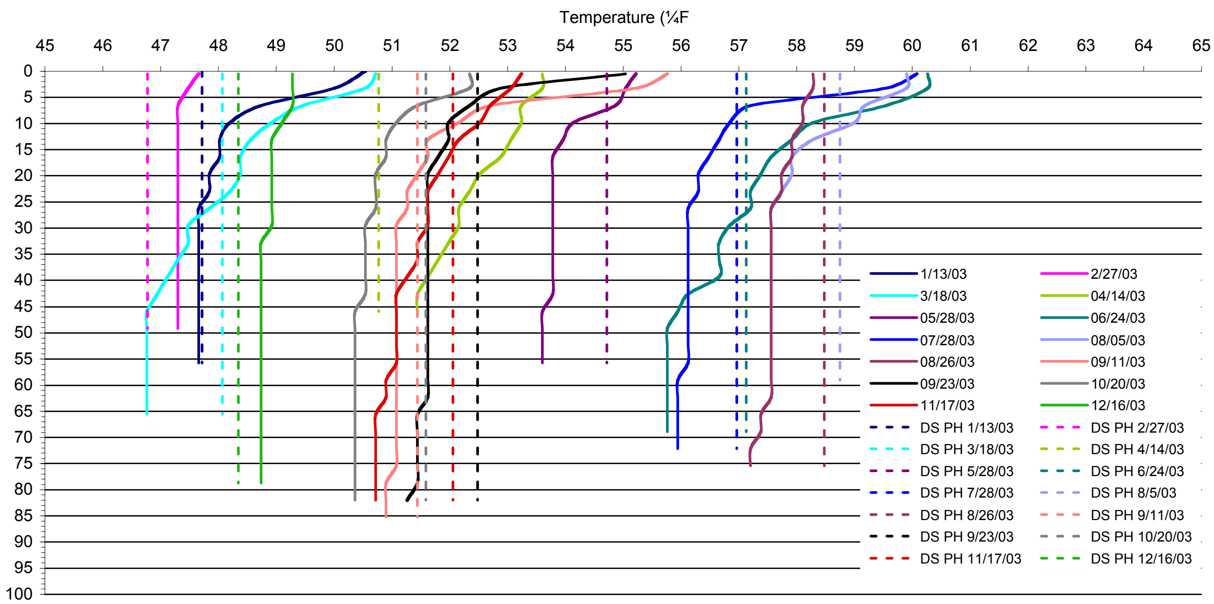


Figure 5.1.1.2-4. Diversion Pool water column temperatures near the dam in 2003.



Fish Barrier Pool

Water released from the Diversion Dam initially controls the temperature of water flowing to the Fish Barrier Pool and Thermalito complex. Water temperatures warm very little in the reach downstream from the Diversion Dam to the Fish Barrier Dam (Figure 5.1.1.2-5). Water temperatures are generally within a degree or so between the upper and lower reaches of the Fish Barrier Pool, with maximum differences occasionally reaching 3 ºF. Water temperatures immediately downstream from the Diversion Dam ranged from 45.5 to 61.0 ºF, while those at the gage near the Fish Barrier Dam were very similar, ranging from 45.9 to 60.6 ºF.

In addition, little temperature stratification is found in the Fish Barrier Pool formed by the Fish Barrier Dam. During the warmer parts of the year, water temperatures very near the surface may become a couple of degrees warmer than the rest of the water column (Figure 5.1.1.2-6). Temperatures in the Fish Barrier Pool follow a pattern similar to that of the Diversion Pool, with water column temperatures increasing in the summer in response to warmer water released to the pool and declining temperatures through the fall due to cooler inflowing water temperatures.

Figure 5.1.1.2-5. Water temperatures at the upper and lower ends of the Fish Barrier Pool.

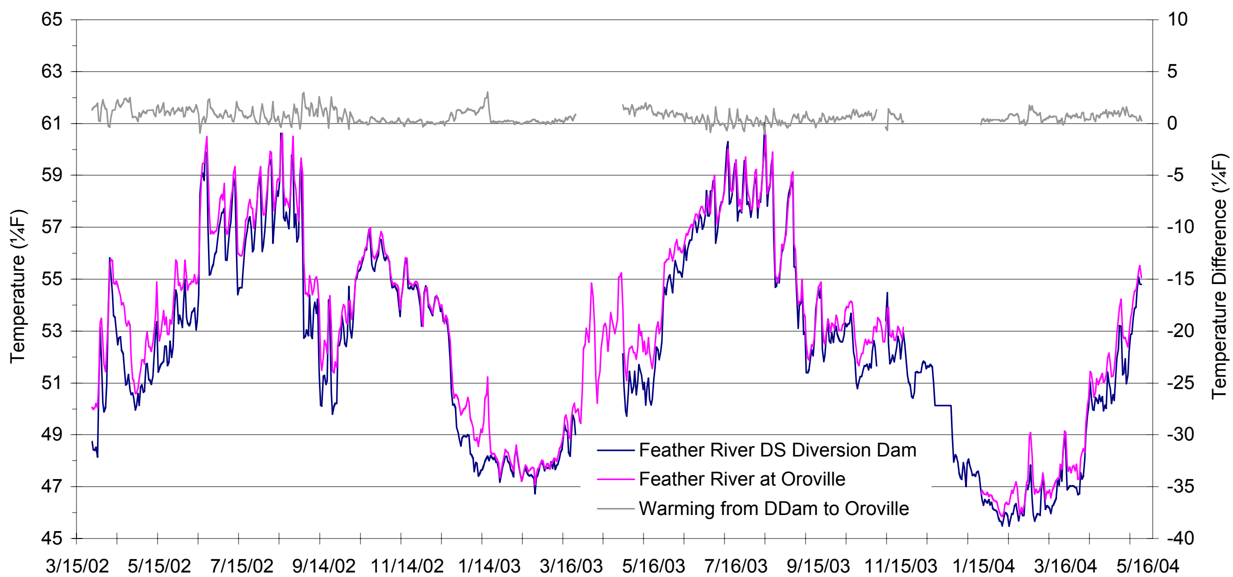
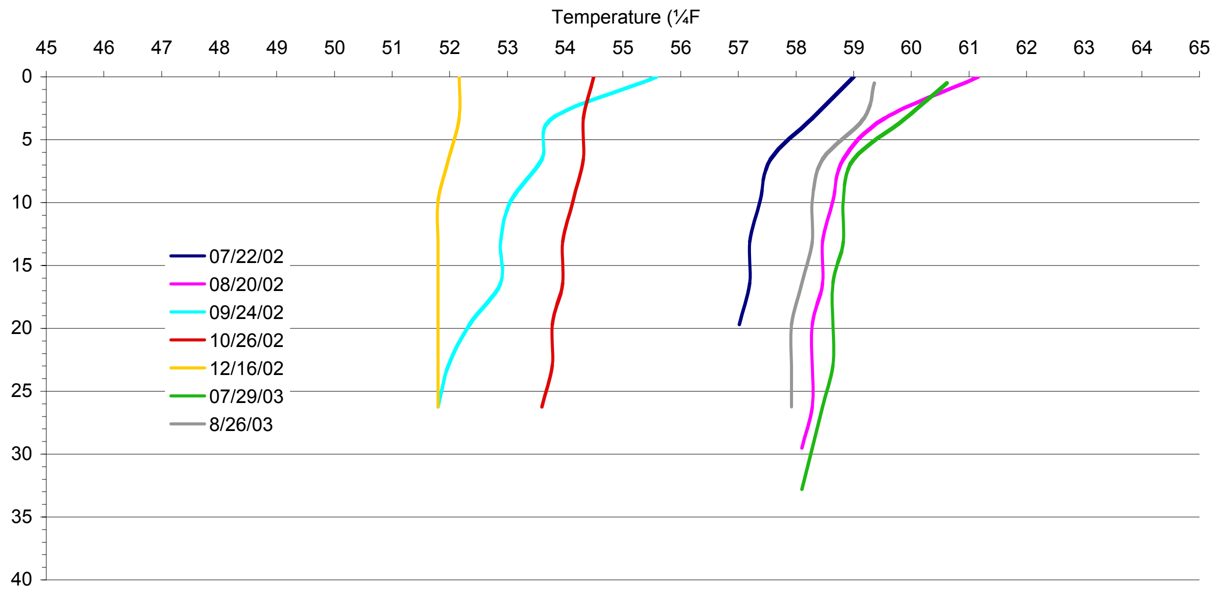


Figure 5.1.1.2-6. Water column temperature profiles in the Fish Barrier Pool near the dam.

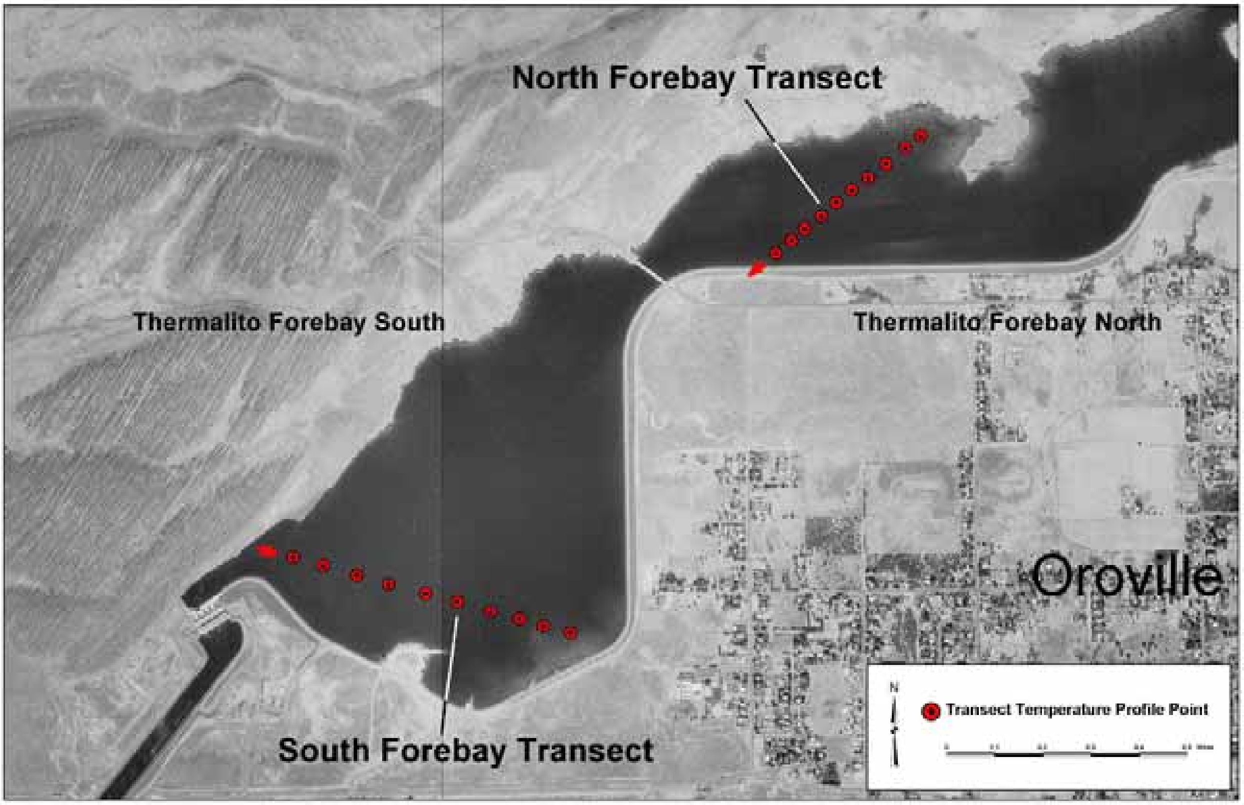


Thermalito Forebay

Water temperature patterns in the Thermalito Forebay are similar to those found in the Diversion and Fish Barrier pools. Water temperatures measured along transects in both the North and South forebays (Figure 5.1.1.2-7) increase from spring through summer in response to the temperature of water delivered from the Diversion Dam, and gradually cool through the fall as Diversion Pool temperatures decrease (Appendix 3a and b).

Little difference is evident in water temperatures between the Forebay and Diversion Pool or between the North and South forebays. Water temperatures in both the North and South forebays are warmer by a few degrees in the upper few feet of the water column during warmer months of the year, especially along the margins of these water bodies where velocities are reduced. Measured water temperatures near the surface ranged from 45.7 ºF during the colder months to 67.5 ºF during the warmer months in the North Forebay and 45.9 to 64.6 ºF in the South Forebay, while temperatures at lower depths ranged from 45.5 to 59.2 ºF in the North Forebay and 45.5 to 59.9 ºF in the South Forebay.

Figure 5.1.1.2-7. Temperature monitoring transects in the Thermalito Forebay.



Thermalito Afterbay

Water temperatures in the Thermalito Afterbay measured along transects (Figure 5.1.1.2-8) also follow the pattern of the upstream water bodies. Water temperatures increase from the spring to summer and subsequently decrease into the winter (Appendix 4a through d) in response to the temperature of water delivered from the South Forebay as well as atmospheric conditions. Water temperatures were also warmer at the transect profile measurement points in areas protected from the main flow of water through the Afterbay (e.g., coves).

Water temperatures in the North Afterbay were very similar to those found in the South Forebay during both the cooler and warmer periods of the year. Water temperatures during the winter were also similar at downstream transects in the South Afterbay. However, water temperatures began progressively increasing from the north to south transects in the spring, with increasing differences between North and South Afterbay temperatures through the summer. Temperature differences between the northern and southern portions of the Afterbay in the deeper portion of the water column ranged from about 6 ºF during the spring (May) to about 9 ºF during the warmest part of the year (August/September) (Figure 5.1.1.2-9).

Figure 5.1.1.2-8. Temperature monitoring transects in the Thermalito Afterbay.

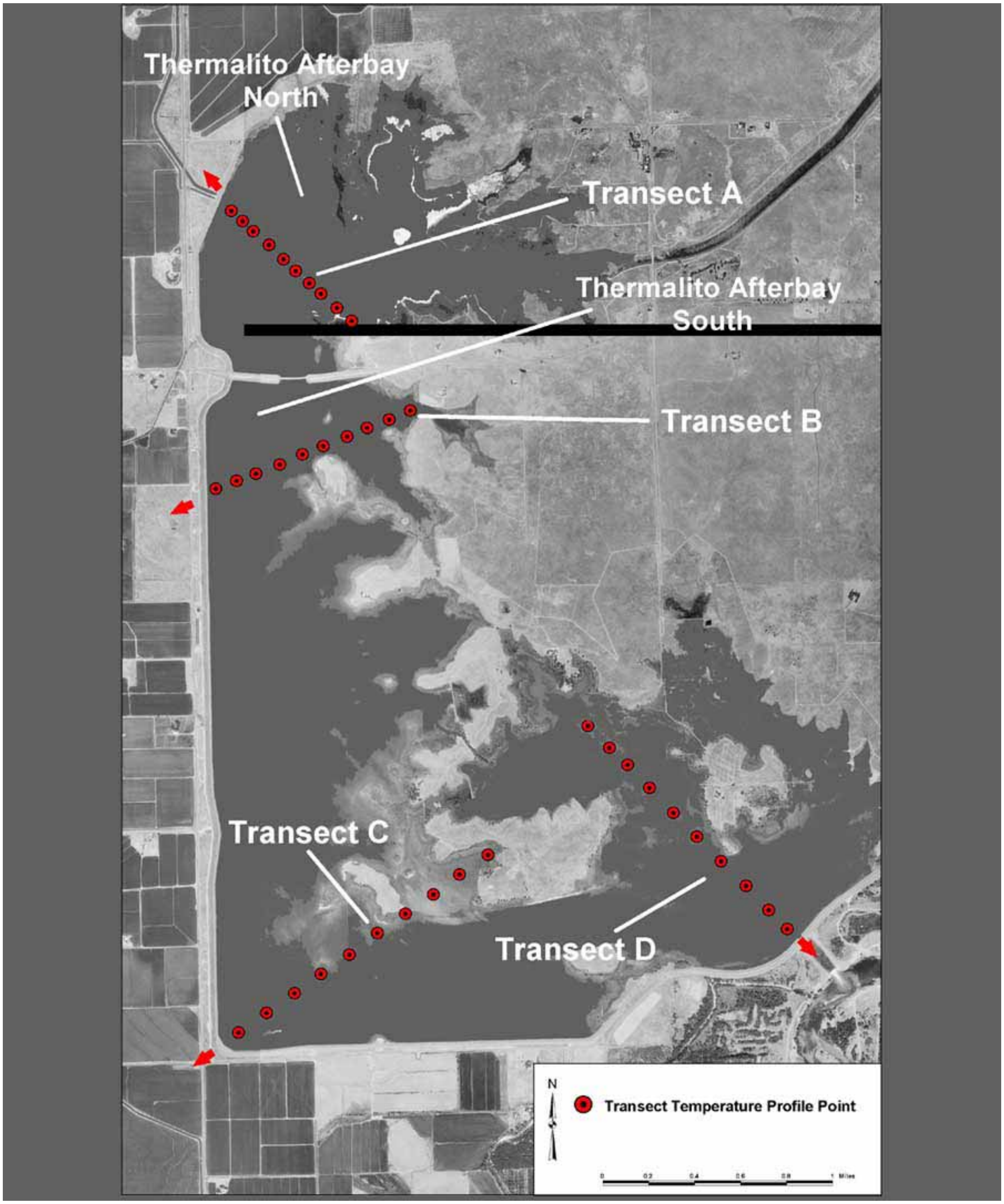
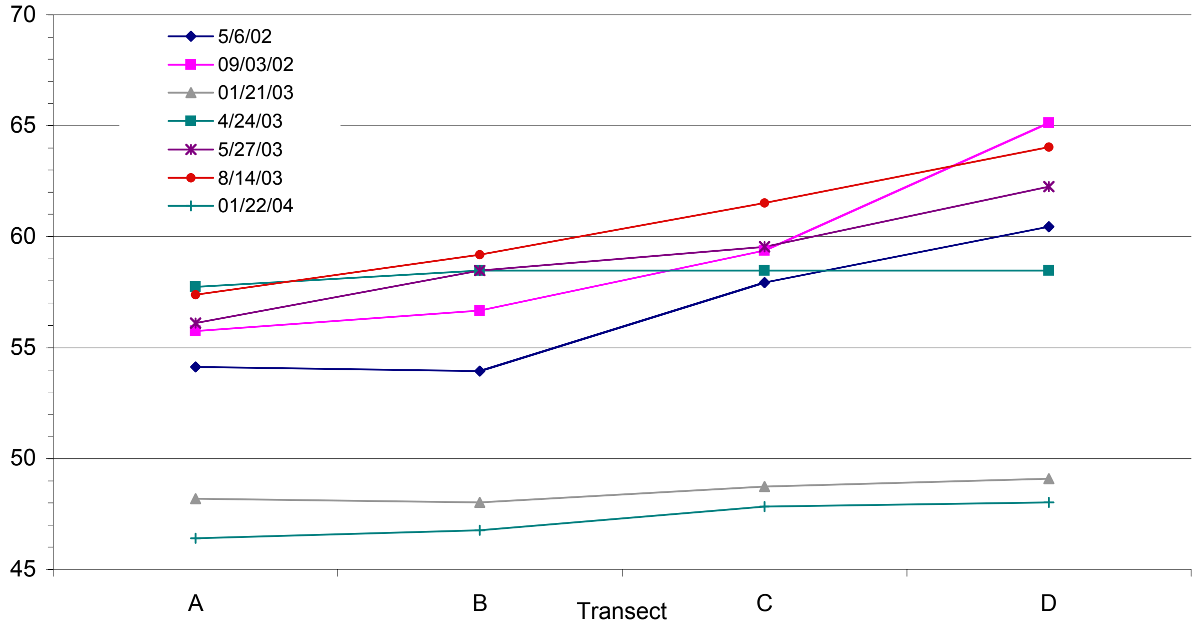


Figure 5.1.1.2-9. Temperature gradient from north to south in the Thermalito Afterbay.



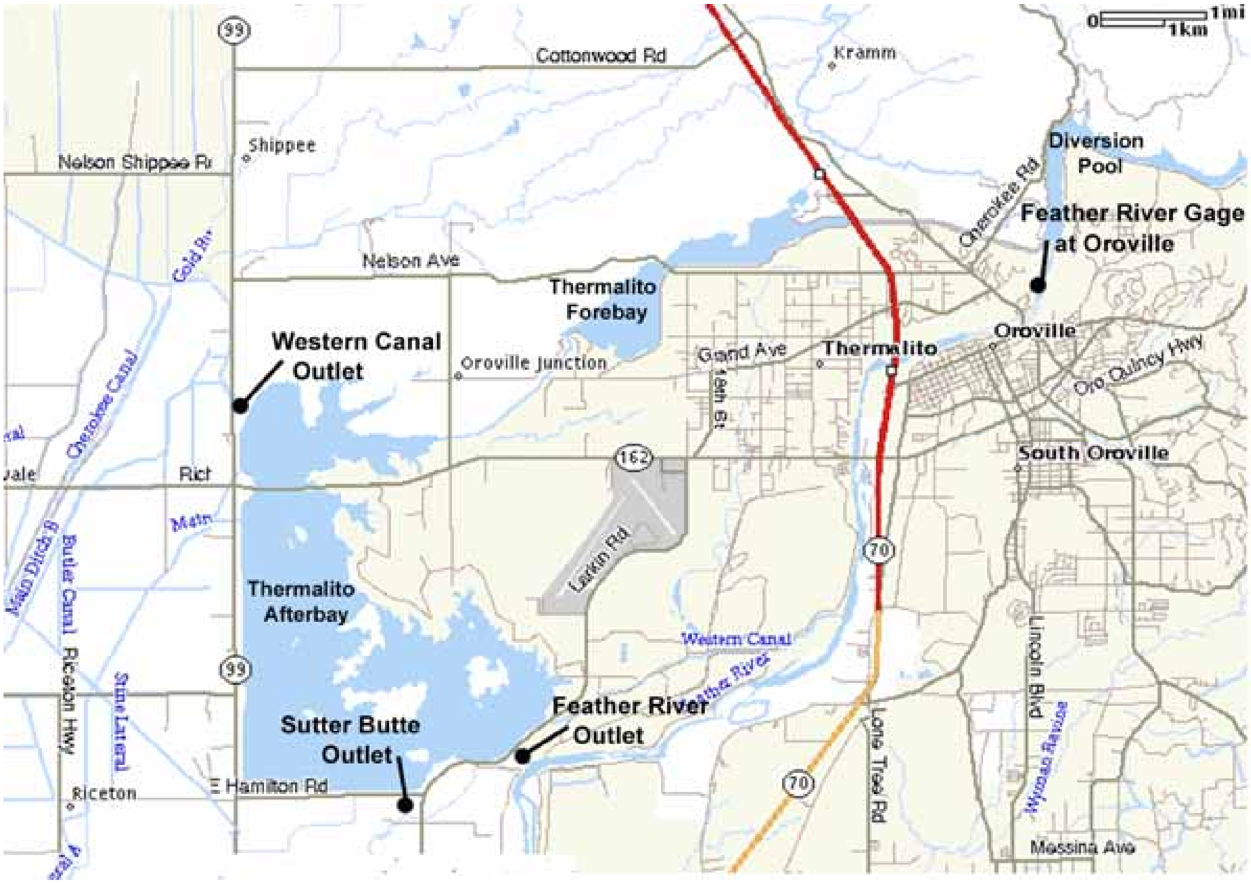
Water temperature differences between the northern and southern portions of the Afterbay diminished through the fall until they were virtually identical in the winter.

Water temperatures also were significantly warmer near the surface of the Afterbay during the warmer months of the year, with warmer temperatures extending to about 10 feet into the water column (Appendix 4a through d). Temperature differences between the surface water and deeper water column during the warmer months ranged from about 9 ºF in the North Afterbay to about 16 ºF in the South Afterbay. Surface and bottom water temperatures were similar during the cooler months of the year.

Thermal Regime of Water Released from the Thermalito Afterbay

Water is released from the Thermalito Afterbay to several canals for irrigation water and to the Feather River. The temperature of water released to the canals can affect crop production, while that of water released to the Feather River can affect fish, other aquatic resources, recreational activities, and other beneficial uses. Water temperatures, as discussed above, vary from the northern to the southern part of the Afterbay. Therefore, the Western Canal is used to represent temperatures from the North Afterbay, while the Sutter Butte Canal is used to represent temperatures from the South Afterbay (Figure 5.1.1.2-10). Releases from the Afterbay through the Outlet to the Feather River affect river temperatures.

Figure 5.1.1.2-10. Outlets from the Thermalito Afterbay.



Water temperatures in the canals closely reflect temperatures in the Afterbay near the outlets. Water temperatures in the canals at the outlets vary throughout the year in response to variation in temperatures in the Afterbay (Figure 5.1.1.2-11). Water temperatures are usually warmer at the outlet to the river than at either the Western or Sutter Butte Canal outlets. Water temperatures at the river outlet in 2002 were as much as 11.3 ºF warmer than at the Western Canal Outlet, and up to 4.3 ºF warmer than at the Sutter Butte Outlet, while in 2003 the river outlet was as much as 9.1 and 7.2 ºF warmer than the Western and Sutter Butte Canal outlets, respectively (Figure 5.1.1.2-12).

Figure 5.1.1.2-11. Western Canal, Sutter Butte Canal, and River Outlet water temperatures.

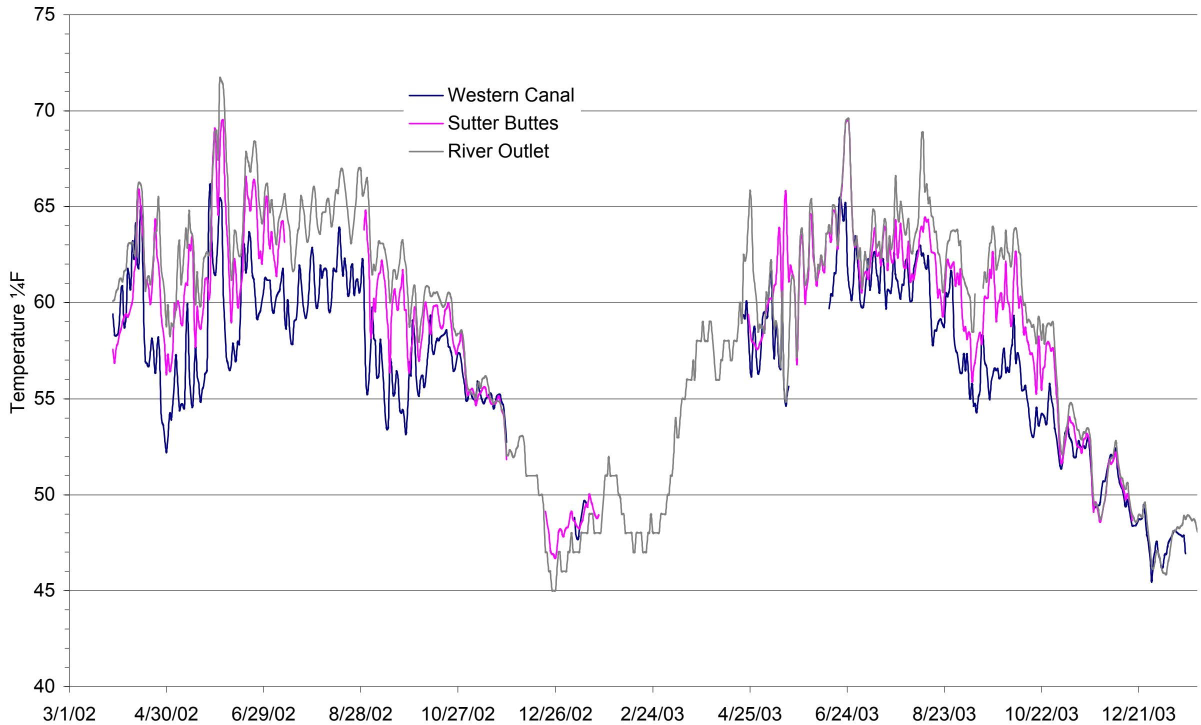
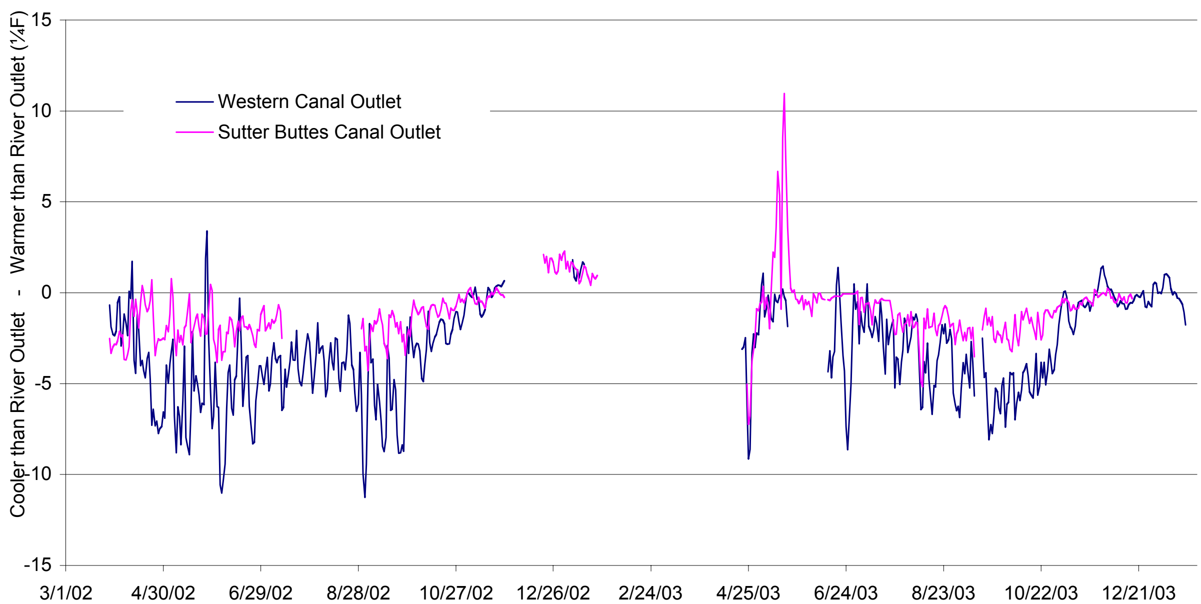


Figure 5.1.1.2-12. Water temperature differences between the river outlet and irrigation canals.



5.1.1.3 Thermal Regime in the Feather River Downstream from the Fish Barrier Dam

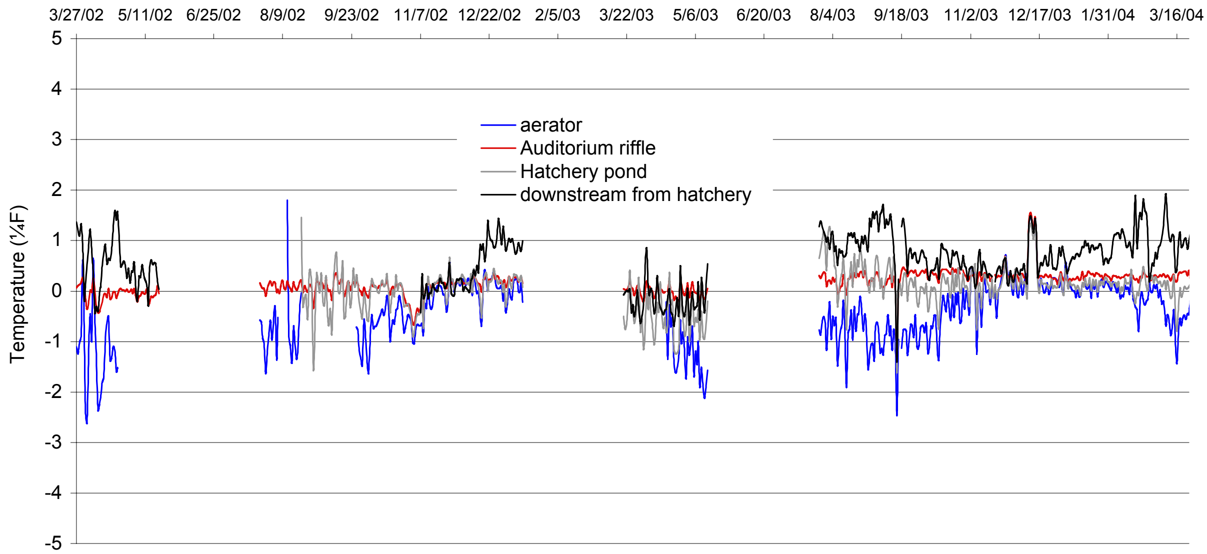
Water temperatures in the Feather River downstream from the Fish Barrier Dam vary seasonally and are best described by dividing the monitoring locations into the following river reaches: from the Fish Barrier Dam to just upstream from the Afterbay Outlet (low-flow channel or LFC) and the Afterbay Outlet to the confluence with the Sacramento River (high-flow channel or HFC). Additionally, data from monitoring stations on the Sacramento River upstream and downstream from the confluence of the Feather River were compared with data from the Feather River near Verona to determine any Feather River influence on Sacramento River temperatures.

Water temperatures in the LFC begin to warm in March (Appendix 5a). Maximum temperatures are reached in July and early August, and range from 61 ºF upstream from the Hatchery to 69 ºF upstream from the Afterbay Outlet. This reach of the river begins cooling in September, with water temperatures dropping to a consistent 45 ºF throughout the reach in February. Pools monitored in this reach exhibited little or no surface-to-bottom temperature stratification (Appendix 5b).

The Feather River Hatchery (FRH) discharges water into the river from two sources. Excess water, which has been chilled in the cooling tower, enters the river through a pipe and down the riverbank from a point between the two settling ponds upstream from Auditorium Riffle. Wastewater from the hatchery raceways percolates through the gravel settling ponds and emerges from the riverbank into Hatchery Ditch, which then empties into the river about 100 yards upstream from the temperature monitoring station located downstream from the hatchery. Discharges from these two accretions appear to have a minor effect on temperatures in the Feather River (Figure 5.1.1.3-1). Water temperatures at the aerator discharge to the river are generally 1 to 2 ºF cooler than temperatures measured at the monitoring site on the Feather River upstream from the hatchery. Temperatures in the hatchery ponds vary up to about 1 ºF warmer as well as cooler than upstream river temperatures, which seems to reflect effects of cooling of the water in the hatchery chiller and atmospheric warming of the water in the raceways. Water temperatures at Auditorium Riffle are slightly higher (a few tenths of a degree) than those at the upstream Feather River monitoring site, while those at the monitoring site downstream from the hatchery are up to about 1.5 ºF warmer than the upstream river. However, warming at the downstream monitoring site appears to be due to atmospheric input rather than effects from hatchery discharges.

Water temperatures in the HFC also begin warming in March and reach maximum temperatures during June and July, which range from 71 ºF at the Afterbay Outlet discharge to 77 ºF at Nicolaus (Appendix a). River cooling begins in late August, with minimum temperatures of 44 to 45 ºF achieved by January or February.

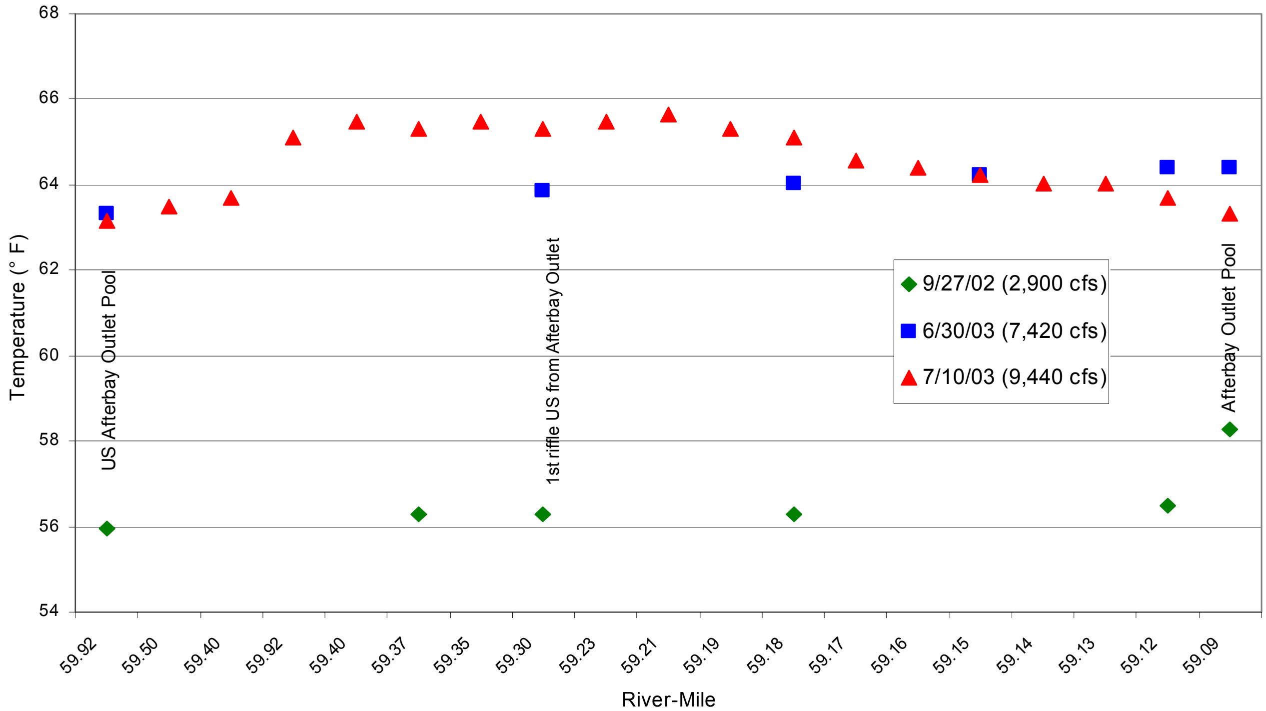
Figure 5.1.1.3-1. Temperature comparisons between the Feather River upstream from the hatchery and downstream monitoring sites.



Little or no temperature stratification occurred in any of the HFC pools (Appendix b), with the exception of the Afterbay Outlet Pool in May 2003, which varied by 5 ºF from surface to bottom. The Afterbay Outlet Pool is the location where water from the LFC mixes with water discharged from the Afterbay. The LFC is maintained at a flow of approximately 600 cfs year-round. Releases from the Afterbay Outlet to the river ranged from 422 to 9,450 cfs during the study period. The larger releases from the Afterbay sometimes make it appear that the Feather River flows upstream from the Outlet. This is not the case. The Afterbay Outlet Pool (river-mile 59), acts as a water dam during high release rates, causing the water in the LFC to back up as far upstream as Steep Riffle near river-mile 61 (J. Kindopp, DWR, pers. comm.). Temperature measurements were made at regular spatial intervals progressing upstream from the Outlet Pool during three varied Afterbay releases. Warming of LFC water appears to occur at higher Afterbay releases due to the increased residence time upstream from the water dam (Figure 5.1.1.3-2).

Inflows from the Afterbay Outlet, Honcut Creek, Yuba River, and Bear River influence Feather River water temperatures in the high-flow section from April through October (Appendix 5c). Afterbay releases to the river raise the mean monthly water temperature downstream from the Outlet, relative to mean monthly temperatures recorded upstream from the Outlet. Honcut Creek and Bear River inflows also tend to increase Feather River temperatures downstream from their confluences during this period. Flows contributed by the Yuba River tend to cool the Feather River during the warmer spring and summer months. Little effect is observed from any tributary inflows to the HFC during winter months.

Figure 5.1.1.3-2. Afterbay release influence on low-flow water temperatures.



Analysis of monthly mean temperature data from the Feather River near Verona, when compared to data from the Sacramento River upstream and downstream from the confluence, indicates the Feather River can either warm or cool Sacramento River temperatures (Appendix 5c). This cooling or warming of the Sacramento River is probably a result of the practice of ramping-up Sacramento River releases and ramping-down Oroville releases, as well as the opposite, to control salinity in the Delta during the time of year that large Delta exports occur.

Warming in the Feather River downstream from the Afterbay Outlet is affected by release rates as well as temperature of water from the Afterbay. Higher releases from the Afterbay result in increased distance downstream before temperatures increase due to atmospheric warming (Figures 5.1.1.3-3 through 5). However, temperature of water released to the Feather River from the Afterbay are also cooler at higher release rates since water has had less residence time in the Afterbay. Decreased residence time in the Afterbay results in less warming, and hence cooler temperatures of water released to the river and agricultural diversions. The effects of these releases on river temperature can be observed as far downstream as the confluence of the Feather River with the Yuba River (river mile 28.5).

Figure 5.1.1.3-3. Thermalito Afterbay Outlet effects on downstream mean daily water temperatures during June 25 to 28, 2003.

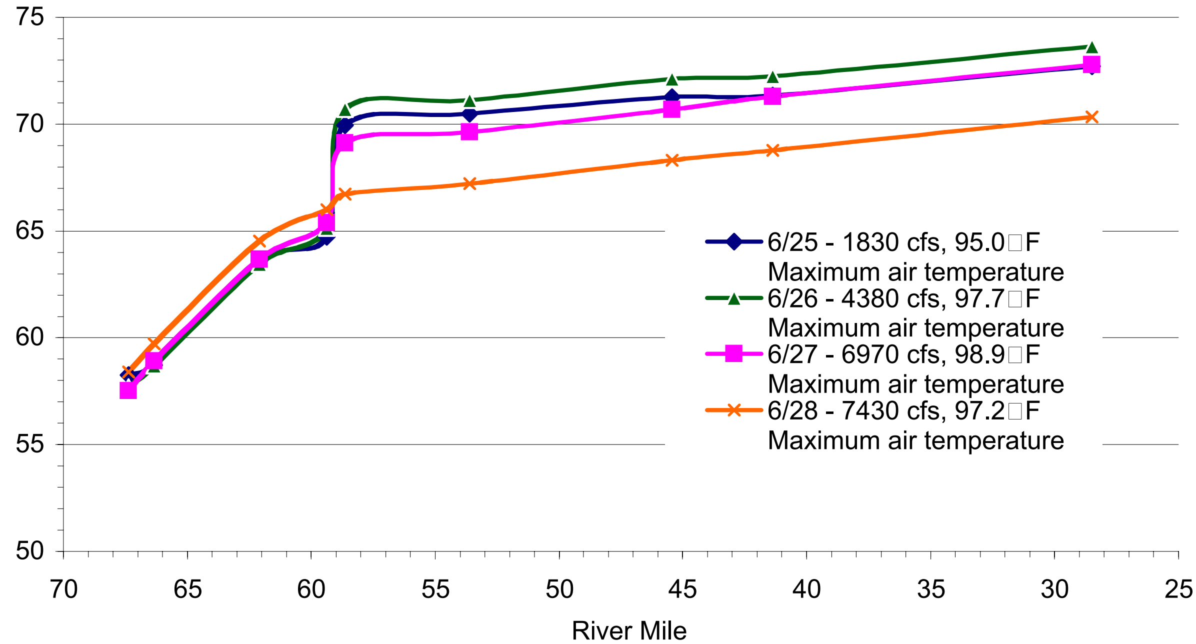


Figure 5.1.1.3-4. Thermalito Afterbay Outlet effects on downstream mean daily water temperatures during August 5 to 8, 2003.

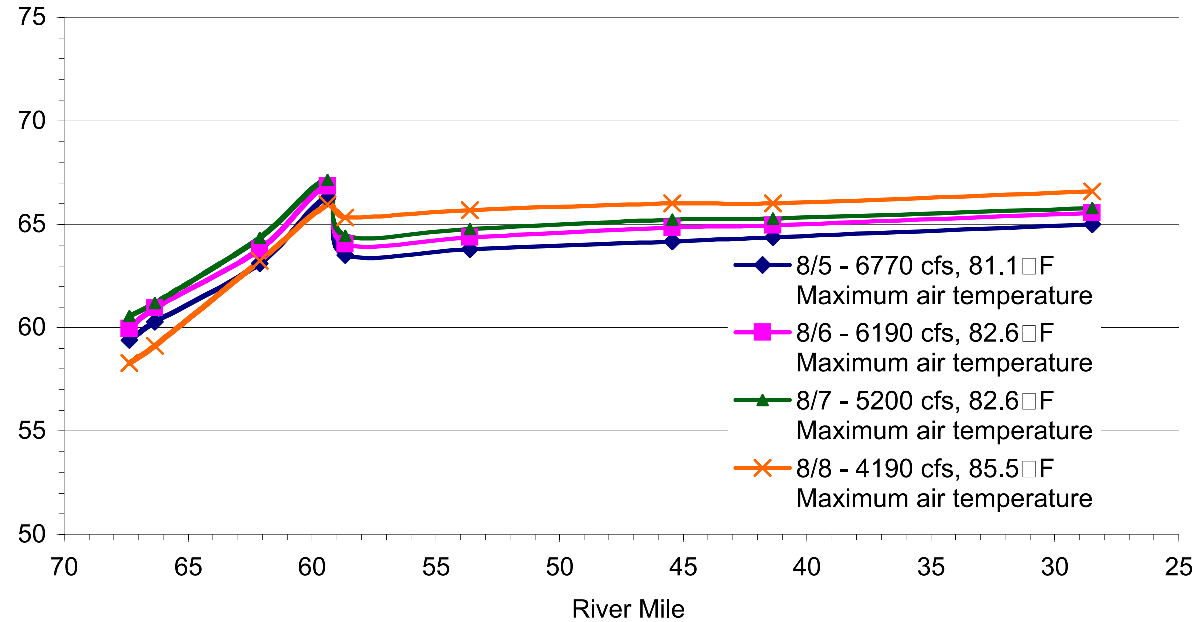
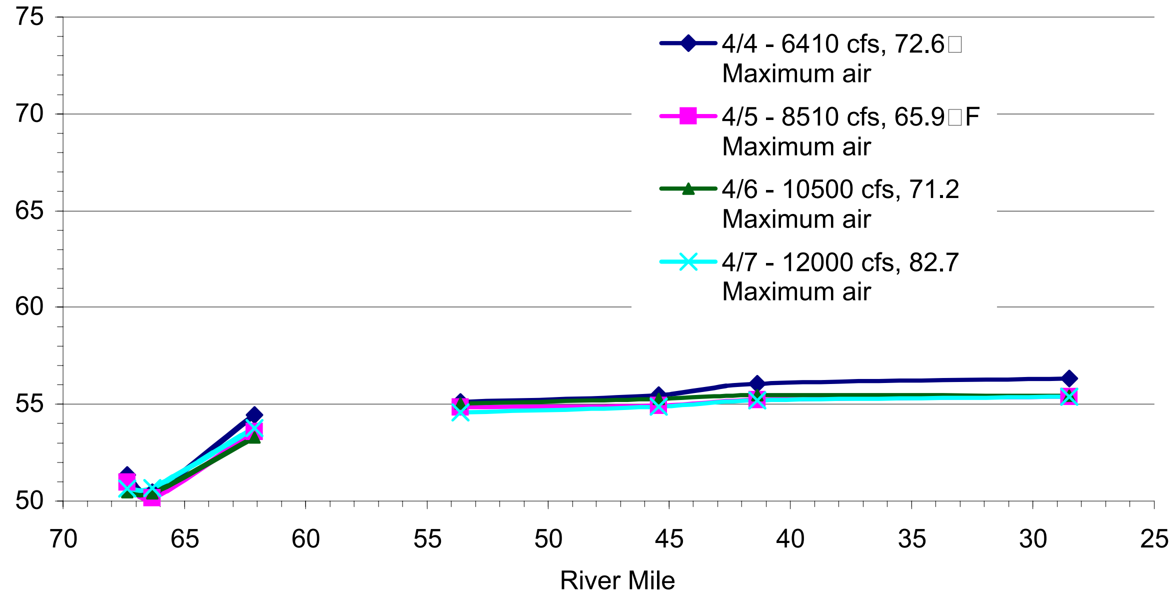


Figure 5.1.1.3-5. Thermalito Afterbay Outlet effects on downstream mean daily water temperatures during April 4 to 7, 2004.



5.1.1..4 Oroville Wildlife Area ponds

Five Oroville Wildlife Area ponds were sampled for water temperature from May/June 2002 through April 2004. Water temperatures recorded in these ponds all follow similar patterns. All ponds warmed during late spring, reaching surface temperatures ranging from 75 to 85 ºF in July and August. Water temperatures were coolest December through February, with temperatures near 50 ºF (Appendix 6).

Mile Long Pond and Lower Pacific Heights ponds had cooler bottom temperatures during the summer months due to the influence of the Feather River. The levee separating Mile Long Pond and the high flow channel of the Feather River is highly permeable. On several occasions during high Afterbay Outlet releases, river water was observed flowing through the levee and into this pond. During these same high releases Lower Pacific Heights Pond, which is connected by a series of culverts to the Feather River, would fill as water flowed into the pond from the river channel.

Oroville Fishing Pond, which is adjacent to the low-flow channel, also experienced cooler bottom temperatures during the summer months. This is attributed to its proximity to the Feather River, and the occasional filling of the fishing ponds from a well by the Feather River Recreation and Parks District.

5.1.2 Project Effects on Temperature Compliance

Temperature data presented in section 5.1.1 are used to evaluate compliance of current project operations with various agreements, Biological Opinions, and Basin Plan objectives.

5.1.2.1 Agricultural Agreements

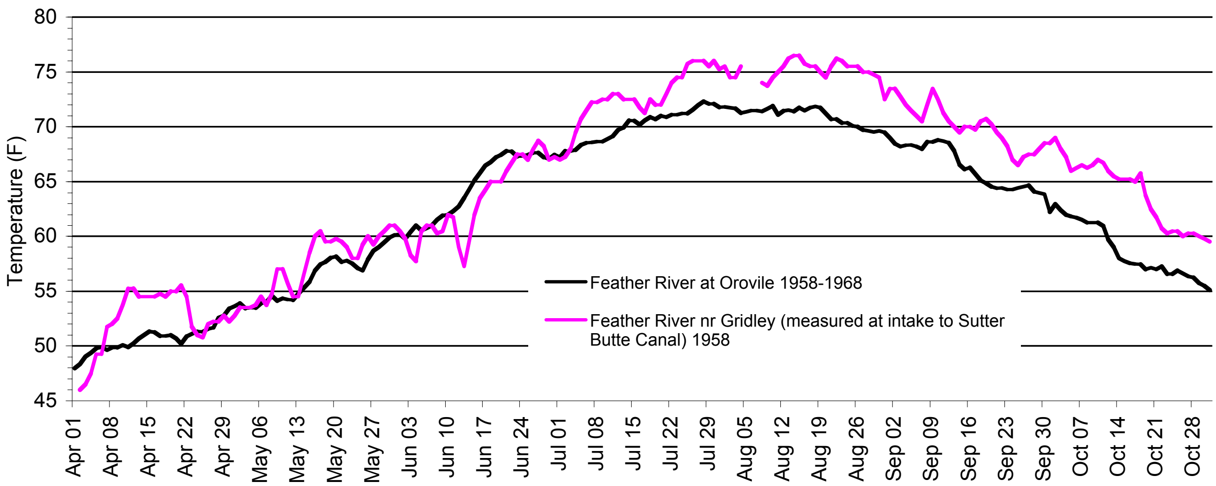
In the 1960s and 1970s, DWR and several Feather River irrigation districts entered into settlement agreements to resolve water rights issues that arose due to the construction of the Oroville Facilities. The 1969 agreement between DWR and the water districts, that are now members of the Joint Water District Board, discusses liability from injuries to crops due to reduction in water temperature during any portion of an irrigation season "as a result of water released from Lake Oroville being colder than water that would have been available in the Feather River for diversion by Districts if Oroville Dam had not been constructed" (DWR 1969). The "irrigation season" is defined by the agreement as April 1 through October 31. A similar agreement between DWR and the Western Canal Water District discusses "liability for the quality or temperature of water released by State from the Oroville-Thermalito Project or delivered to Western hereunder" (DWR 1986).

Because of concern by local water districts that water temperatures are adversely affecting rice production, water temperature data for the Feather River and Thermalito Afterbay were reviewed to analyze the extent of changes in temperature of water available for diversion by the Feather River settlement contractors before and after the construction of the Oroville Facilities. Available water temperature records were compiled from the U.S. Geological Survey (USGS), DWR, and U.C. Davis. Temperature data were obtained for the Feather River both prior to and since completion of the Project.

Review of the available data found that prior to construction of the Oroville Facilities, water temperatures in the Feather River at the gage near Oroville were less than optimal for rice cultivation during the early portion of the growing season (Figure 5.1.2.1-1). Water temperatures in the Feather River as far downstream as Gridley, a distance of about 26 river miles, were similar to those found at the gage near Oroville until after the first of July. Pre-project daily mean water temperatures of less than 55 ºF during the first two weeks following the current planting date of May 1 were at levels that current researchers (Mutters et al. 2003a) identified as leading to loss of an entire crop, while temperatures during the following two weeks of the irrigation season were below the 60 ºF threshold which researchers estimate could reduce yield by up to 60 percent. Data for warming in the present Western Canal (C. Mutters, pers. comm.) lead to the conclusion that canals leading from the Feather River near Oroville to rice fields probably did not contribute more than a degree or two of warming, especially during the early portion of the irrigation season. Mid-season pre-project water temperatures in the

Feather River, however, did exceed the threshold of 60 to 65 ºF that was identified by Mutters et al. (2003b) as being required for rice production.

Figure 5.1.2.1-1. Pre-project water temperatures in the Feather River during the irrigation season.



Following completion of the Oroville Facilities, water temperatures in the Feather River at the Oroville gage became even less suitable for rice cultivation during the early irrigation season, and have not met the threshold required for rice production, except on intermittent occasions, during mid-summer. However, water diversions from the Feather River to local irrigation districts were replaced by diversions from the Thermalito Afterbay, where warming occurs prior to diversion to rice fields.

Water temperatures at the Afterbay Outlet to the Feather River and Sutter Butte Canal have been more suitable for rice production than pre-project river conditions. However, project operation changes in the early 1990's resulted in cooler temperatures in the Afterbay (Figure 5.1.2.1-2). While daily mean water temperatures from 1993 through 2002 exceed 55 ºF by May 1 at the river outlet, the 60 ºF threshold is not reached for three weeks, which is 11 days later than the threshold was reached before project operations were changed, but still is a week sooner than pre-project diversions from the Feather River. Water temperatures above the 60 ºF threshold persist for an average of 19 days less than under conditions prior to operation changes, but do not exceed 65 ºF, which was exceeded for 14 weeks prior to the changes.

Water diverted for irrigation from the Afterbay to the Western Canal has not achieved the same level of warming as found at the Afterbay Outlet to the Feather River and Sutter Butte Canal (Figures 5.1.1.2-11 and 12). Water temperatures measured from 2000 through 2002 were several degrees cooler at the diversion to the Western Canal, but have still reached 55 ºF by May 1 on average (Figure 5.1.2.1-3). The threshold

Figure 5.1.2.1-2). Thermalito Afterbay and pre-project Feather River temperatures during the irrigation season.

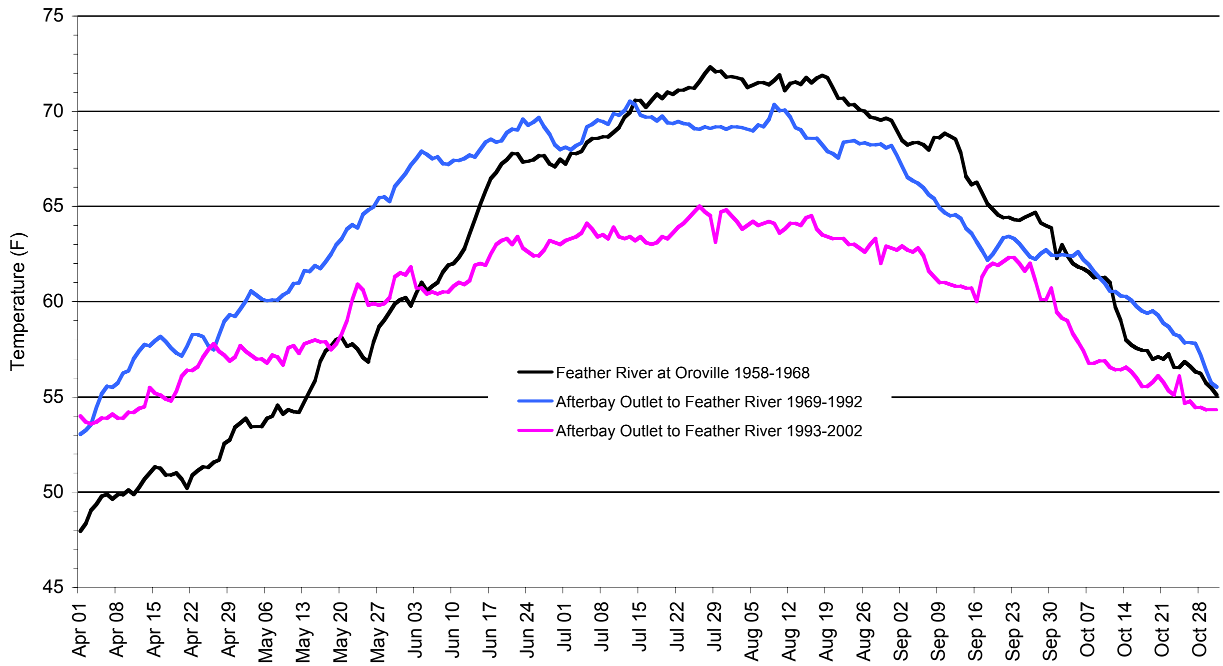
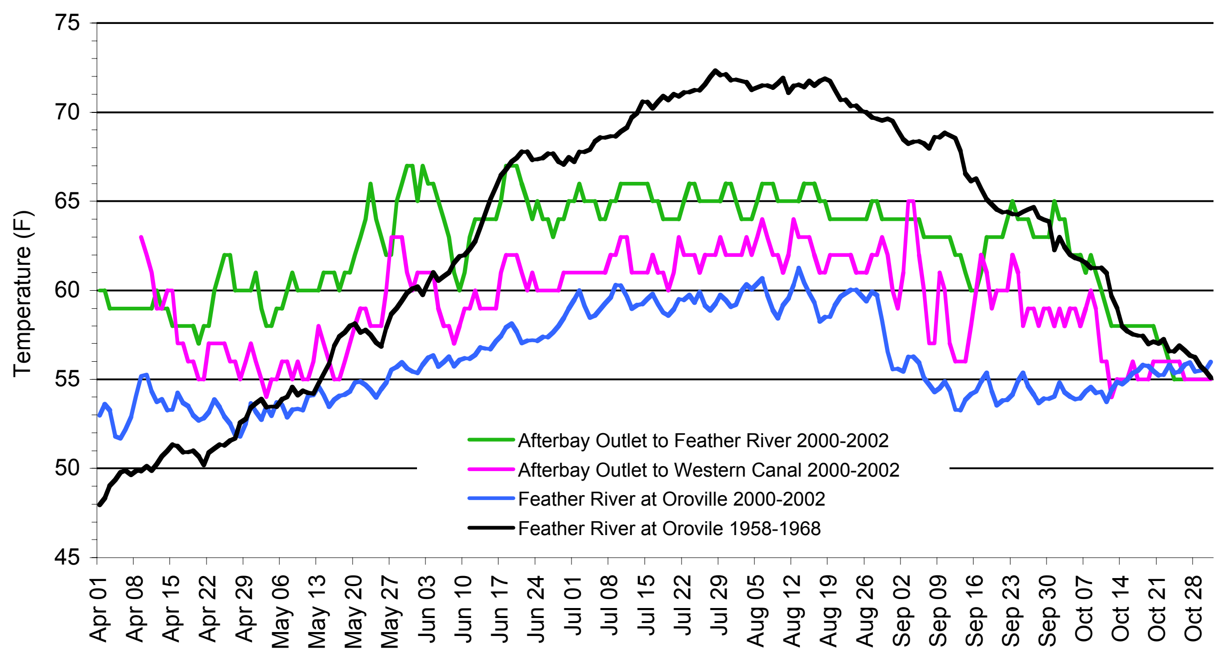


Figure 5.1.2.1-3. Temperatures at the Afterbay Outlet to the Feather River and Western Canal.



temperature of 60 ºF was not reached in the Western Canal Outlet for slightly more than three weeks following the May 1 planting date, which is just slightly before the threshold was met by pre-project temperatures in the Feather River, but then dropped below the threshold until the middle of June. While subsequent mid-season daily mean water temperatures in diversions at the Western Canal Outlet were above the threshold temperature of 60 ºF, water temperatures generally did not reach 65 ºF.

The amount of warming of water in the Afterbay is affected by residence time as well as air temperatures. When residence time is decreased due to increased releases to the Western and Sutter Butte canals and the Feather River, the temperature of water released from the Afterbay also decreases (Figures 5.1.2.1-4 and 5). Water temperatures also tend to follow the pattern of air temperatures, which generally increase from the spring to mid summer and then decrease, but also fluctuate significantly. Much higher releases from the Afterbay dampens the influence of air temperatures on water temperatures in the mid-summer.

Figure 5.1.2.1-4. Effects of Discharge on Temperatures during the Growing Season 2002.

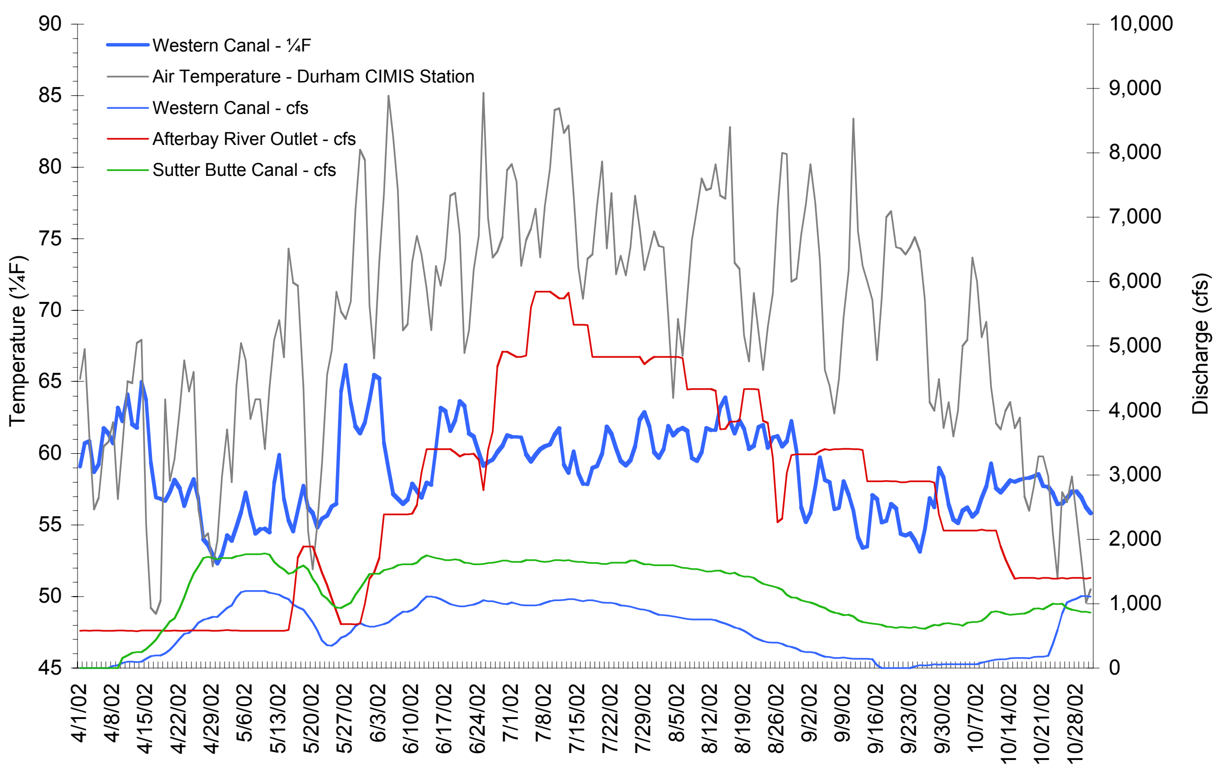
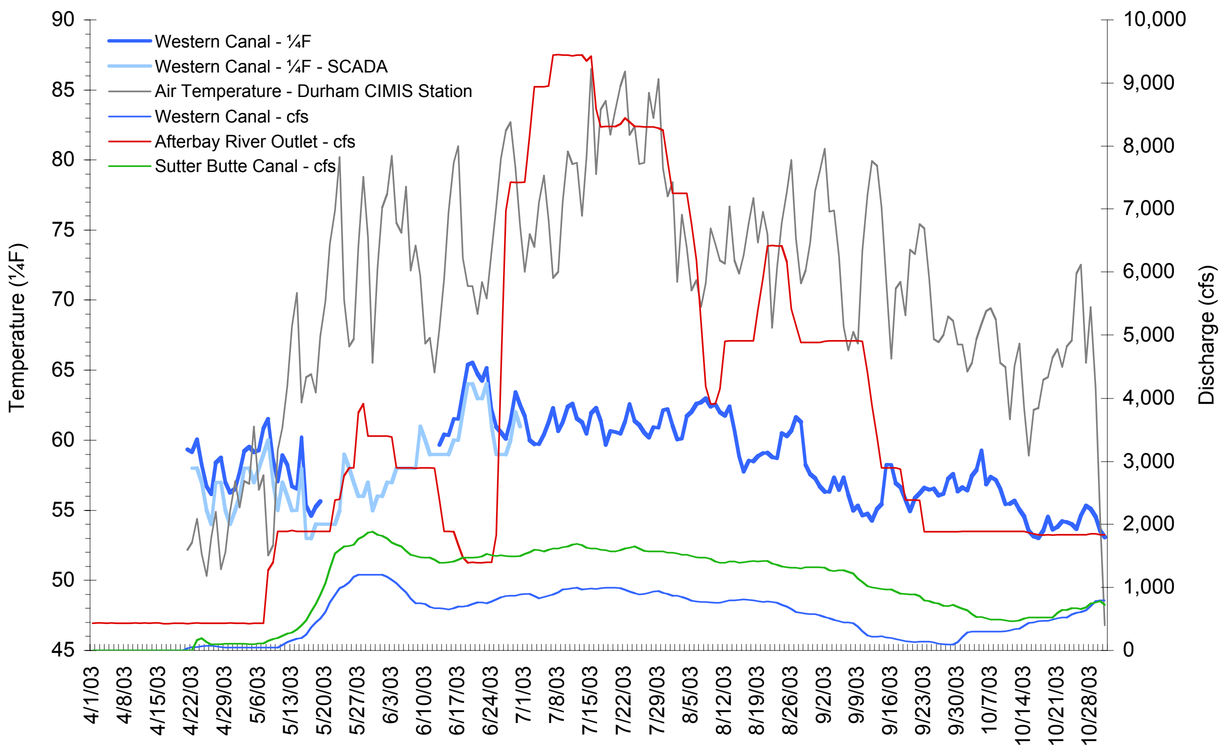


Figure 5.1.2.1-5. Effects of Discharge on Temperatures during the Growing Season 2003.

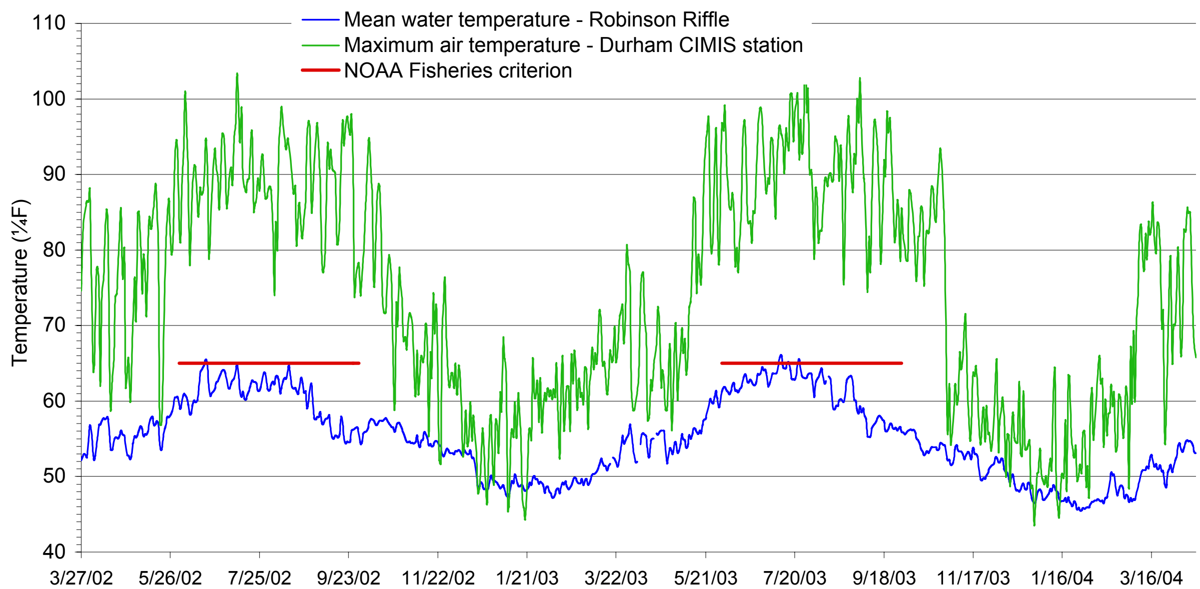


The review of water temperature data shows that temperatures at the river outlet of the Thermalito Afterbay are more suitable for rice production during the early portion of the irrigation season and meet the mid-season threshold required for rice production earlier than pre-project temperatures in the Feather River at the Oroville gage and near Gridley. Water temperatures at the Sutter Butte Canal Outlet from the Afterbay are nearly identical to those at the outlet to the Feather River, and thus diversions to the Sutter Butte Canal from the Afterbay are also more suitable for rice production than pre-project temperatures in the Feather River. However, while water temperatures are slightly warmer during the early irrigation season in diversions at the Western Canal Outlet from the Afterbay, water temperatures in subsequent months at the Western Canal Outlet are much cooler than pre-project temperatures in the Feather River near Oroville. Water temperatures at the Western Canal Outlet do not consistently reach the threshold for rice production as soon as the threshold was reached by pre-project temperatures in the Feather River. Western Canal Outlet water temperatures also do not warm during the mid-season as much as pre-project temperatures in the Feather River or at the Afterbay Outlet to the Feather River (and Sutter Butte Canal), and cool to below the threshold earlier in the irrigation season.

5.1.2.2 Biological Opinion

The NOAA Fisheries objective for salmonids is a mean daily temperature of less than or equal to 65 ºF from June 1 through September 30 at Feather River mile 61.6 (Robinson Riffle in the low-flow channel). Controlling temperatures at Robinson Riffle (Figure 5.1.2.2-1) requires Project operators to evaluate water temperatures in Lake Oroville to determine appropriate release depths, forecasted weather conditions, and preservation of the cold water pool. However, warmer air temperatures do not always result in warmer water temperatures at Robinson Riffle. As an example on June 19, 2002 the mean daily water temperature at Robinson Riffle was 65.5 ºF (exceeding the objective), but the maximum air temperature only reached 94.8 ºF. Meanwhile on July 10, 2002 the mean daily water temperature was 64.8 ºF (below the objective), while the maximum air temperature reached 103.4 ºF.

Figure 5.1.2.2-1. Effects of air temperatures on water temperatures at Robinson Riffle.



Exceedance curves created using this data show that the NOAA Fisheries temperature objective was exceeded a small percentage of the time in both 2002 and 2003 (Figures 5.1.2.2-2 and 3). Analysis of the data shows the objective was exceeded on June 19 in 2002, with a maximum temperature of 65.5 ºF, and on five occasions in July 2003, with a maximum temperature of 66.0 ºF.

Water temperature requirements must also be met at the Feather River Fish Hatchery, which may result in some exceedances of the requirement at Robinson's Riffle. For example, when the temperature exceeded the requirement at Robinson's Riffle on June 19, 2002, the hatchery requirement was 60 ºF (±4 ºF), which leaves little leeway for the effects from atmospheric warming as water flows to Robinson's Riffle.

Figure 5.1.2.2-2. Robinson Riffle exceedance graph for June 1 to September 30, 2002.

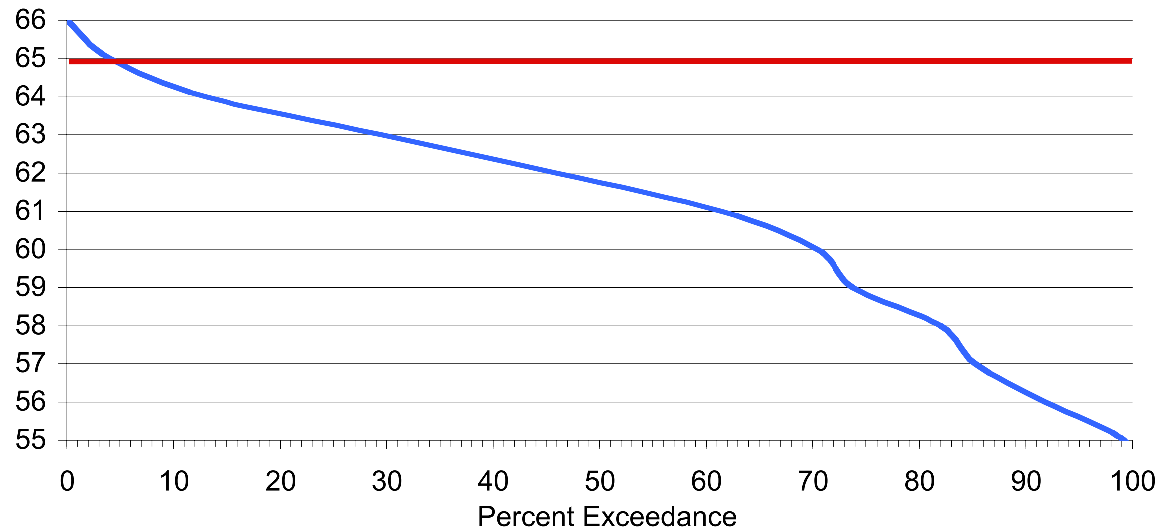
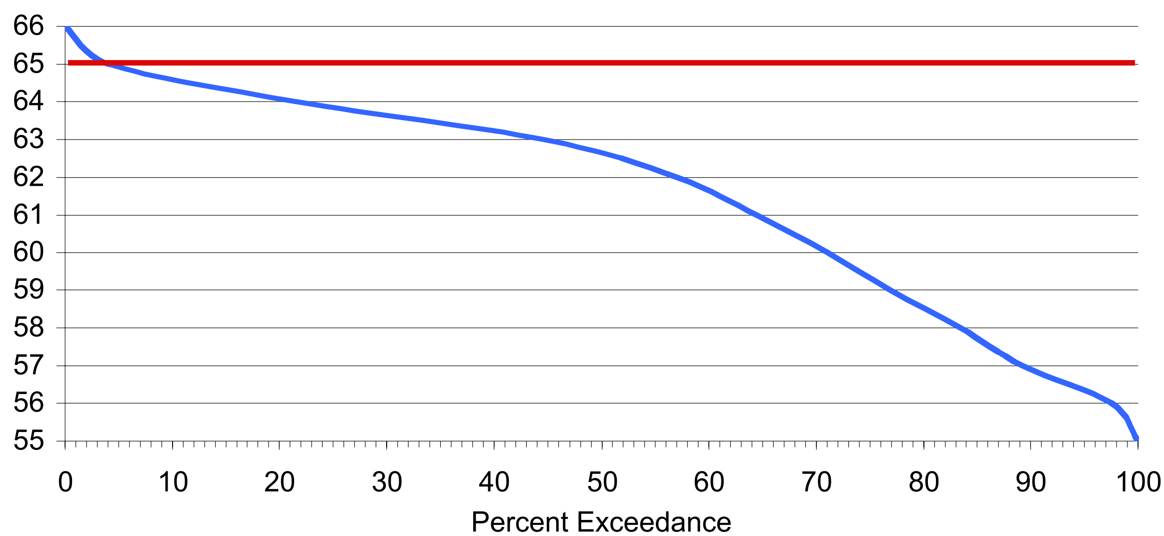
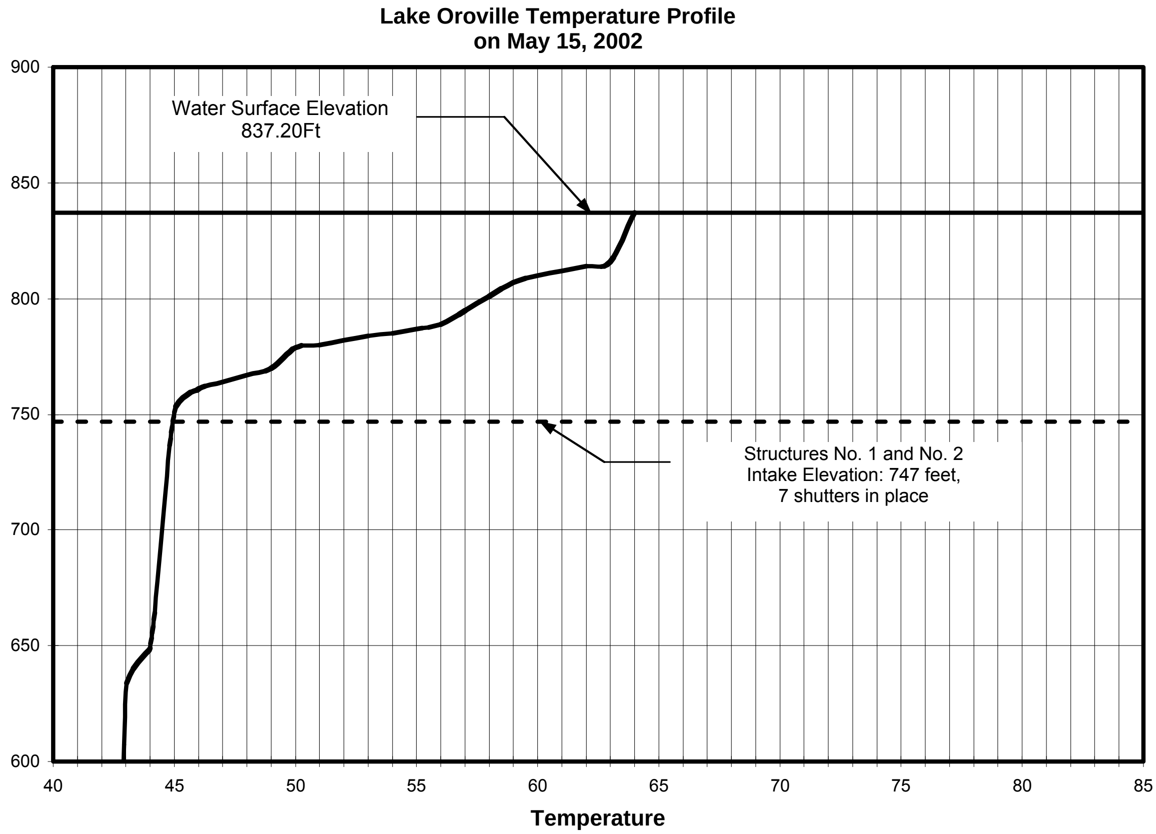


Figure 5.1.2.2-3. Robinson Riffle exceedance graph for June 1 to September 30, 2003.



Water is withdrawn from the reservoir at depths which, after warming due to prevailing air temperatures, will provide the required temperature at the hatchery and Robinson's Riffle (Figure 5.1.2.2-4). The depth from which water is released from the reservoir initially controls temperatures in the river. Air temperatures, which fluctuate from day to day, modify the river temperatures. Altering the depth from which water is released requires installation or removal of shutters at the intake structures, which is an arduous process. The release depth cannot be changed quickly to meet day to day variations in air temperatures. Shutters are held at the minimum depth required to generally meet the criterion at Robinson's Riffle in order to preserve the cold water pool in the reservoir.

Figure 5.1.2.2-4. Example of release depth to achieve desired temperatures at the Feather River Hatchery and Robinson's Riffle.



5.1.2.3 DFG Agreement

The 1983 agreement between DWR and DFG specifies a narrative objective for water temperature below the Thermalito Afterbay river outlet and a numerical objective for temperatures of water provided to the Feather River Fish Hatchery (DFG 1983). Below the Thermalito Afterbay Outlet, temperatures must be suitable for fall-run salmon during the fall months after September 15. From May through August, temperatures must be suitable for shad, striped bass, and other warmwater fish. Under the agreement, the water supply for the hatchery must adhere to specific water temperature objectives (Table 5.1.2.3-1), though a deviation of ±4 ºF is allowed from April 1 through November 30.

The Feather River Hatchery temperature objectives vary with hatchery operations (i.e., holding, spawning, rearing, etc.), and also provide for suitable temperatures in the Feather River downstream from the Thermalito Afterbay Outlet during the fall for fall-run Chinook salmon and during the spring through summer for shad, striped bass, and other warmwater species.

Table 5.1.2.3-1. Hatchery temperature requirements and exceedances in 2002 and 2003.

Date	Year	Temperature Objective	%Exceedance of Objective	%Exceedance of Objective +4 ºF	% Exceedance of Objective -4 °F
April 1 to May 15	2002	51 °F	62.2	2.0	0.0
May 16 to May 31	2002	55 °F	100	0.0	0.0
June 1 to June 15	2002	56 °F	100	0.0	0.0
June 16 to August 15	2002	60 °F	88.5	0.0	11.5
August 16 to August 31	2002	58 °F	81.3	0.0	12.5
September 1 to September 30	2002	52 °F	83.3	0.0	0.0
October 1 to November 30	2002	51 °F	100	37.7	0.0
December 1 to March 31	2002-2003	≤55 °F	0.0	N/A	N/A
April 1 to May 15	2003	51 °F	80.0	0.0	0.0
May 16 to May 31	2003	55 °F	31.3	0.0	6.3
June 1 to June 15	2003	56 °F	26.6	0.0	0.0
June 16 to August 15	2003	60 °F	3.2	0.0	3.2
August 16 to August 31	2003	58 °F	12.5	0.0	5.9
September 1 to September 30	2003	52 °F	33.3	0.0	0.0
October 1 to November 30	2003	51 °F	44.2	0.0	0.0
December 1 to March 31	2003-2004	≤55 °F	0.0	N/A	N/A

In 2002, mean daily FRH temperatures surpassed the objective frequently, although the allowed ±4 ºF deviation from April 1 to November 30 reduced the number of exceedances substantially (Table 5.1.2.3-1 and Figure 5.1.2.3-1). In 2002, except for one day in May during which the water temperature was warmer than allowed by the objective and allowed deviation, water temperatures at the hatchery were cooler than the objectives and allowed deviation until October 1. After October 1 to the end of November, water temperatures were warmer than allowed on several days. After December 1, 2002 to the end of March 2003, water temperatures were always less than the maximum allowed by the objective.

Mean daily hatchery temperatures in 2003 did not exceed the maximum allowed deviation, but were cooler than the objective and allowed deviation once in May, and once in early August and again at the end of August (Table 5.1.2.3-1 and Figure 5.1.2.3-2). As in 2002, water temperatures from December 1, 2003 to the end of March 2004 were cooler than the maximum allowed by the objective.

The warm water species American shad and striped bass require water temperatures of 59 to 68 ºF and 60 to 68 ºF, respectively, for spawning (Moyle 1976). Shad exhibit high spawning mortality when water temperatures exceed 68 ºF. Striped bass cease spawning when water temperatures reach 70 ºF and are stressed when temperatures exceed 77 ºF. Data collected from monitoring sites downstream from the Thermalito Afterbay Outlet indicate that suitable water temperatures for shad and striped bass spawning are available under current Project operations (Appendix 5c).

Figure 5.1.2.3-1. Feather River Hatchery temperature objectives in 2002.

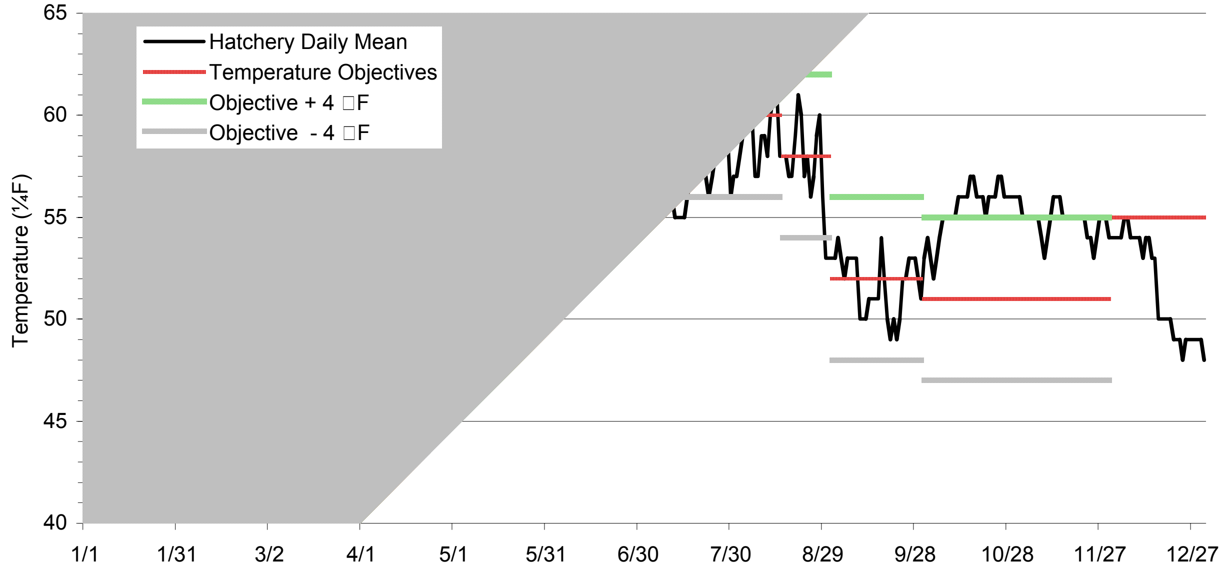
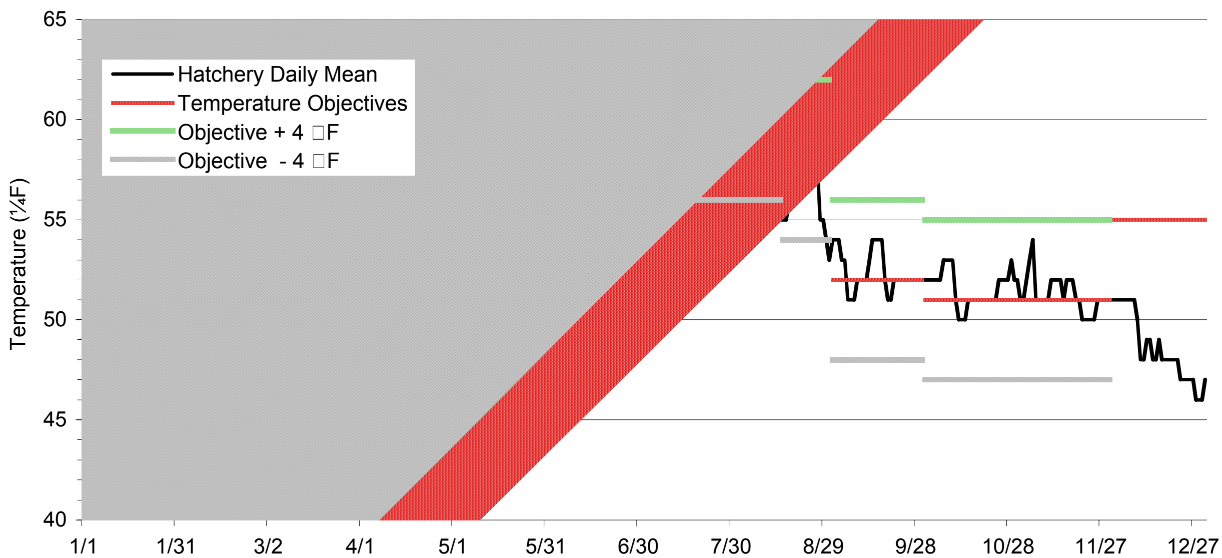


Figure 5.1.2.3-2. Feather River Hatchery temperature objectives in 2003.

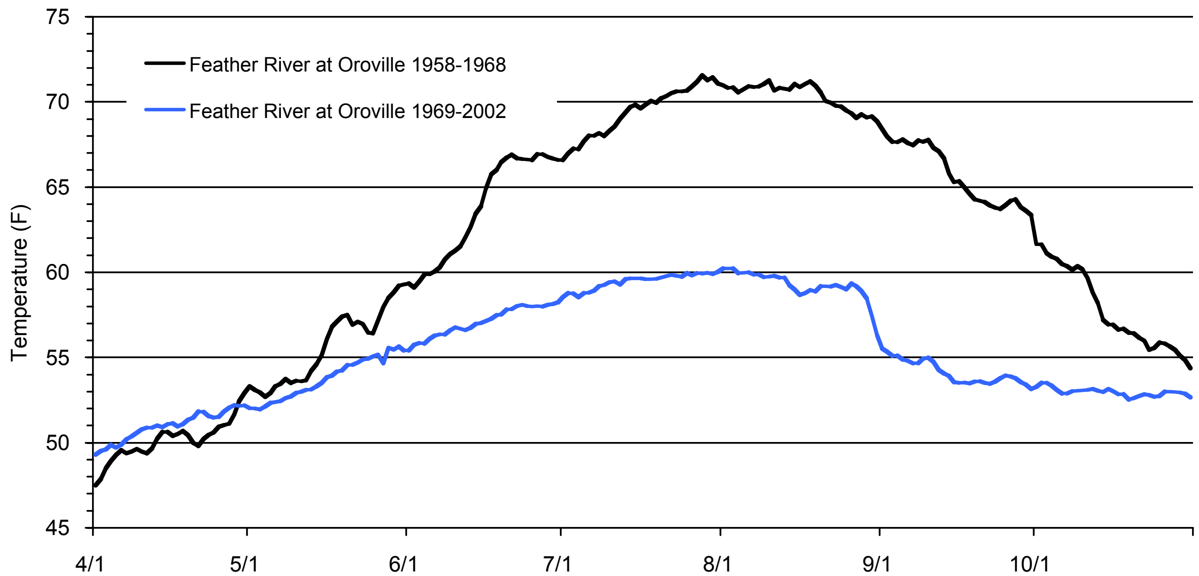


5.1.2.4 Basin Plan

The CVRWQCB Basin Plan has designated beneficial uses for the Feather River from the Fish Barrier Dam to the Sacramento River as municipal and domestic supply, irrigation, contact and non-contact recreation, wildlife habitat, cold and warm freshwater habitat, salmon and steelhead migration, and salmon and steelhead spawning. Of these beneficial uses, temperature criteria apply to irrigation, warm and cold freshwater habitat, salmon and steelhead migration, and salmon and steelhead spawning. Water temperatures and their implications to irrigation beneficial uses were discussed previously.

Although there are no temperature criteria for contact recreation, there has been concern from the Oroville community that post-project water temperatures in the Feather River downstream from Oroville Dam are colder and less comfortable for contact recreational uses than pre-project temperatures. Prior to completion of the Project, water temperatures at the USGS gage at Oroville reached an average maximum of about 72 ºF in mid-summer (Figure 5.1.2.4-1). However, since completion of the Project, maximum water temperatures at the gage have reached an average of only about 60 ºF in mid-summer.

Figure 5.1.2.4-1. Average maximum temperatures in the Feather River at Oroville.



The Basin Plan stipulates that segments with both cold and warm freshwater habitat designations will be considered cold water bodies for the application of water quality objectives. The water temperature criteria at the Feather River Hatchery and Robinson's Riffle are the main targets controlling Project operations.

Spring-run Chinook salmon begin migration into the Feather River in late spring and hold in pools throughout the summer before the onset of spawning in early September, while fall-run Chinook salmon begin showing up in late summer and hold more briefly before spawning begins concurrently with the spring-run fish. Optimal temperatures for migration and holding of spring and fall-run Chinook salmon have been determined to range to 60 to 64 ºF (EWG-36, 2004). Optimal spawning and egg incubation temperatures for both spring and fall-run Chinook salmon have been determined to range to 56 to 58 ºF. Chinook spawning concludes near the end of December and egg incubation lasts until the middle of February.

Adult steelhead begin arriving in September and spawn from about December to April, with egg incubation continuing through May. Suitable spawning and egg incubation temperatures for steelhead range to 52 to 54 ºF.

Analysis of pool profile data reveals that suitable Chinook salmon holding temperatures existed from the Fish Barrier Dam, near river-mile 67, as far downstream as the Project Boundary, near river-mile 54, in late August 2002 (Appendix 5b). Appropriate holding temperatures extended downstream as far as Star Bend near river-mile 19 in late August 2003. Appropriate spawning and egg incubation temperatures for Chinook salmon were available in the LFC for the entire spawning and egg incubation period in both 2002 and 2003 (Appendix 5c).

Suitable spawning and egg incubation temperatures for Chinook salmon were available in the HFC from the Afterbay Outlet downstream to near river-mile 57 for the entire spawning and egg incubation period in both 2002 and 2003. Downstream from river-mile 57, mean daily water temperatures exceeded 58 ºF until the middle of October before cooling to suitable spawning and egg incubation temperatures in both years.

Steelhead spawning and egg incubation temperatures of 52 to 54 ºF were available from late November 2002 until the middle of May 2003. Temperatures fell below 50 ºF from late December 2002 until the middle of March 2003 in the upper reaches of the LFC (Auditorium Riffle), and from late December 2002 until late February 2003 in the lower reaches of the LFC (Eye Riffle). Review of pool profile data reveals that suitable steelhead holding temperatures existed from the Fish Barrier Dam, near river mile 67, as far downstream as the Highway 162 crossing, near river mile 64.5, in late October 2002 (Appendix 5b). Appropriate holding temperatures extended downstream to just above the Afterbay Outlet, near river mile 60, in late October 2003. Late January pool temperatures were suitable for steelhead holding for the entire Feather River in both years. Optimal steelhead spawning and egg incubation temperatures of 52 to 54 ºF were available in the HFC from late November 2002 until the middle of May 2003. Mean daily water temperatures fell below 50 ºF from late December 2002 until the middle of March 2003 in the HFC, and between late December 2003 and late February 2004.

5.1.3 Access to Cold Water Pool

The cold water pool (hypolimnion) in Lake Oroville is affected by summer stratification, reservoir drawdown through the summer and fall, downstream releases for temperature maintenance for cold-water fish species, and water year type. The water year type affects the level of filling of the reservoir during the winter and spring. Different water years are characterized by the Sacramento Valley 40-30-30 Index as wet, above normal, below normal, dry, and critically dry. The Sacramento Valley 40-30-30 Index was developed by the SWRCB for the Sacramento hydrologic basin as part of the SWRCB's Bay-Delta regulatory activities. The Sacramento Valley 40-30-30 Index is computed as a weighted average of the current water year's April-July unimpaired runoff forecast (40 percent), the current water year's October-March unimpaired runoff forecast (30 percent), and the previous water year's index (30 percent). A cap of 10 maf is put on the previous year's index to account for required flood control reservoir releases during wet years. Unimpaired runoff (calculated in the 40-30-30 Index as the sum of Sacramento River flow above Bend Bridge near Red Bluff, Feather River inflow to Oroville, Yuba River flow at Smartville, and American River inflow to Folsom) is the river production unaltered by water diversions, storage, exports, or imports. A water year with a 40-30-30 index equal to or greater than 9.2 maf is classified as "wet," while a water year with an index equal to or less than 5.4 maf is classified as "critical."

Water temperatures were monitored during this study during a “dry” year (2002) and an “above normal” year (2003), and therefore do not provide the information needed to evaluate the availability of cold water in other year types. However, the Engineering and Operations Workgroup developed a model in SP-E1 for use in simulation studies in SP-E2. These simulation studies provide information for assessment of the cold water pool in different water year types. The simulation model was developed in SP-E1 using CALSIM, which uses historical data that is modified to represent unimpaired conditions. These data are modified for a given level of development that is the same for each year. This synthetic hydrology, developed from estimates of historic flows, is then used in the SP-E1 model to evaluate effects of different operational scenarios.

The Sacramento Valley 40-30-30 Index indicates that water year 1983 was a “wet” year (Figure 5.1.3-1). The simulation model indicates reservoir storage (in thousand acre feet) below various temperatures during this water year (Figure 5.1.3-2). This information can be used for identifying cold water fish habitat in the reservoir at various times of the year, availability of cold water for release downstream, and other purposes. However, other water years with similar “wet” designations can display different temperature conditions. For example, water year 1984 was also “wet” with similar total reservoir storage on June 1, but the pool of cold water at a temperature not exceeding 50 ºF was only half that present in 1983 by the fall (Figure 5.1.3-3). Reservoir operations affect the storage of cold water, as can be seen by comparing the graphs for the 1983 and 1984 water years. The reservoir was operated more fully in the 1984 water year, resulting in less total reservoir volume as well as cold water in storage. Of interest is that the warm water pool of both years is similar, as could be expected since hypolimnetic, rather than epilimnetic, withdrawals are necessary to maintain downstream temperature conditions for cold water species of fish.

Examples of an "above normal" year (Figure 5.1.3-4) and a "below normal" year (Figure 5.1.3-5) identified by the Sacramento Valley 40-30-30 Index shows little difference from that of a "wet" year (Figure 5.1.3-3). Reservoir releases and water deliveries are managed for carryover into the next water year, in case of drought, which helps preserve the cold water pool. However, obligations for delivery of water for agricultural contractors, Delta maintenance flows, and fisheries habitat in the Feather River result in greater reduction of the cold water pool carryover in the fall of "dry" years (Figure 5.1.3-6). "Critically dry" water years, such as that of 1976 (Figure 5.1.3-7), result in even less carryover of cold water due to low reservoir elevations, while back to back "critically dry" years could lead to depletion of the cold water pool, as indicated for 1977 (Figure 5.1.3-8). The model can be used to evaluate the cold water pool available in other water years, and patterns, such as a series of "dry" years.

Figure 5.1.3-1. Sacramento Valley 40-30-30 Index for Water Years 1906 to 2003.

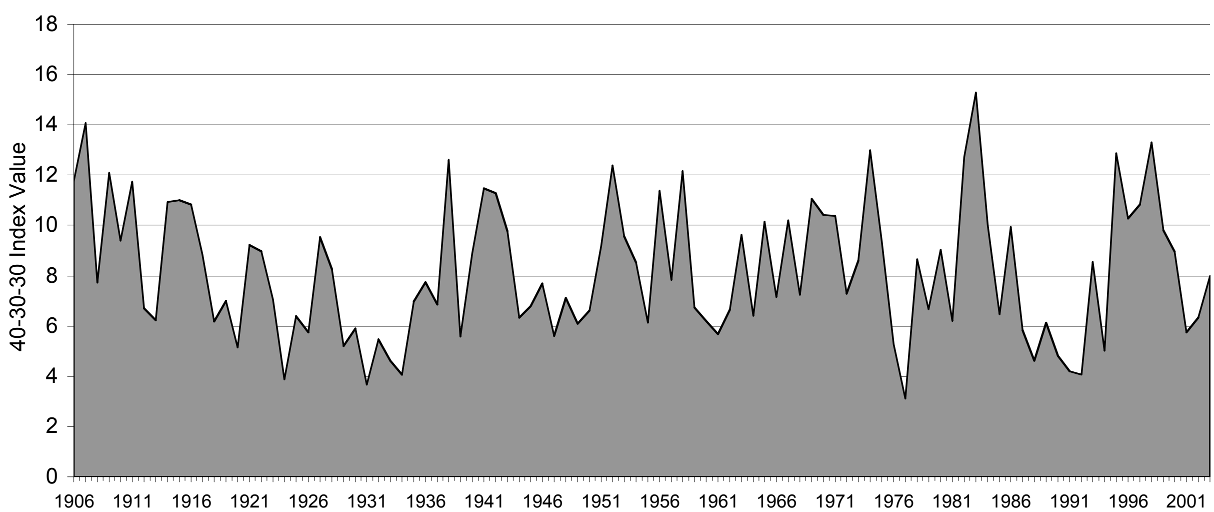


Figure 5.1.3-2. Total Lake Oroville cold water pool volume in “wet” water year 1983.

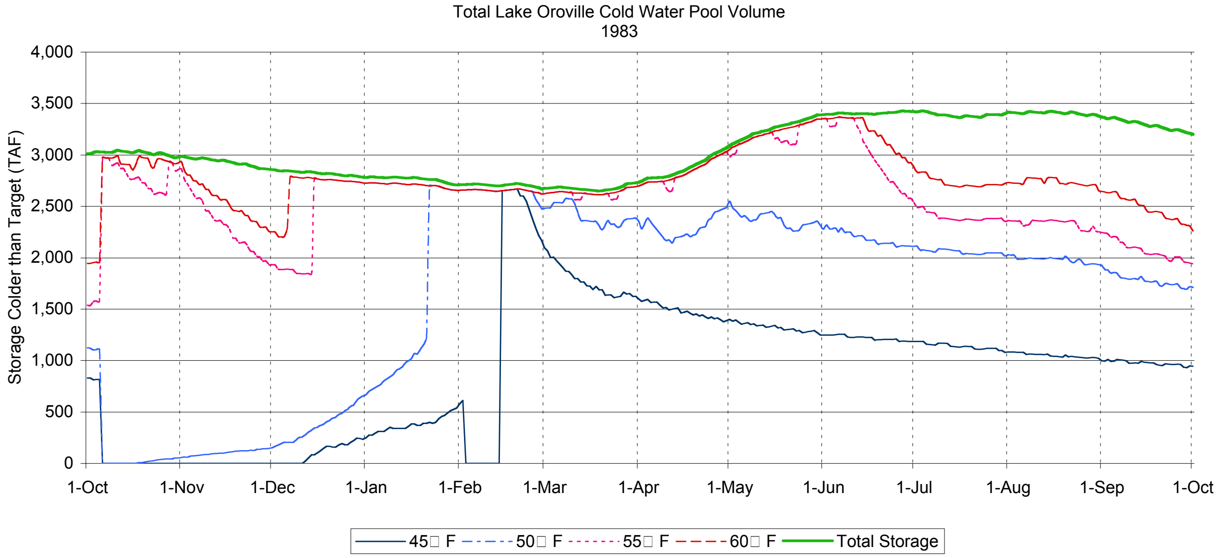


Figure 5.1.3-3. Total Lake Oroville cold water pool volume in “wet” water year 1984.

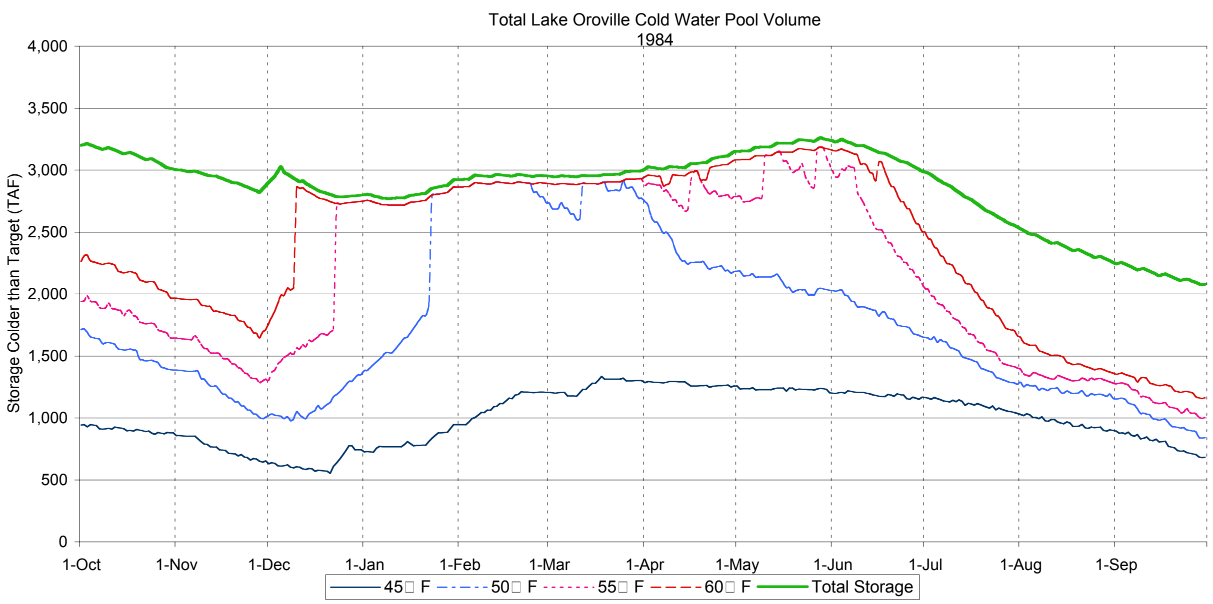


Figure 5.1.3-4. Total Lake Oroville cold water pool volume in “above normal” water year 1980.

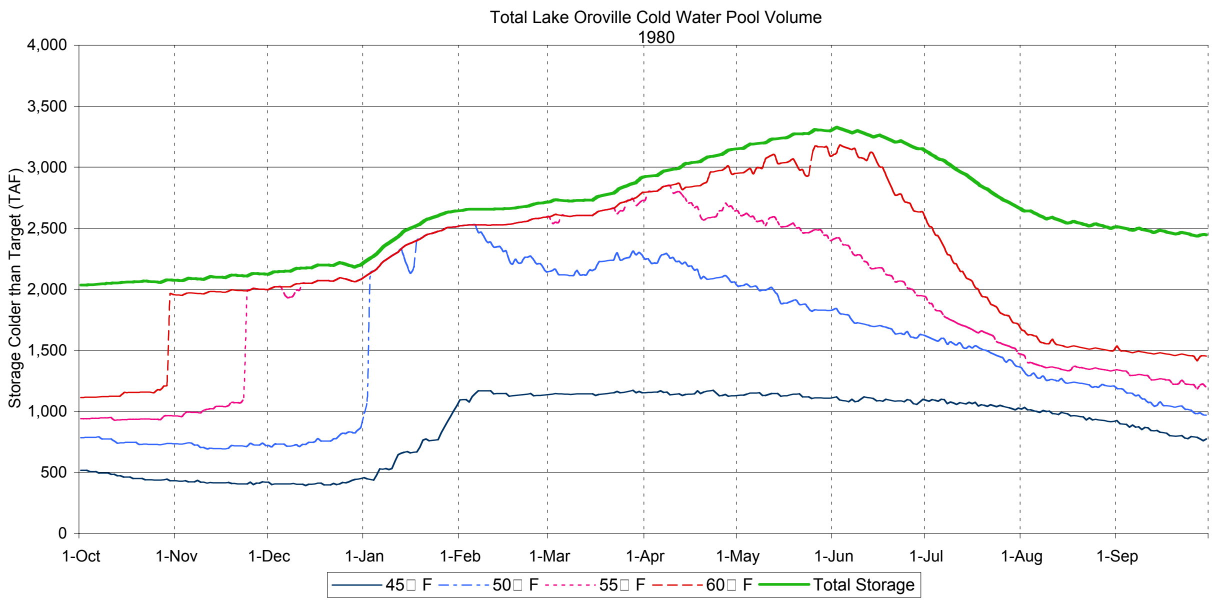


Figure 5.1.3-5. Total Lake Oroville cold water pool volume in “below normal” water year 1979.

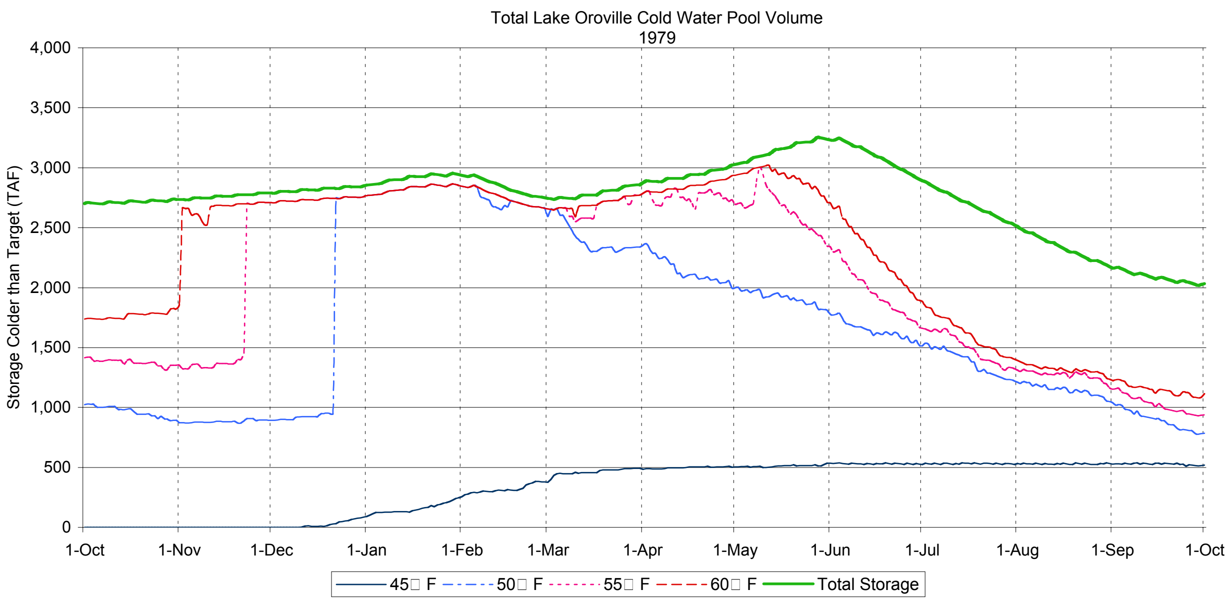


Figure 5.1.3-6. Total Lake Oroville cold water pool volume in “dryl” water year 1981.

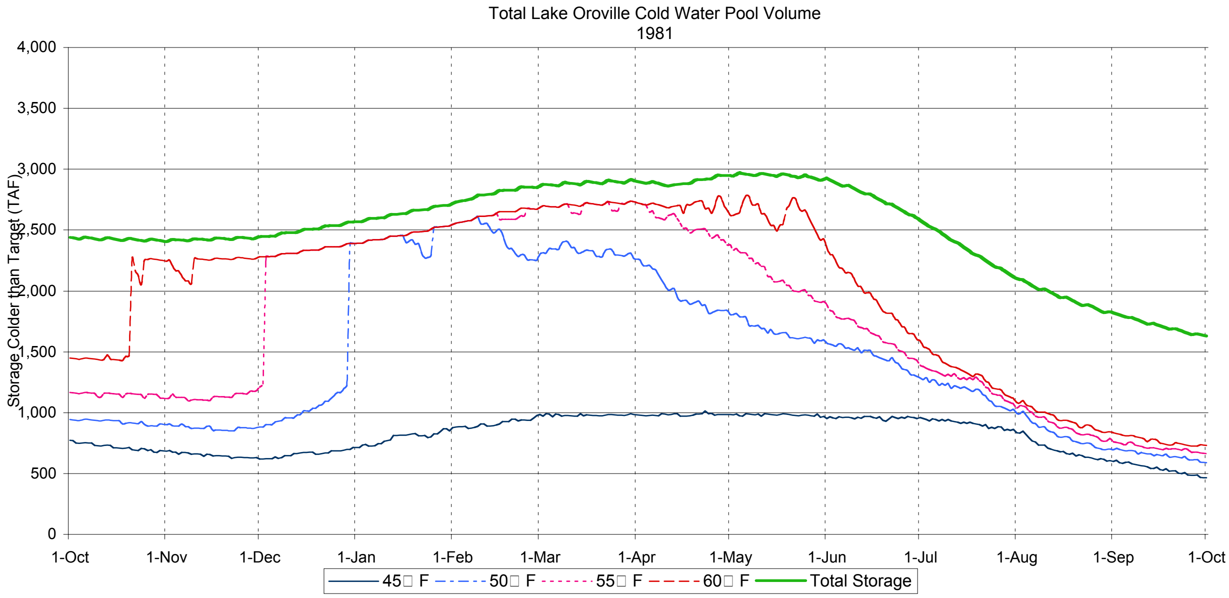


Figure 5.1.3-7. Total Lake Oroville cold water pool volume in “critically dryl” water year 1976.

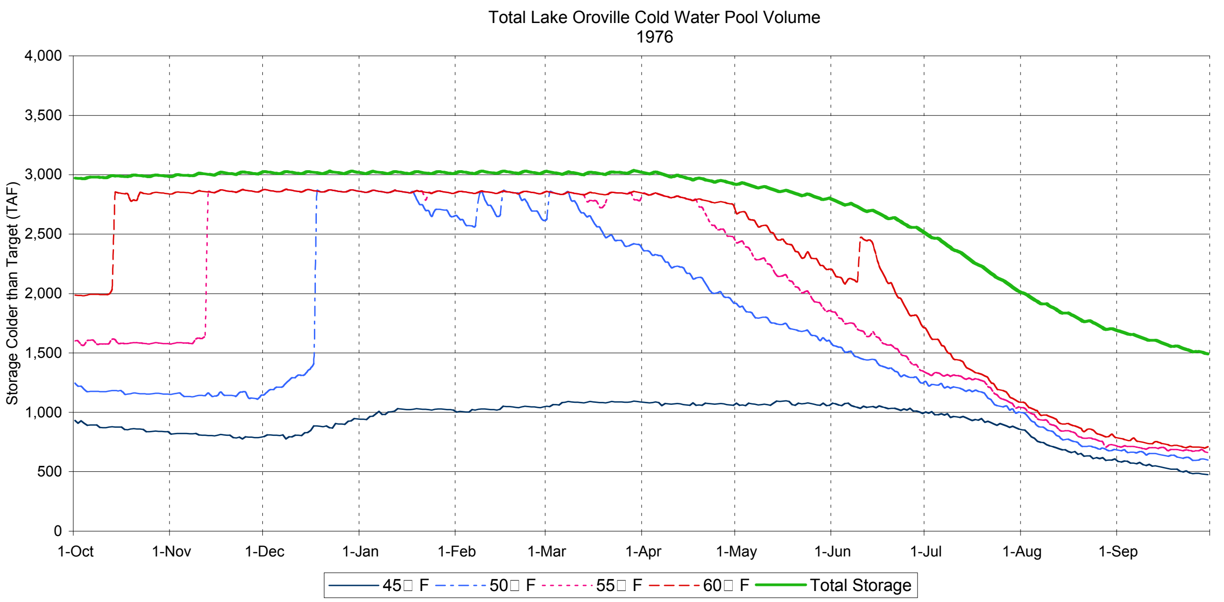
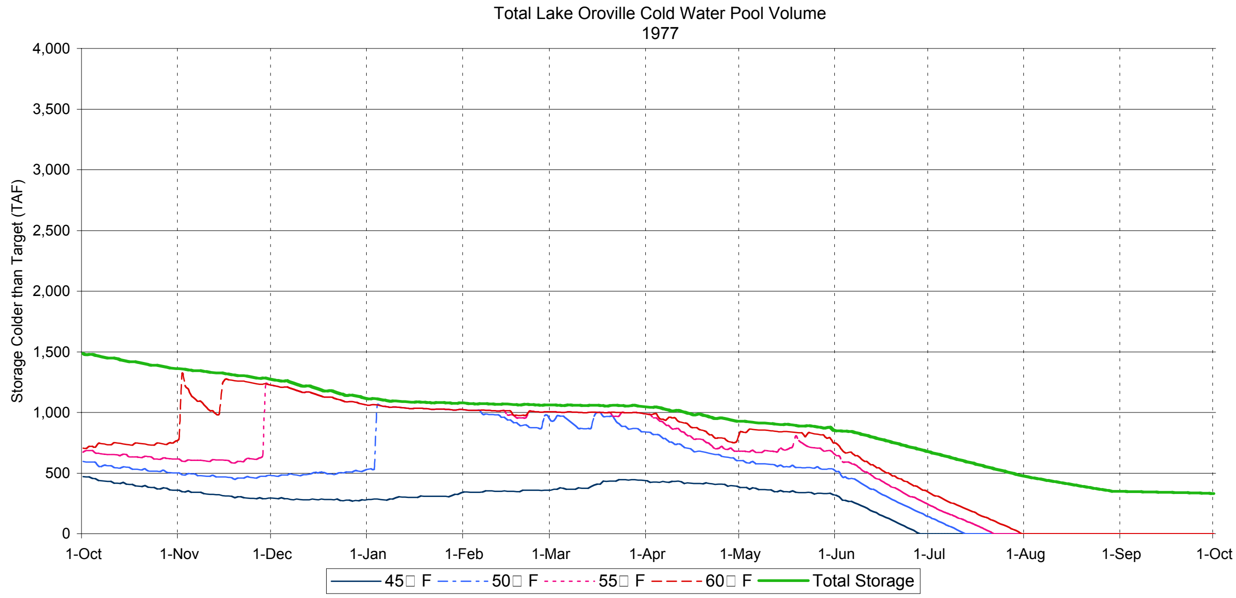


Figure 5.1.3-8. Total Lake Oroville cold water pool volume in "critically dryl" water year of 1977.



The temperature of water available for release from the hypolimnion in Lake Oroville affects the temperature of water in the Feather River. Water temperatures in the Feather River measured at the gage just upstream from the Fish Barrier Dam indicate that in most years since Project completion river temperatures reach a maximum of about 63 ºF (Figure 5.1.3-9). The highest water temperature at the gage since Project completion was during the critically dry water year of 1977 in which temperatures reached 68 ºF. Prior to Project construction, water temperatures at the gage regularly approached 75 ºF (Figure 5.1.3-10).

Figure 5.1.3-9. Water temperatures in the Feather River near Oroville since Project completion.

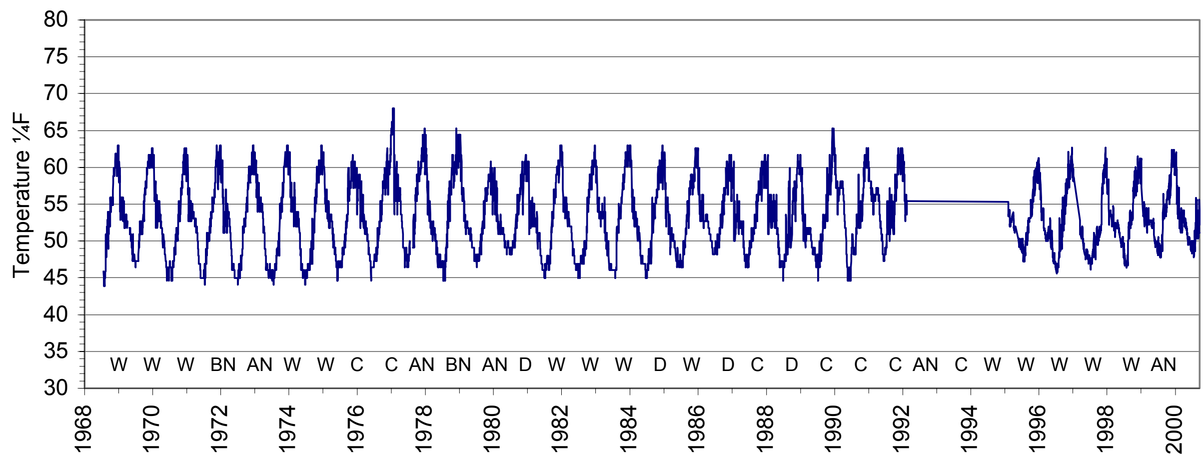
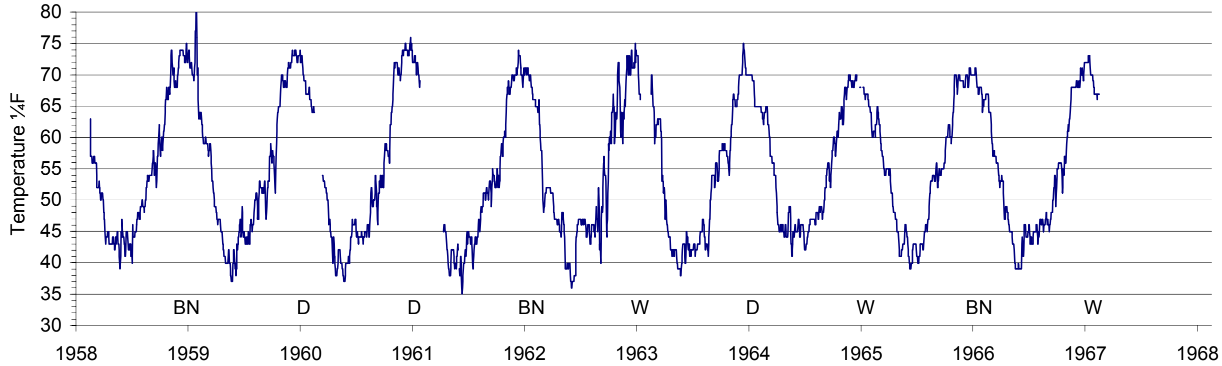


Figure 5.1.3-10. Pre-Project Water temperatures in the Feather River near Oroville.



Downstream releases from the hypolimnion have the potential to affect the cold water pool and stratification patterns in the reservoir, depending on the depth from which water is withdrawn for release to the Feather River. However, temperature data collected in the vicinity of the intake structure (Figure 4.1.4.1-1) do not indicate any effect to water temperature profiles (Figures 5.1.3-11 through 14). Water temperature profiles are similar at monitoring sites closest to the intake structure and those further away during the warmer months when any effects would be expected to be the most pronounced.

Figure 5.1.3-11. Spring 2002 temperature pattern at the Lake Oroville intake structure.

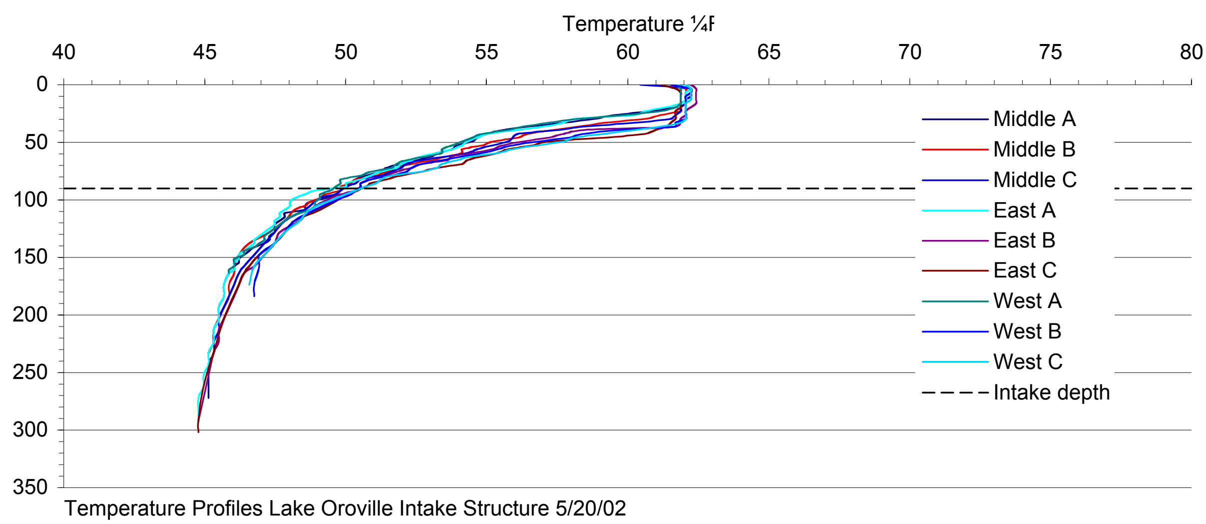


Figure 5.1.3-12. Mid-summer 2002 temperature pattern at the Lake Oroville intake structure.

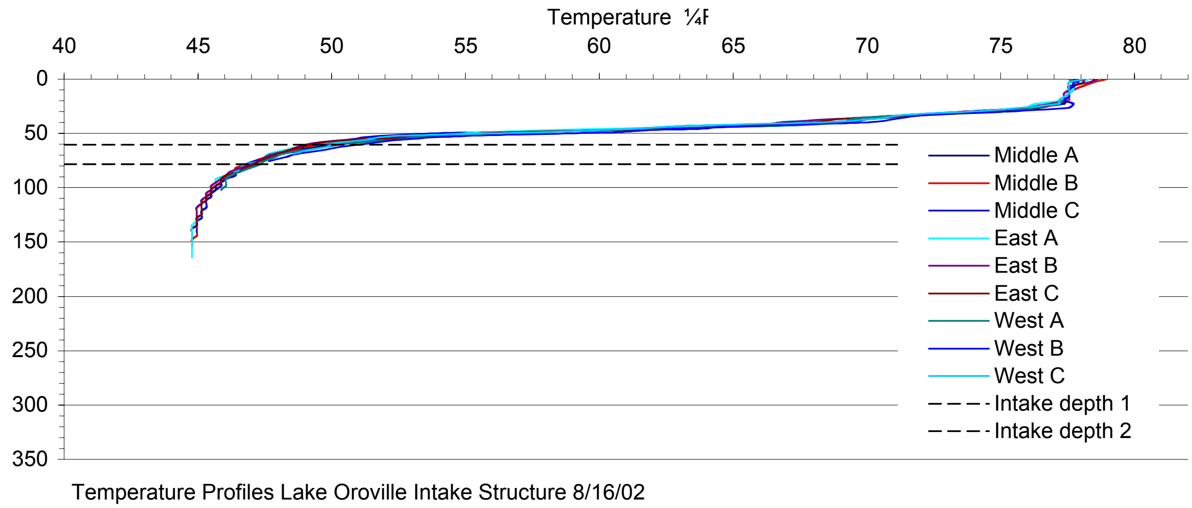


Figure 5.1.3-13. Fall 2002 temperature pattern at the Lake Oroville intake structure.

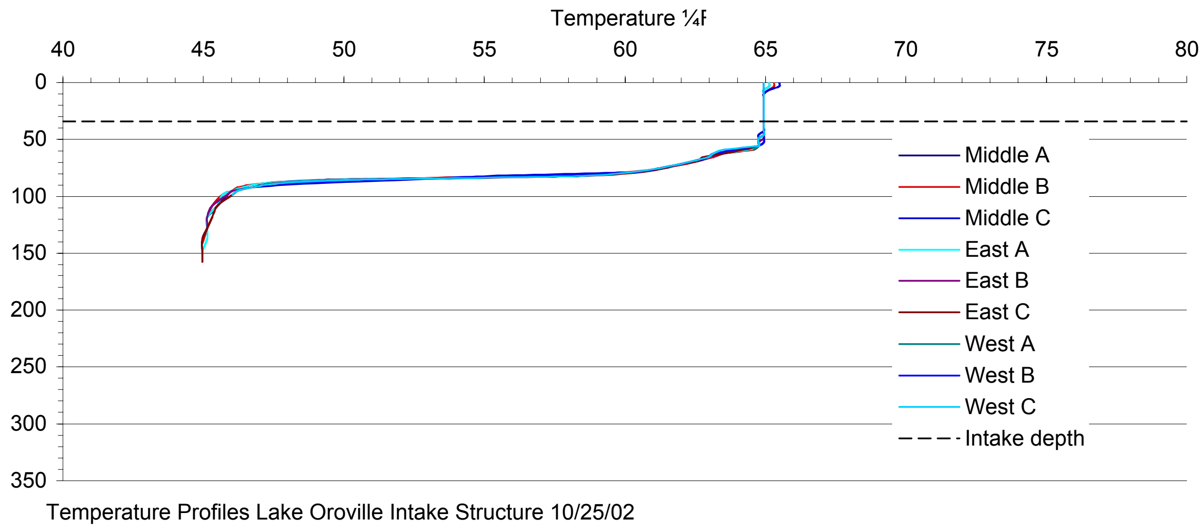
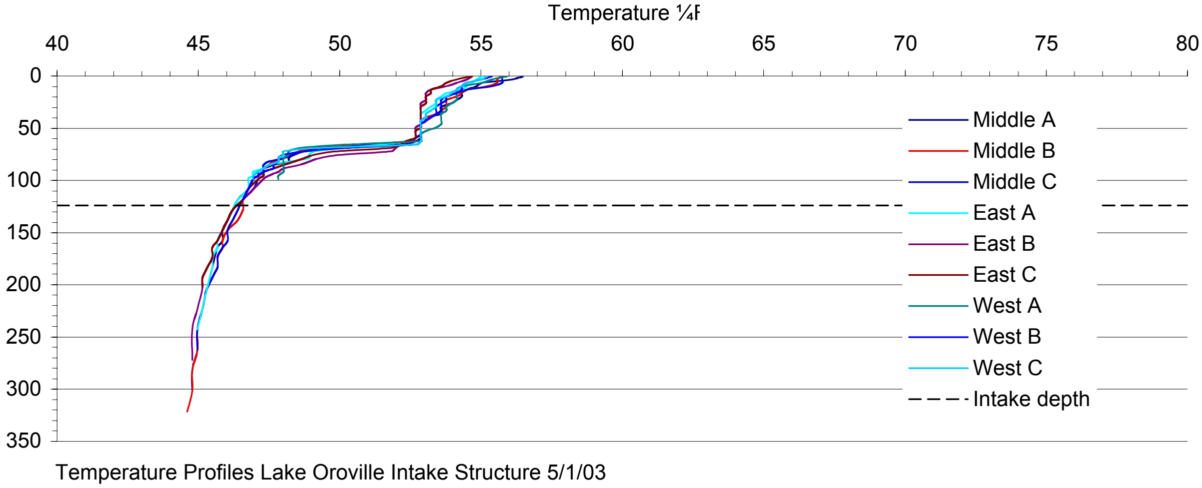


Figure 5.1.3-14. Spring 2003 temperature pattern at the Lake Oroville intake structure.



5.1.4 Hatchery Effects on Temperature

Water temperatures in the Feather River downstream from Oroville Dam are controlled by the temperatures required under the 1983 agreement at the Feather River Fish Hatchery. The NOAA Fisheries criterion at Robinson's Riffle also controls water temperatures, but is usually satisfied by releasing water of suitable temperature to meet the temperature requirements at the hatchery (EWG-36 2004).

However, the 1969 agreement between DWR and Joint Water Districts allows DWR to provide water at temperatures reasonably related to achieving agricultural production within the Joint Water District service area (DWR 2001). Relatively warm water is needed for rice germination early in the irrigation season, with slightly cooler temperatures suitable for the remainder of the growing season. DWR accommodates temperature requirements for agricultural production by releasing water that is as close as possible to the maximum temperature allowable under the 1983 agreement with DFG. However, as discussed previously, water temperatures provided through the Afterbay do not consistently meet the requirements for rice production at all the irrigation diversions. Warmer water might be provided by releasing water from nearer the surface of Lake Oroville, but the warmer water temperatures desired for rice irrigation would not meet hatchery requirements.

Water temperatures in the Feather River also affect contact recreation. Feather River water temperatures are much cooler than pre-project temperatures due to hatchery temperature requirements. The cooler temperatures may make swimming less comfortable under current Oroville Dam releases than pre-project conditions.

5.1.5 Effects of Pump Back Operations

Data representing more recent pump back operations (Appendix 7) were reviewed to evaluate effects to hatchery temperatures and reservoir stratification. During pump back, water is pumped from the Thermalito Afterbay, to the Forebay, into the Power Canal, to the Diversion Pool, and back into Lake Oroville. Generally, the purpose of pump back is to retrieve water by pumping back into Oroville Reservoir through the power plants when energy costs and demands are low, and then use this same water for power generation when energy costs and demands are high. The data show that pump back can occur during any time of the year. The greatest volume pumped since 1997 was 13,900 af in January of 2001. While temperatures in Lake Oroville have been regularly monitored by the OFD, these measurements have not been performed to ascertain the effects of pump back on water column temperatures. Water temperatures at the hatchery, however, are monitored by the SCADA system to provide real-time information for use in monitoring effects of pump back on hatchery temperatures.

Water temperatures at the hatchery are regulated by selective withdrawal from Lake Oroville to comply with temperature requirements in the 1983 agreement with DFG. Water for the hatchery is diverted at the Diversion Dam. Pump back operations can draw water back to the Diversion Pool which has warmed slightly in the Thermalito Forebay or Afterbay. This warmed water can subsequently be released from the Diversion Pool to the hatchery. However, water temperatures at the hatchery are closely monitored during pump back operations, which are curtailed if hatchery temperatures begin to approach the limits in the agreement.

Water temperatures at the hatchery may be affected by both air temperatures and pump back operations, though the specific influences are difficult to discern since air temperatures fluctuate significantly (Appendix 7). Increases in water temperatures at the hatchery during pump back occasionally occur, depending on the volume of water pumped and time of year. However, as mentioned above, water temperatures at the hatchery are maintained within the limits of the agreement by curtailing pump back operations and releasing cooler water from the reservoir. Pump back operations are closely monitored and regulated so that no adverse effects to water temperatures at the hatchery occur. Maintenance of temperatures at the hatchery also insures that water temperatures are maintained at suitable levels for cold water fish species in the low flow channel of the Feather River.

Water temperatures were monitored near the reservoir intake structure to ascertain effects from pump back on stratification. However, during the period of this study, pump back operations were extremely limited. Pump back of 3,437 af occurred on May 20, 2002 and 1,943 af on May 1, 2002. Monitoring data collected around the intake structure (Figure 4.1.4.1-1) do not indicate any effects to water column temperatures from these pump back operations (Figures 5.1.3-11 and 14).

5.2 EFFECTS OF FUTURE PROJECT OPERATIONS TO WATER TEMPERATURES

As potential future project operation changes are identified, the temperature models developed by the Engineering and Operations Work Group can be used to evaluate compliance with temperature objectives. Data obtained from this study can be used to verify model outputs as well as provide empirical analyses.

6.0 ANALYSES

Water temperature data collected for this study provides information for assessing current baseline conditions of the Project. The data are also used to verify temperature models, and can be use to evaluate proposed project operation changes.

Water temperatures downstream from Oroville Dam are largely controlled by temperature requirements at the Feather River Fish Hatchery. Water is released from Oroville Dam to meet the hatchery temperature requirements, as well as those of the NOAA Fisheries at Robinson's Riffle, while also conserving the cold water pool in Lake Oroville. Water is released from Lake Oroville that is as close as possible to the maximum temperature allowable under the 1983 agreement with DFG to accommodate temperature requirements, as much as possible, for irrigation. However, due to conflicting temperature requirements for fisheries, it is not always possible to provide the temperatures desired by rice farmers.

During dryer years when reservoir levels are low, the cold water pool is diminished. In critically dry years, the cold water pool could be exhausted, resulting in water that is warmer than desired for the most critical needs (e.g., salmonid egg incubation). Deliveries from the reservoir are governed by the water year type. In dryer years, deliveries to water contractors are reduced so that carryover storage is increased and water may be conserved for critical in-stream needs.

Water released for power generation may be pumped back into the reservoir for re-use. While pump back operations can draw water that has warmed in the Thermalito Forebay or Afterbay back into the Diversion Pool and Lake Oroville, these activities are carefully monitored to insure that no adverse effects occur to other beneficial uses. Water temperatures at the hatchery, which receives water diverted from the Diversion Pool, are monitored during pump back. Pump back is curtailed if water temperatures approach the limits of hatchery requirements. No effects from pump back to water column temperatures in the reservoir could be determined.

7.0 REFERENCES

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DWR 1969. Agreement on diversion of water from the Feather River. Department of Water Resources, Richvale Irrigation District, Butte Water District, Biggs-West Gridley Water District, and Sutter Extension Water District.

DWR 2001. Initial Information Package. Relicensing of the Oroville Facilities. Department of Water Resources. Sacramento, California.

EWG-36. 2004. Operate the Oroville Facilities to Provide Additional Cold Water in the Low Flow Channel of the Feather River for Benefit of Chinook Salmon and Steelhead. Draft Narrative. Oroville Facilities Relicensing Environmental Workgroup.

Moyle, P. B. 1976, Inland Fishes of California. UC Press. Berkeley, California. 405 pp.

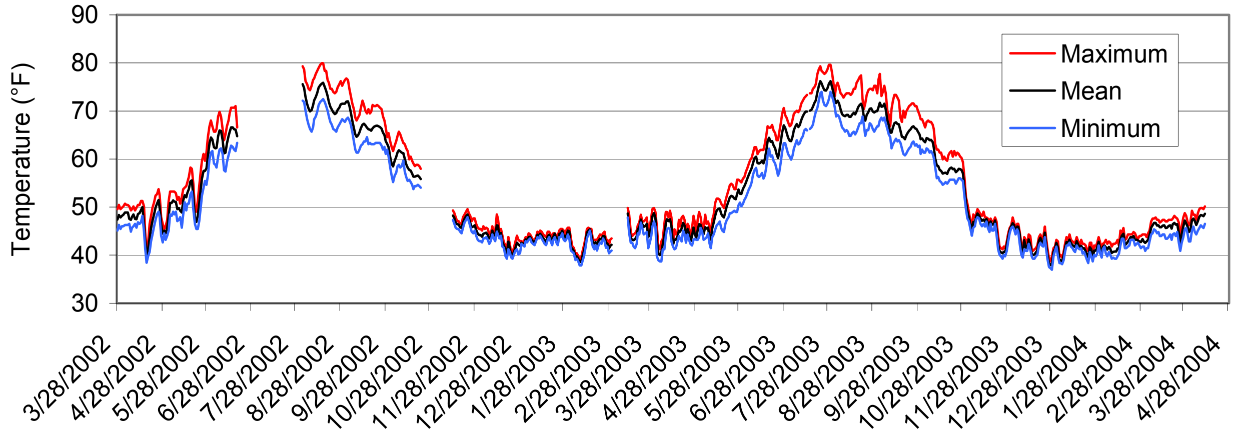
Mutters, R. G., J. W. Eckert, A. Roel, and R. E. Plant. 2003a. Measuring the effect of low water temperature on blanking and grain yield in California rice production. Submitted for publication.

Mutters, R. G., J. W. Eckert, A. Roel, and R. E. Plant. 2003b. Measuring the effect of low water temperature on blanking and grain yield. PowerPoint Presentation to Environmental Work Group.

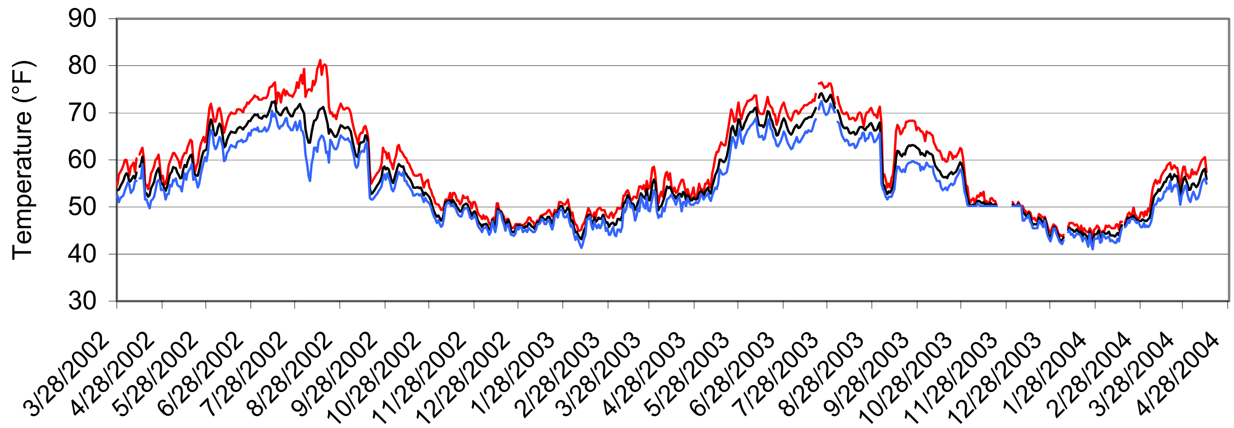
APPENDICES

Appendix 1. Thermal Regime of Tributaries to Lake Oroville.

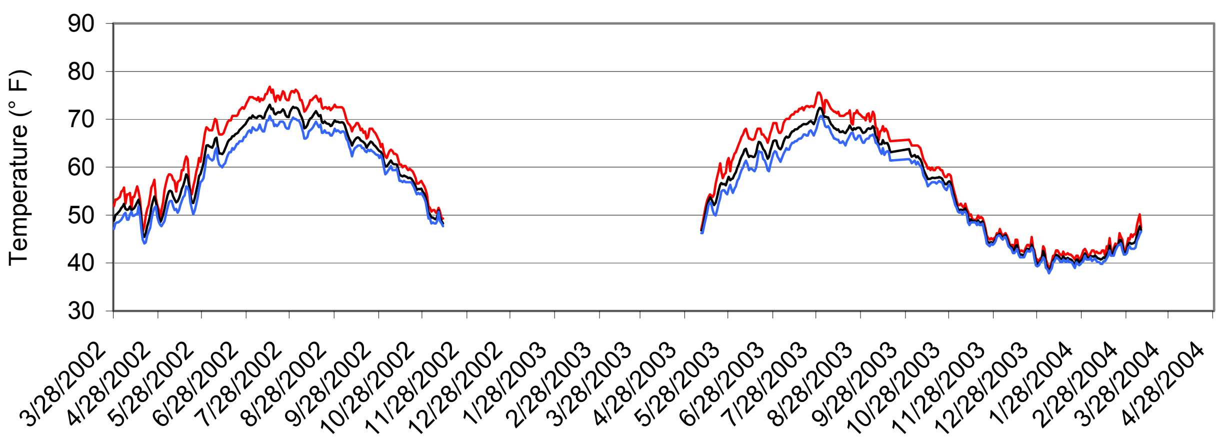
West Branch Feather River near Paradise (A5-2600.00)



Concow Creek at Jordan Hill Road (A5-2260.50)

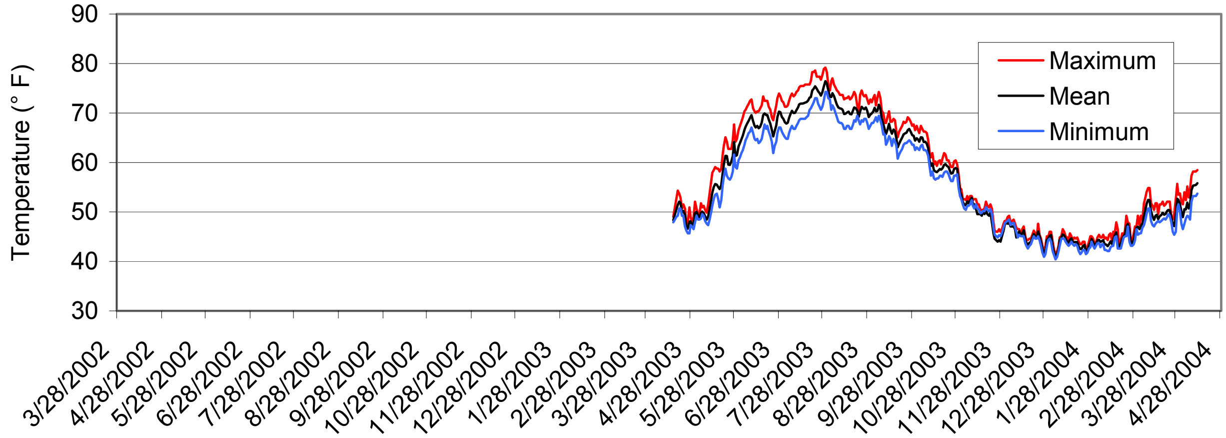


Feather River North Fork at Pulga (A5-3140.00)

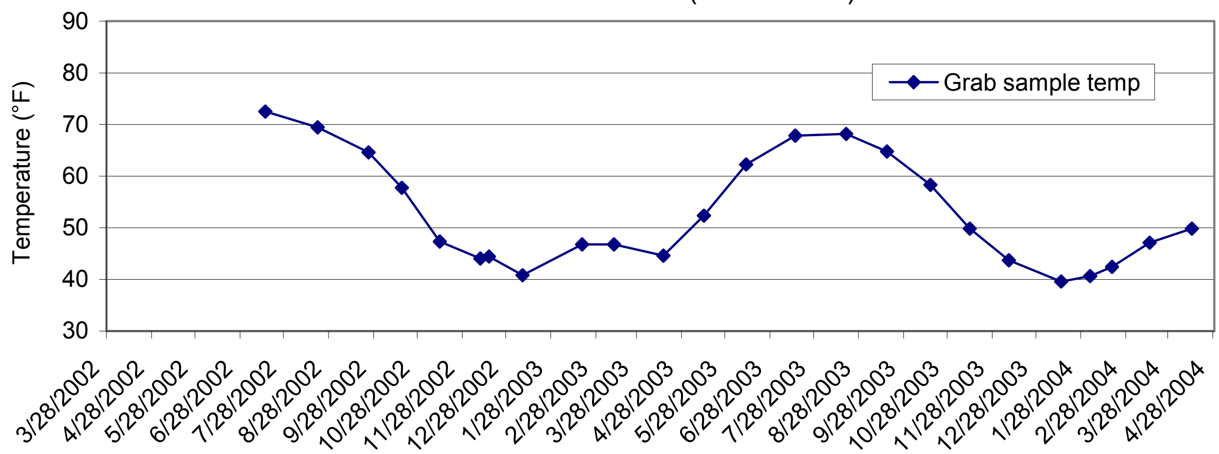


Appendix 1. Continued.

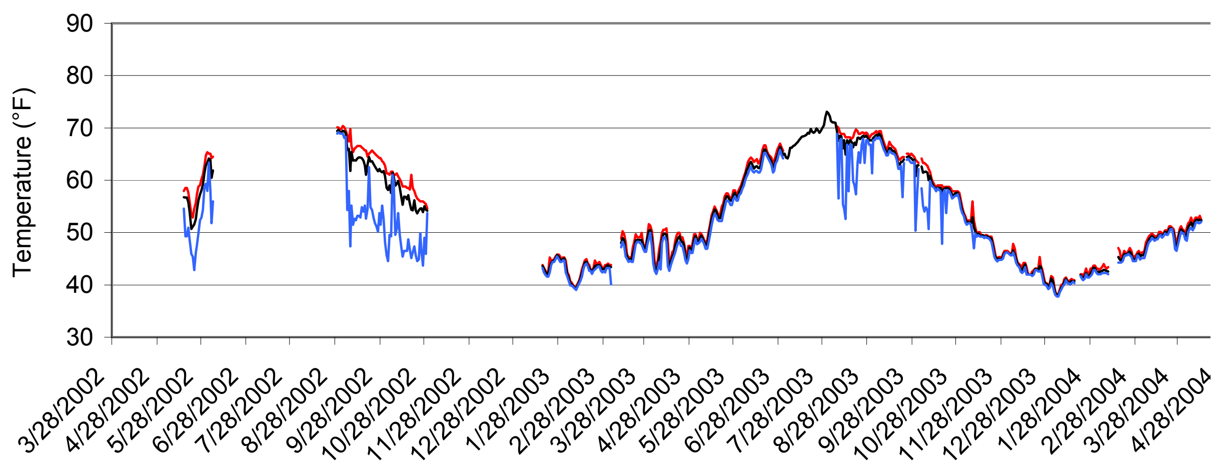
Feather River North Fork upstream of Poe Powerhouse (A5-3132.50)



Poe Powerhouse Outflow (A5-3931.50)



Feather River North Fork downstream of Poe Powerhouse (A5-3130.50)



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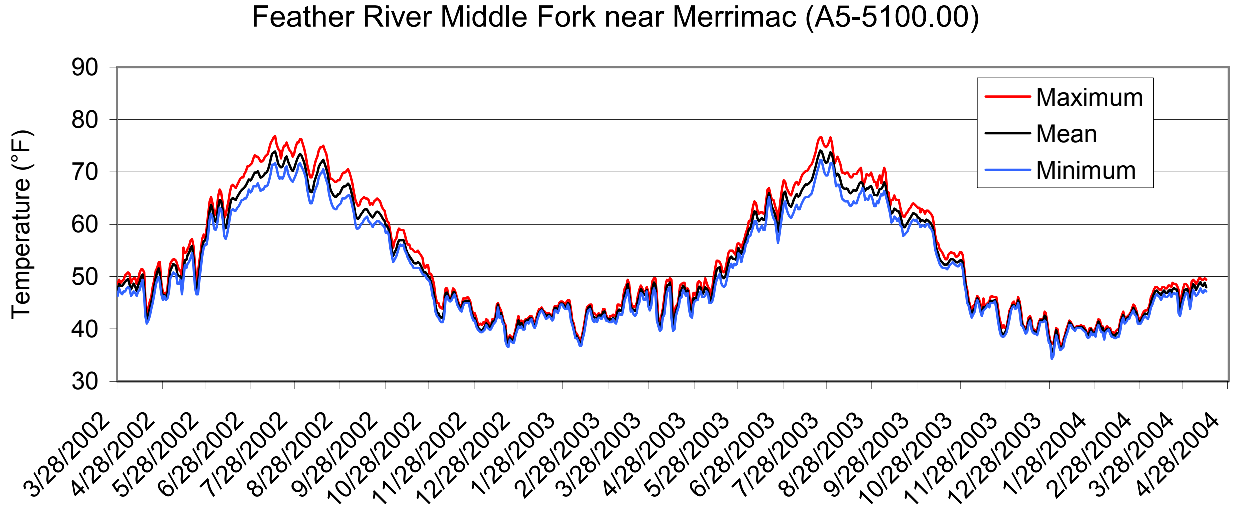

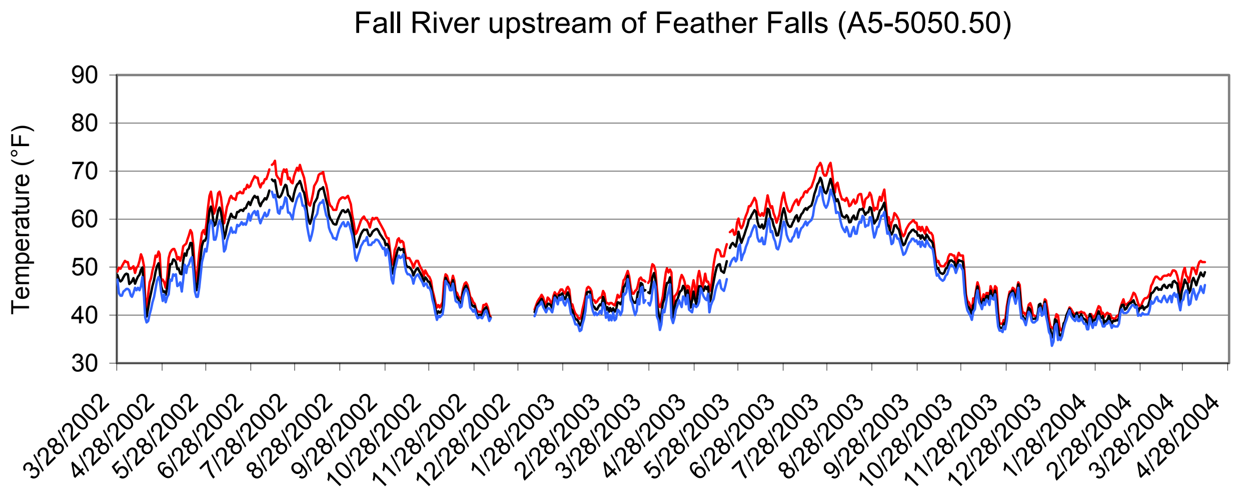

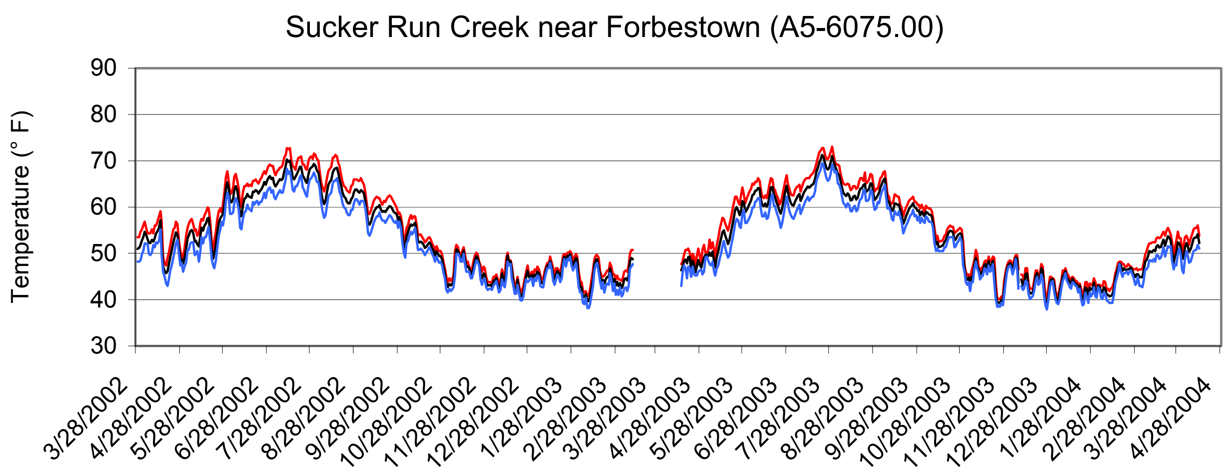

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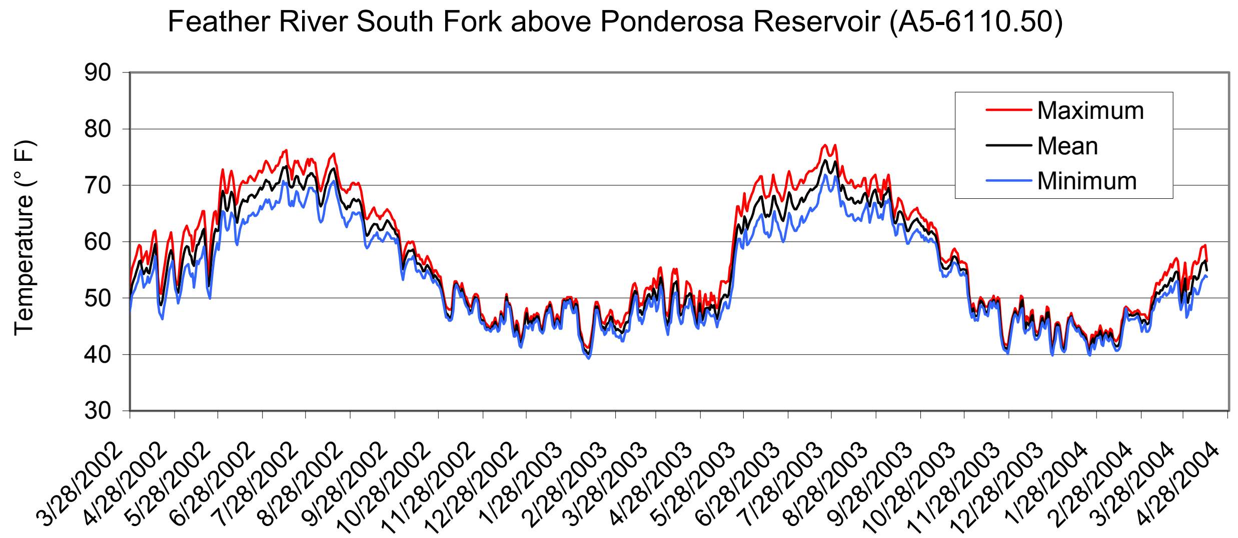
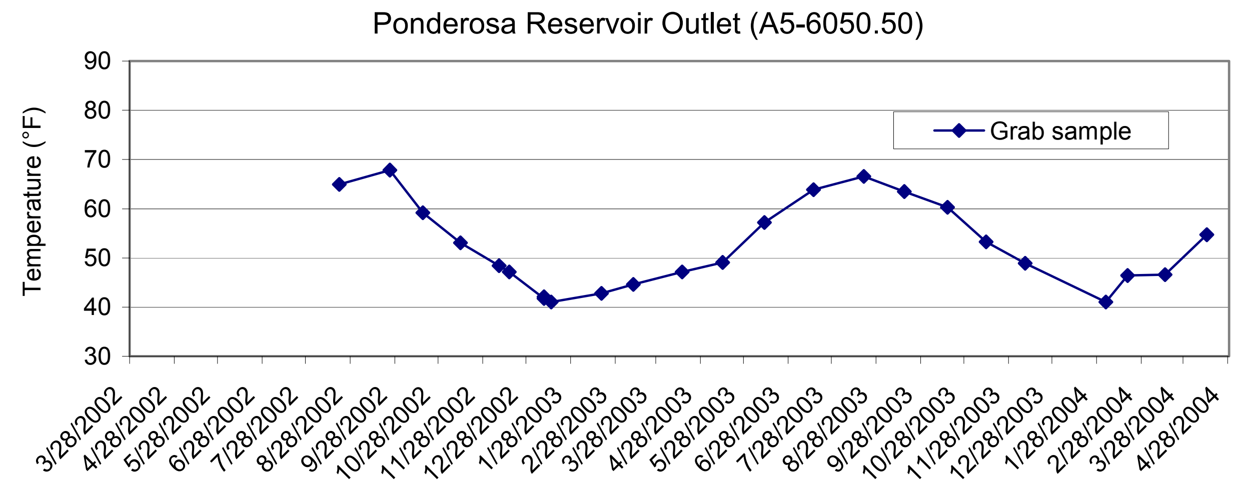
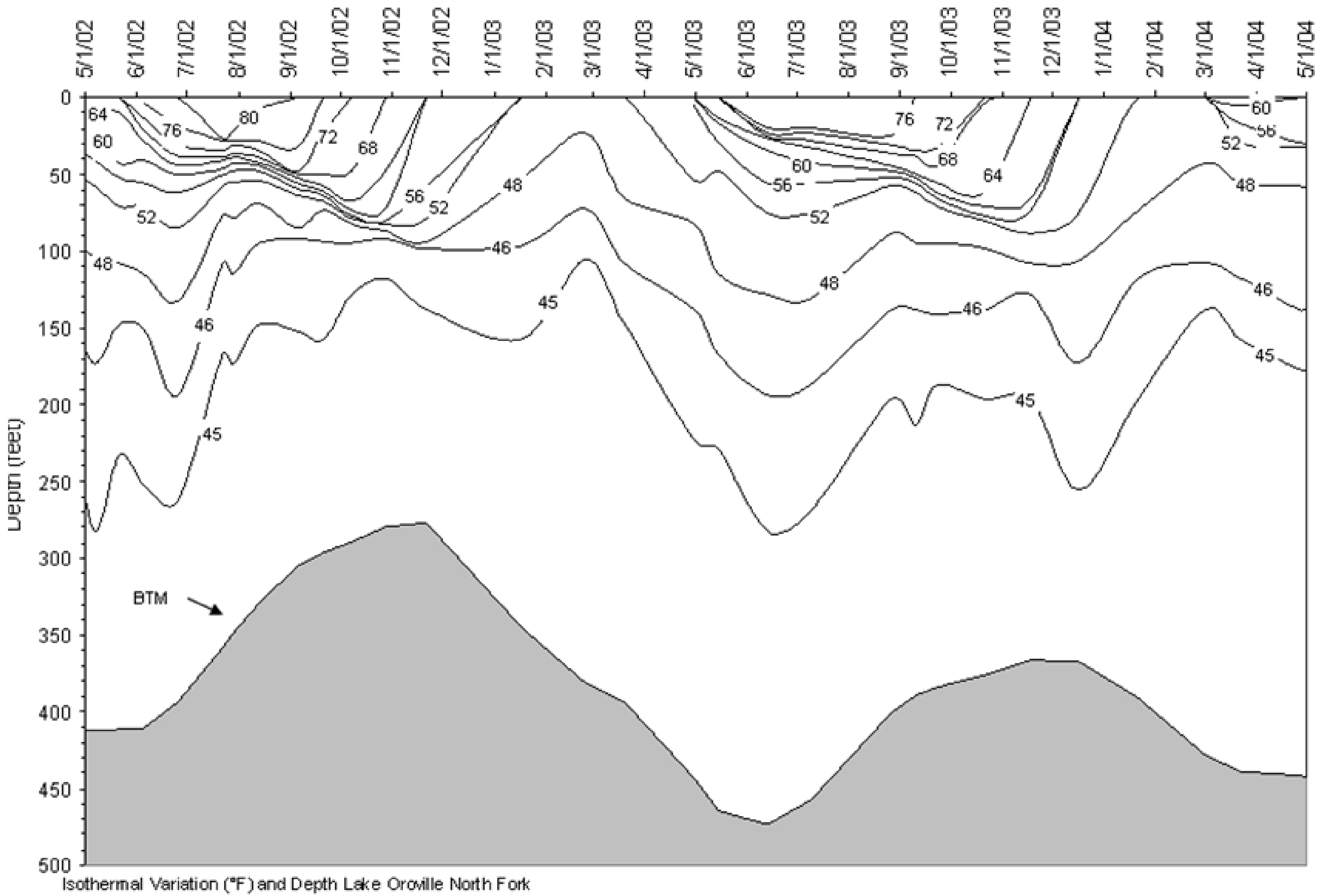
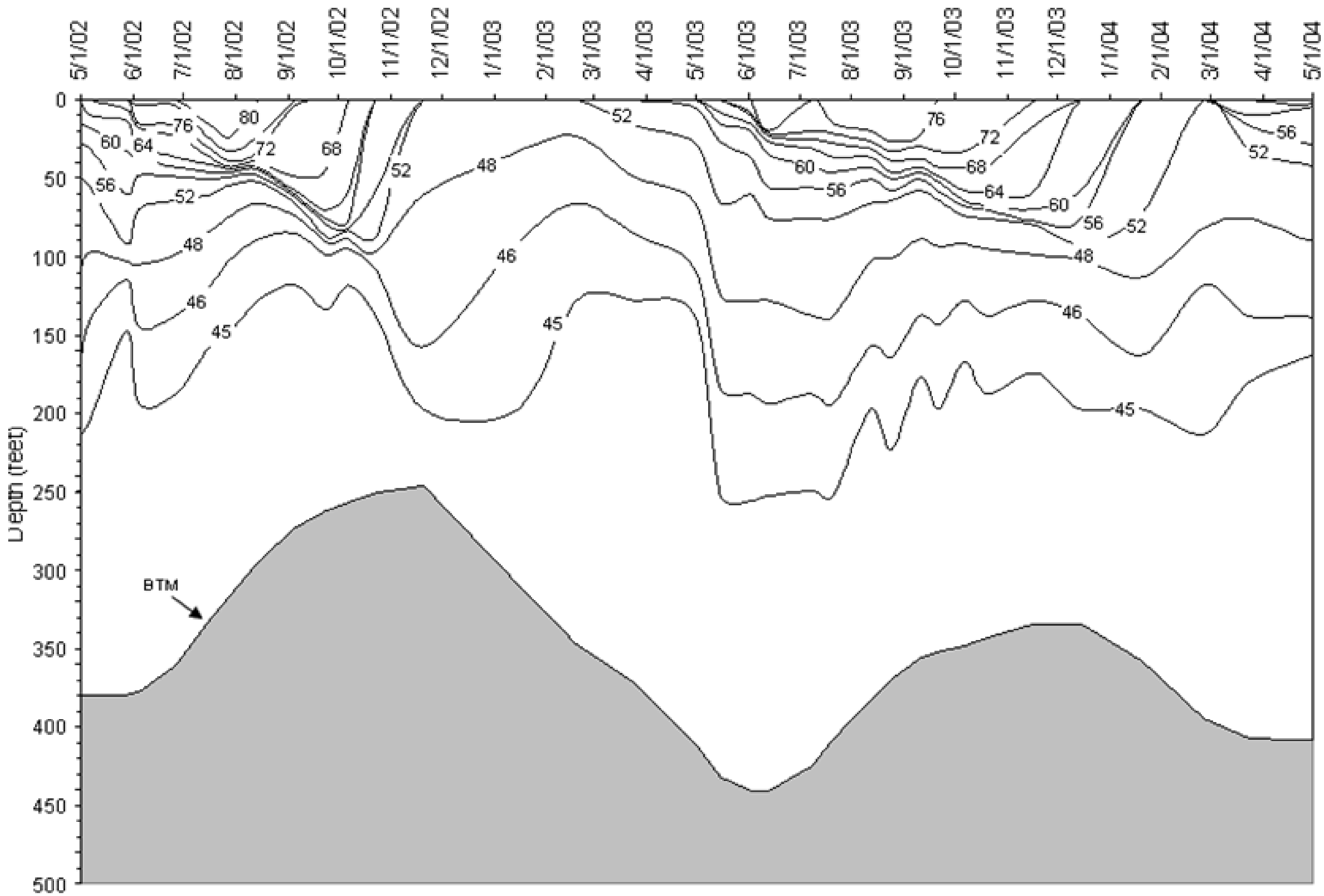




Appendix 2a. Isothermal variation and depth in the North Fork Arm of Lake Oroville.

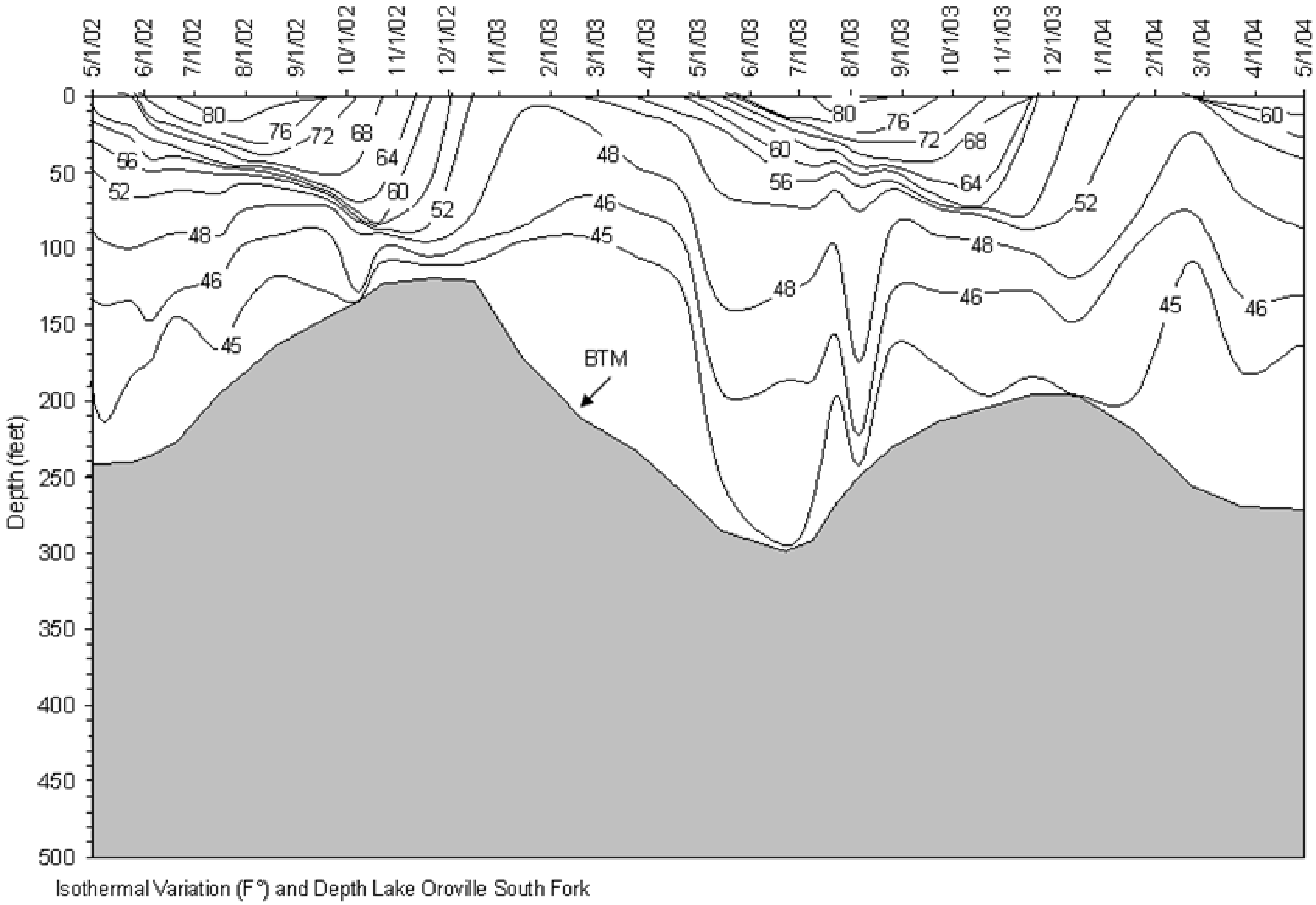


Appendix 2b. Isothermal variation and depth in the Middle Fork Arm of Lake Oroville.

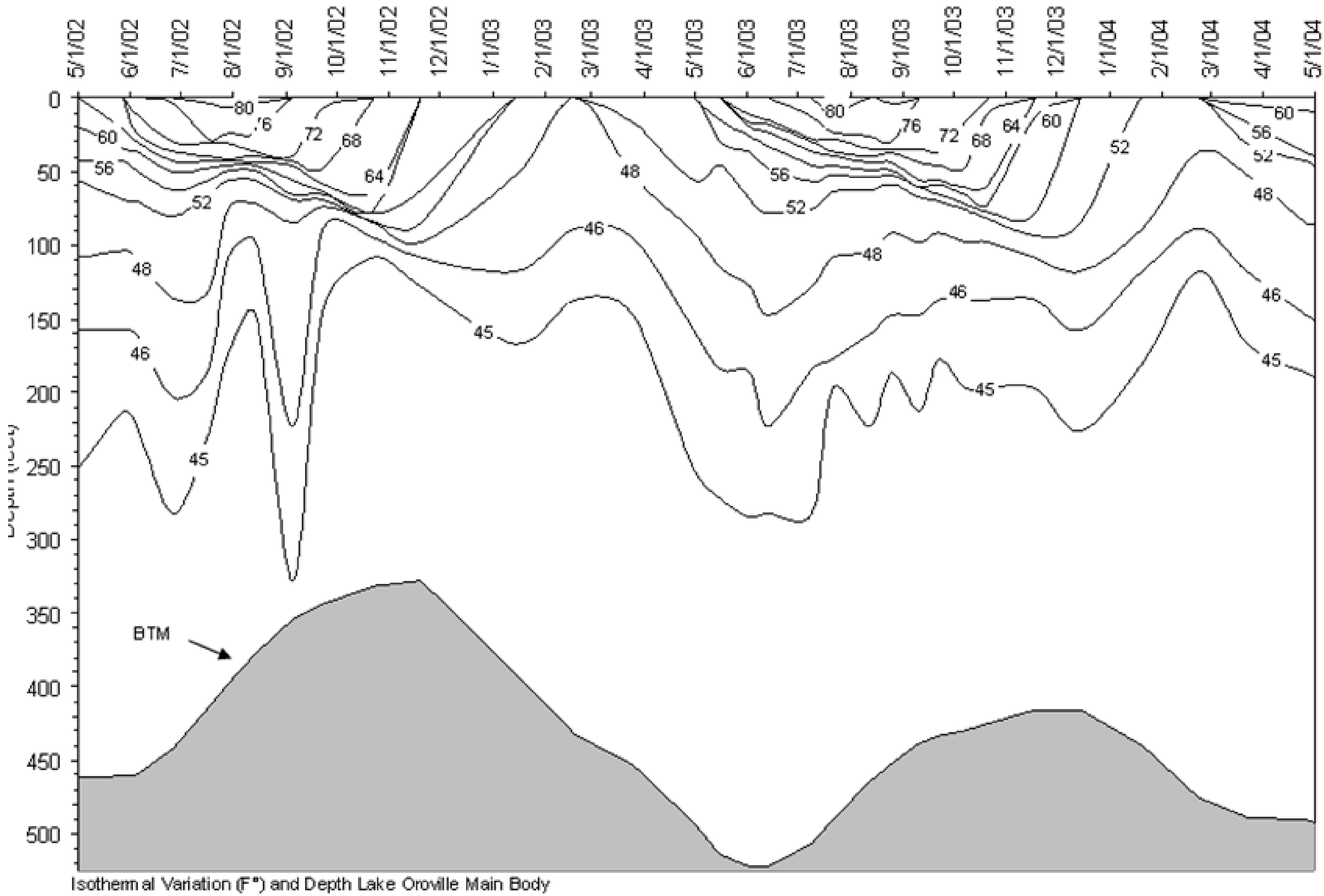


Isothermal Variation (F°) and Depth Lake Oroville Middle Fork

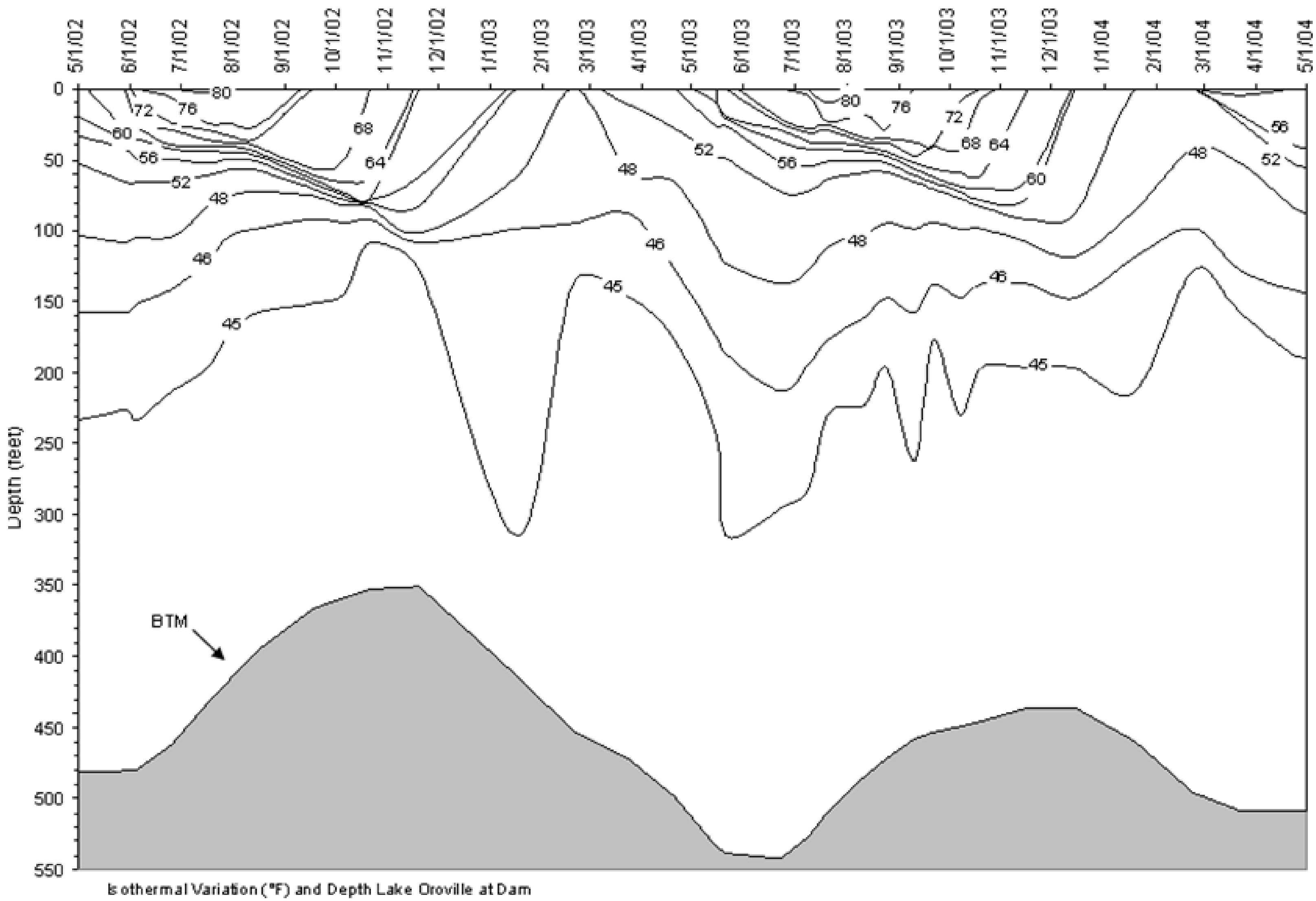
Appendix 2c. Isothermal variation and depth in the South Fork Arm of Lake Oroville.



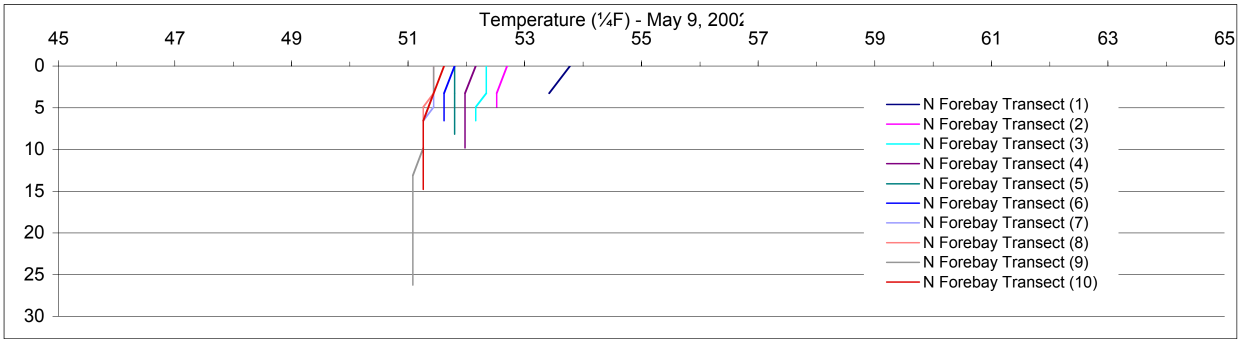
Appendix 2d. Isothermal variation and depth in the Main Body of Lake Oroville.

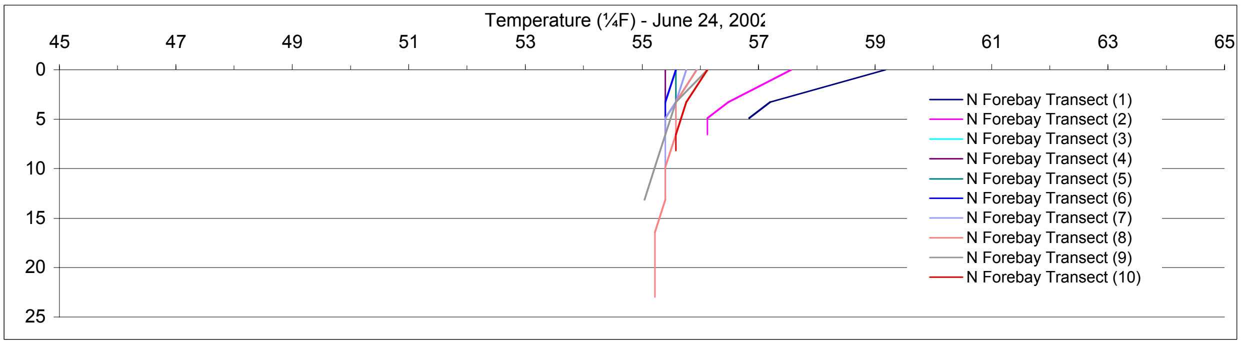


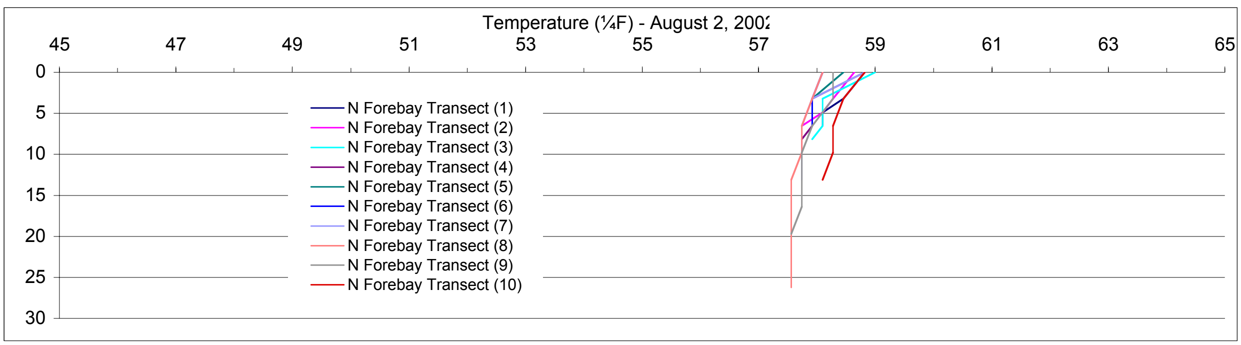
Appendix 2e. Isothermal variation and depth near the dam of Lake Oroville.

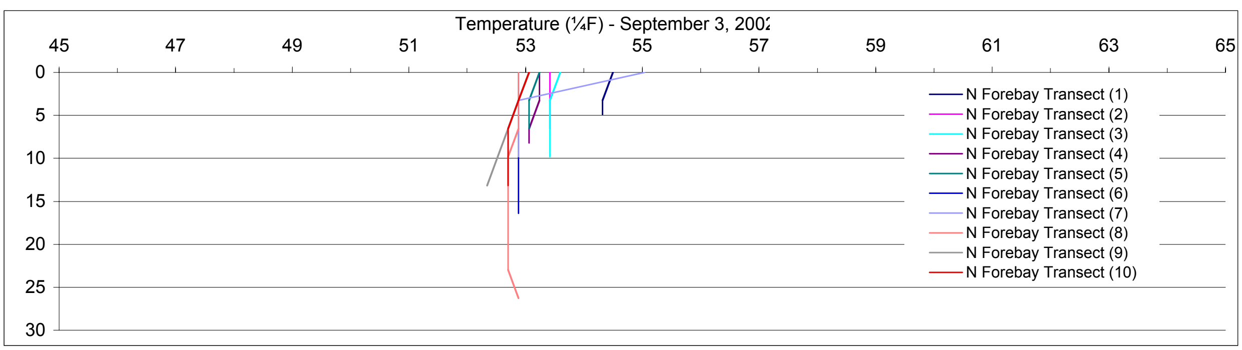


Appendix 3a. Water temperatures along transects in the North Thermalito Forebay.









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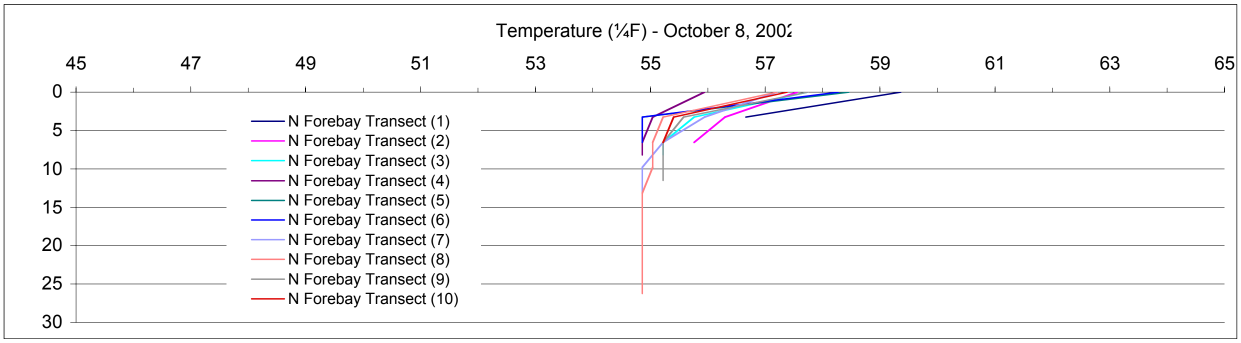

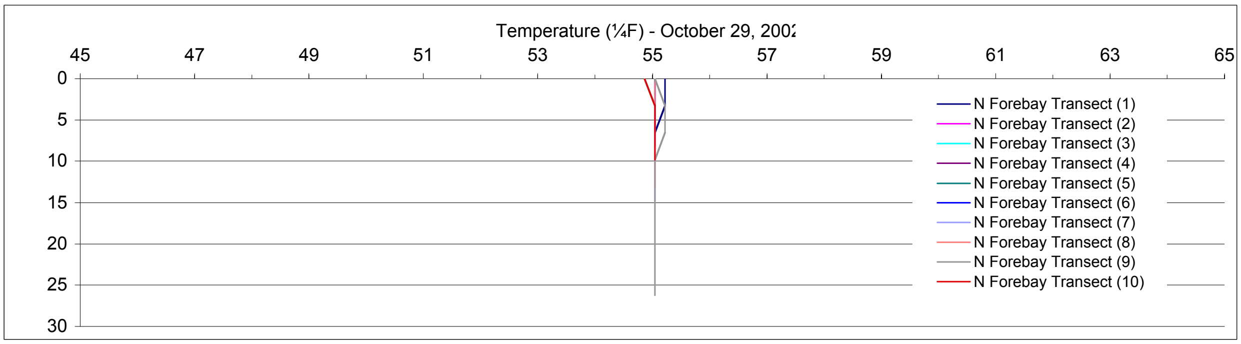

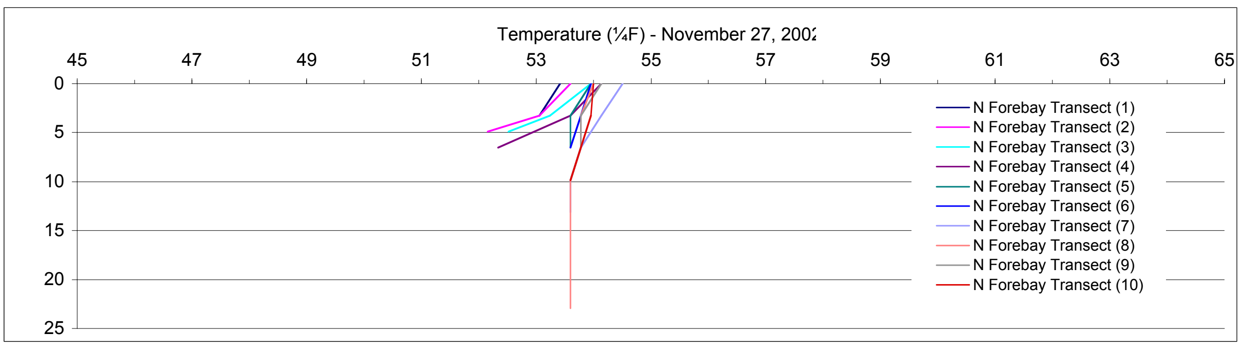

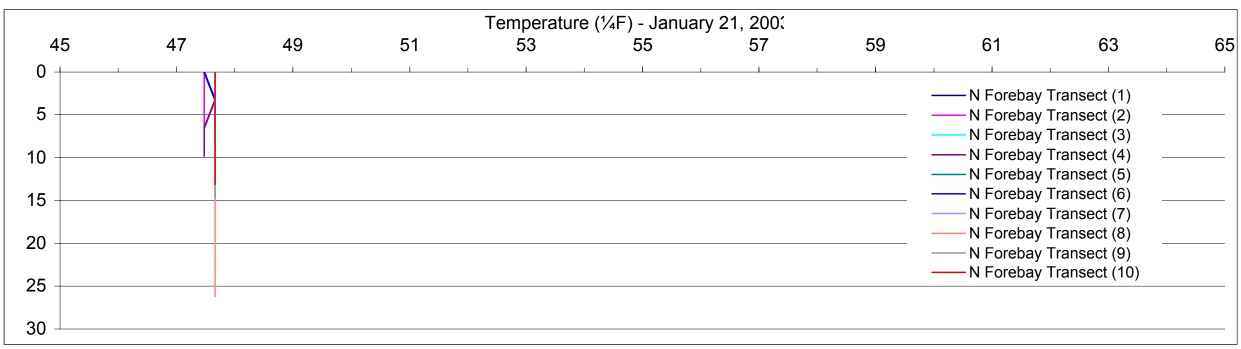

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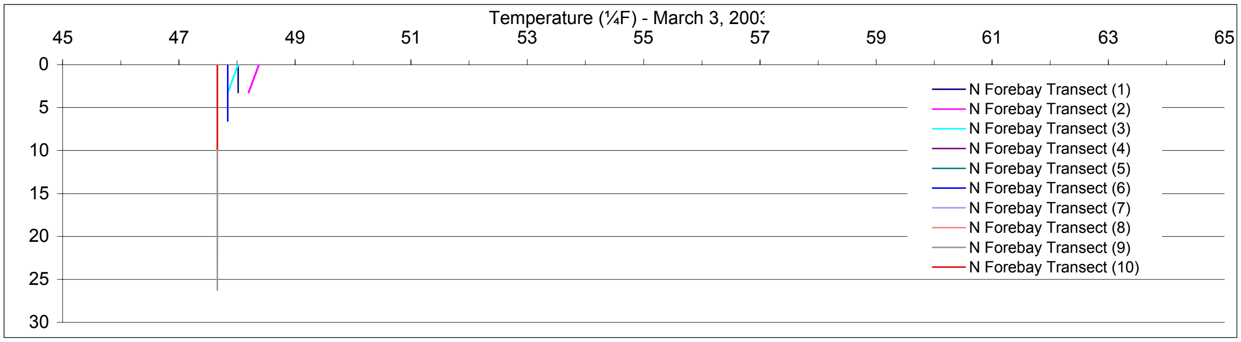
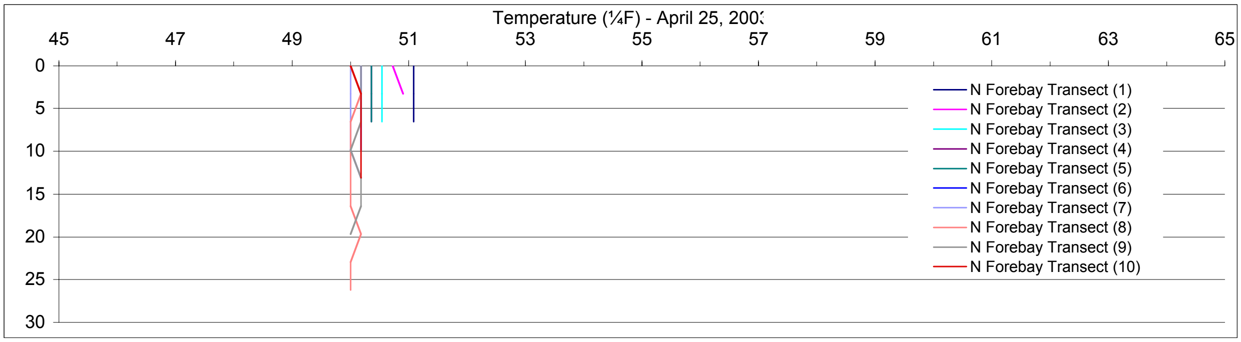
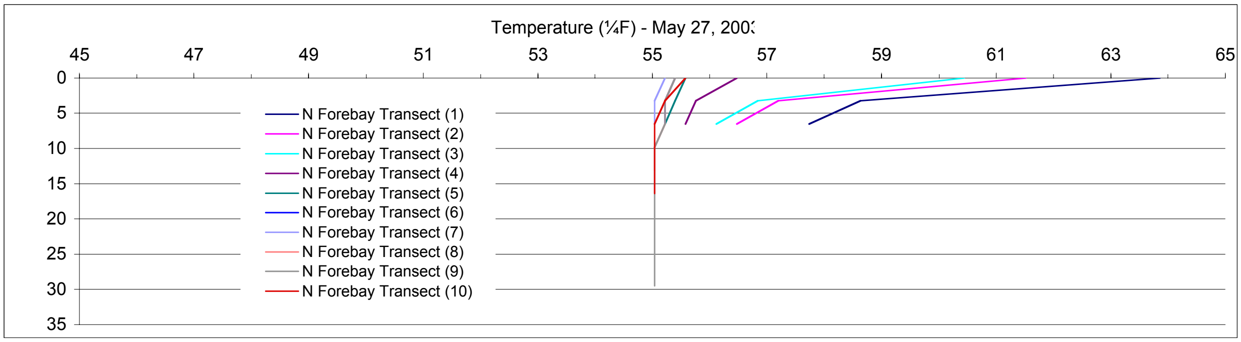
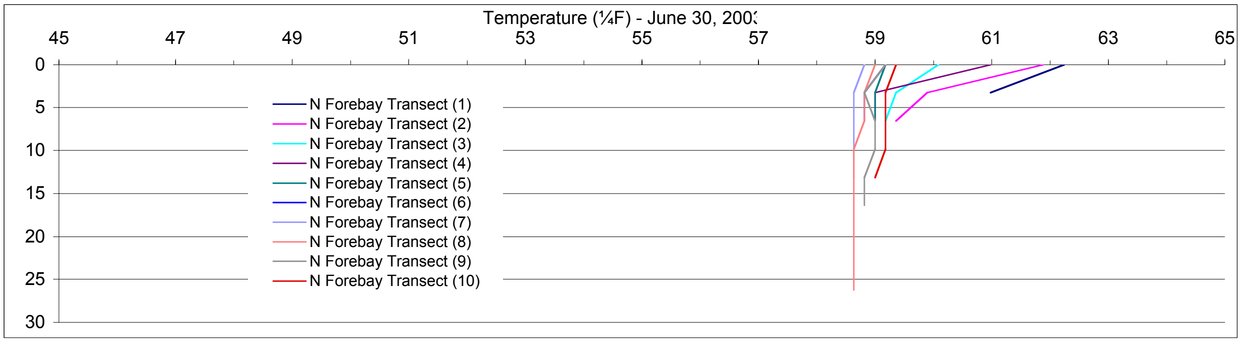
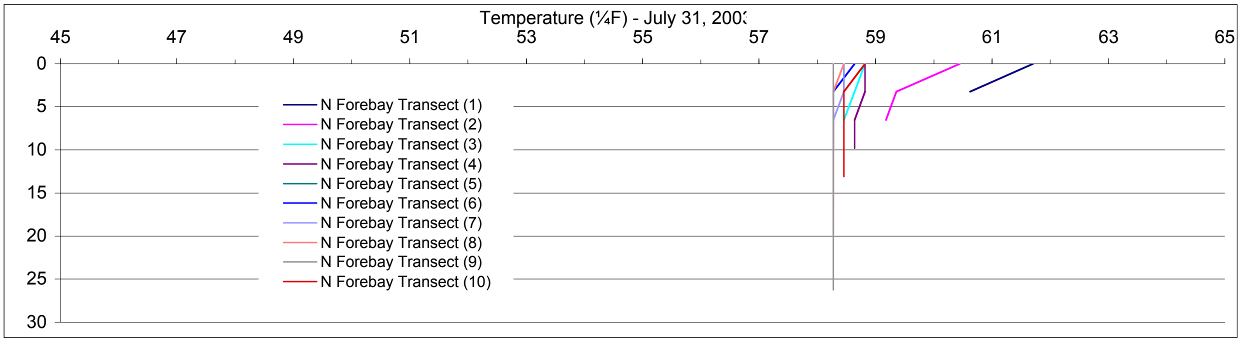


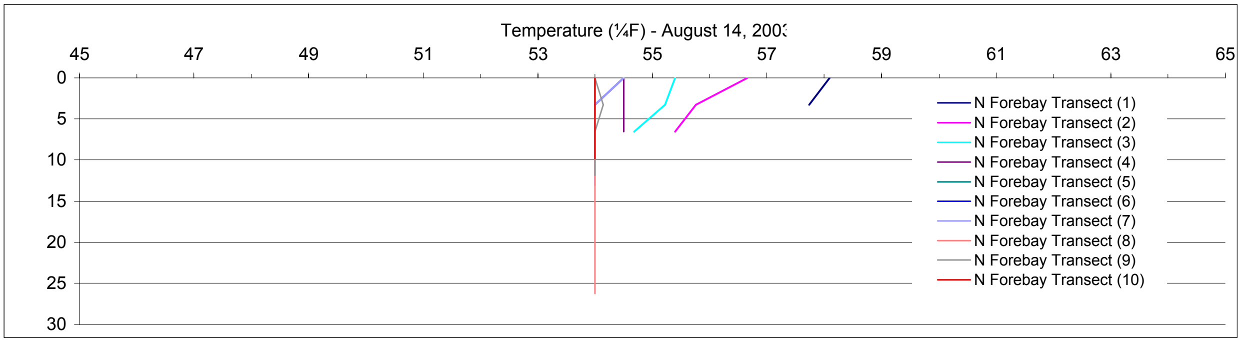


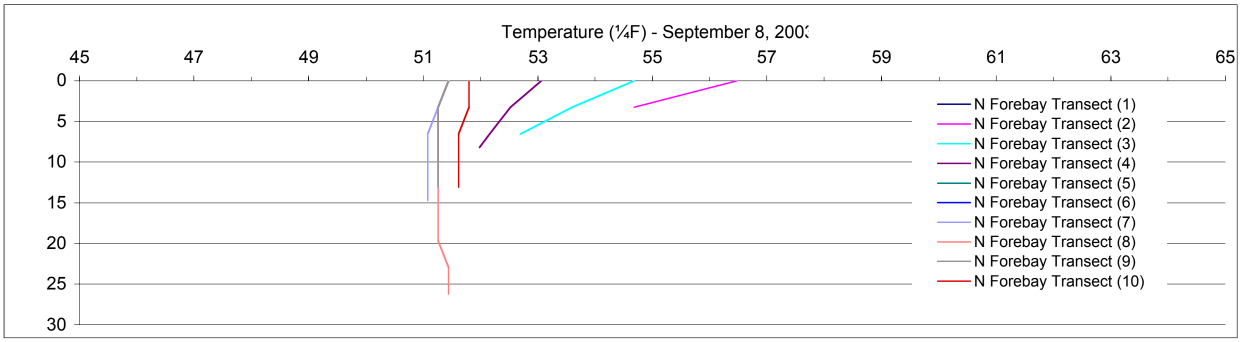


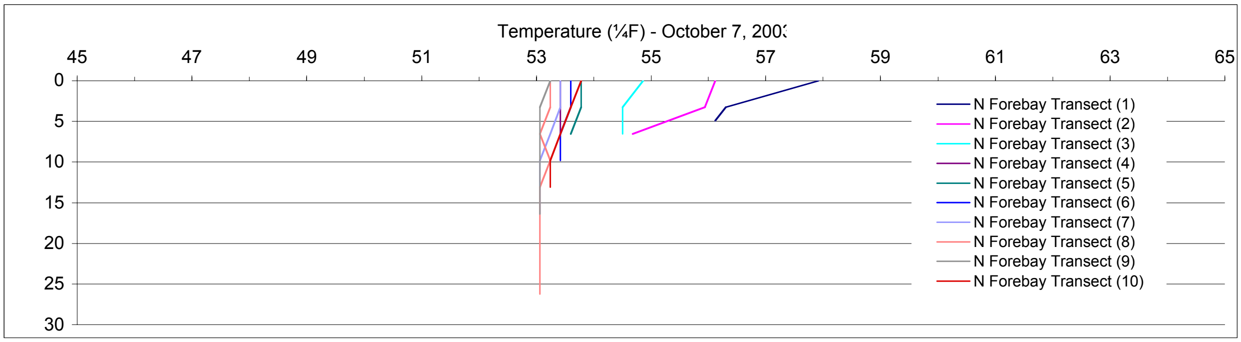


Appendix 3a. Continued.

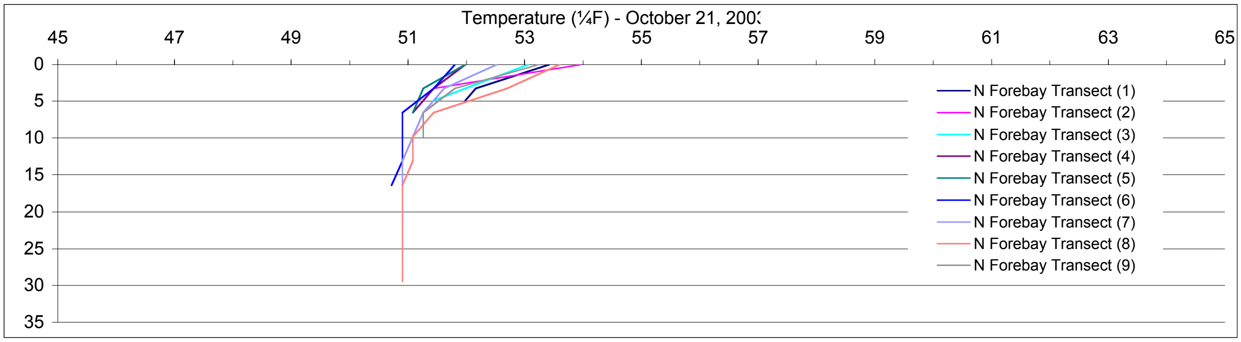


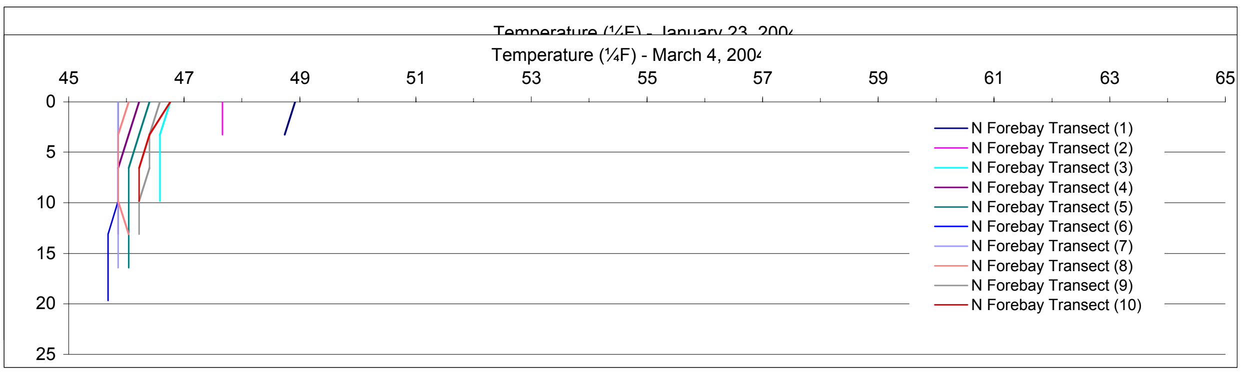


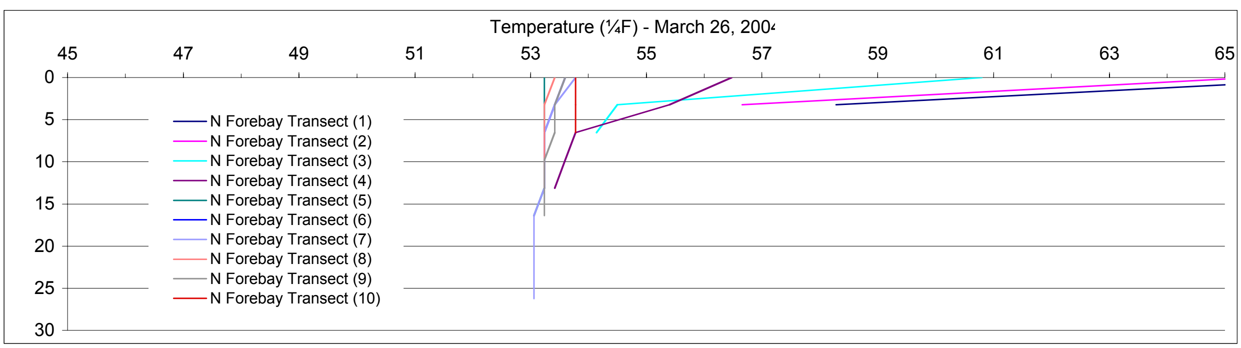




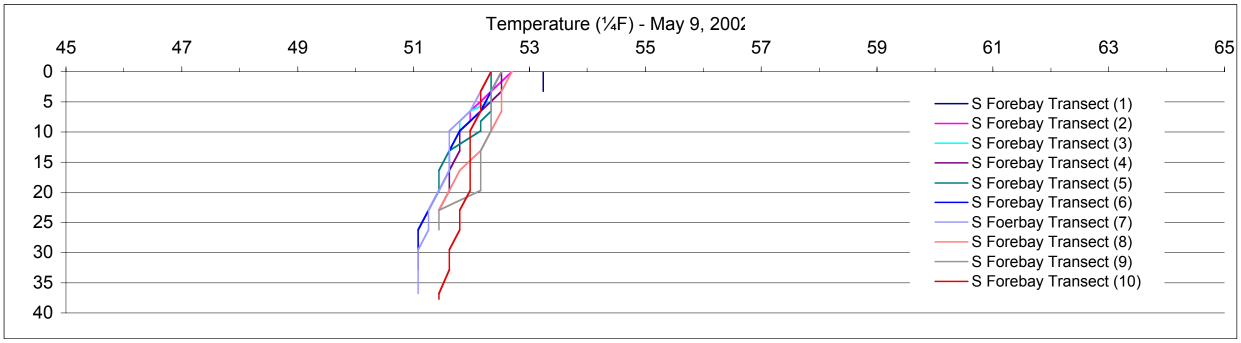
Appendix 3a. Continued.

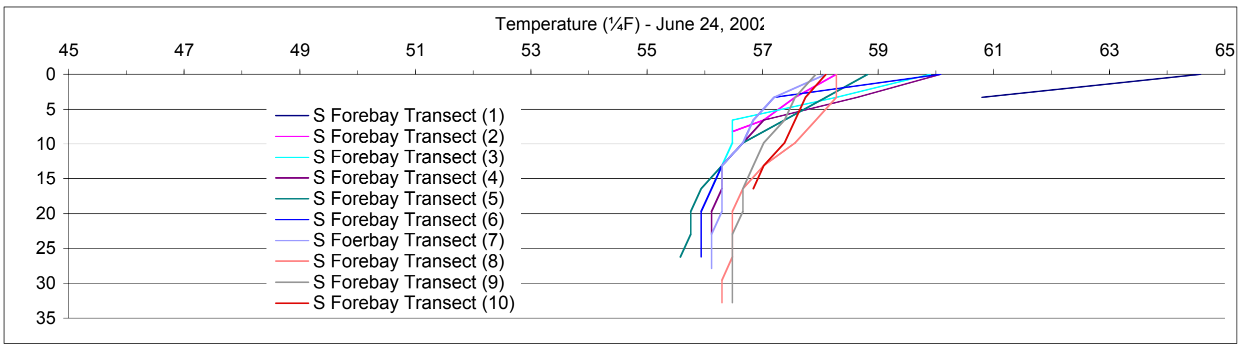


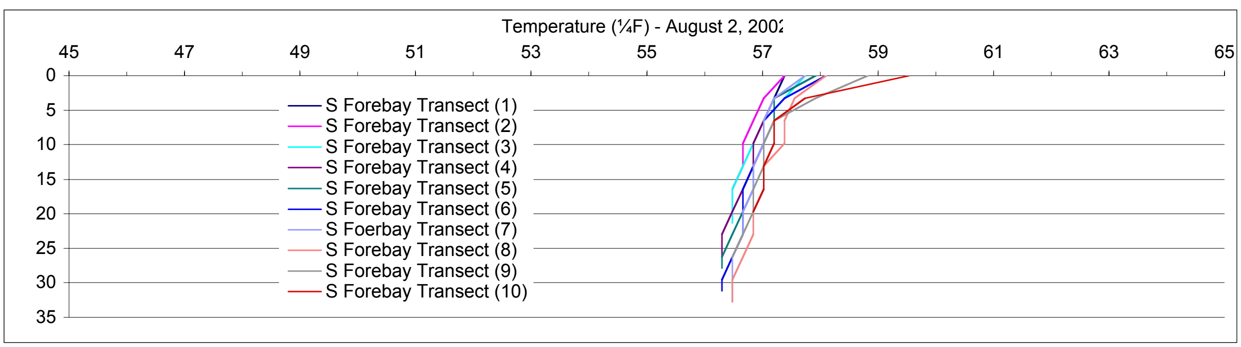


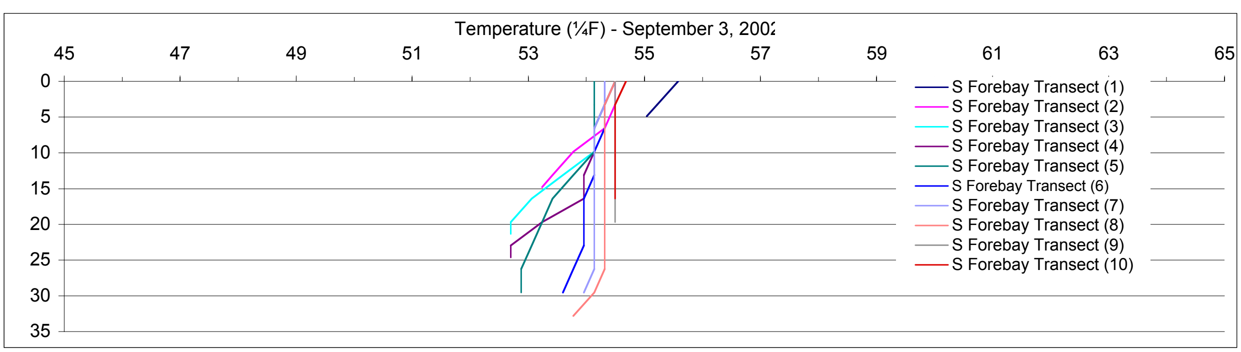


Appendix 3b. Water temperatures along transects in the South Thermalito Forebay.









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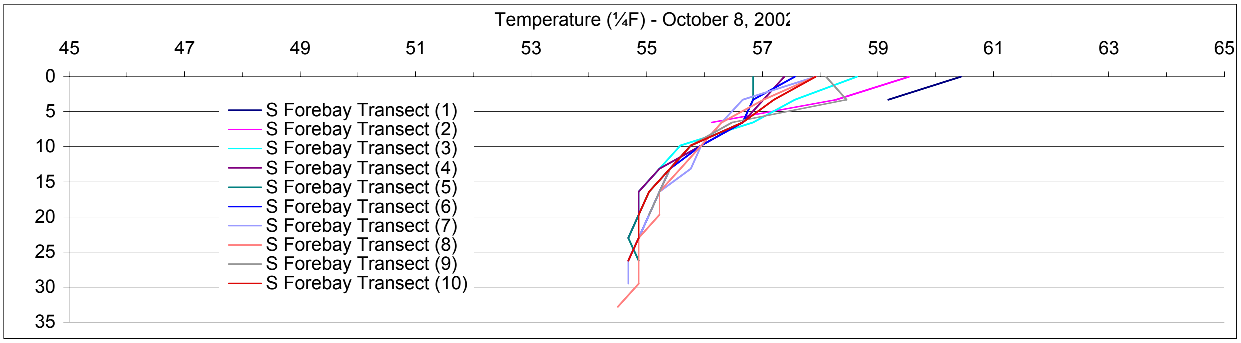

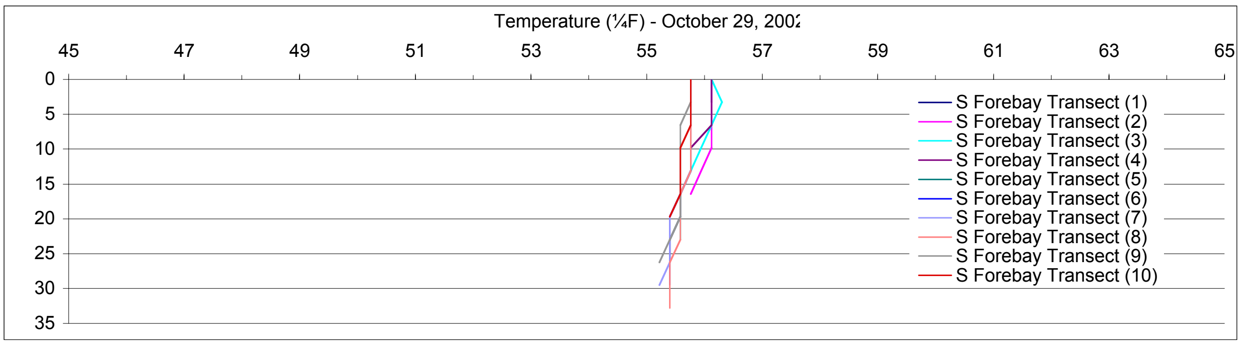

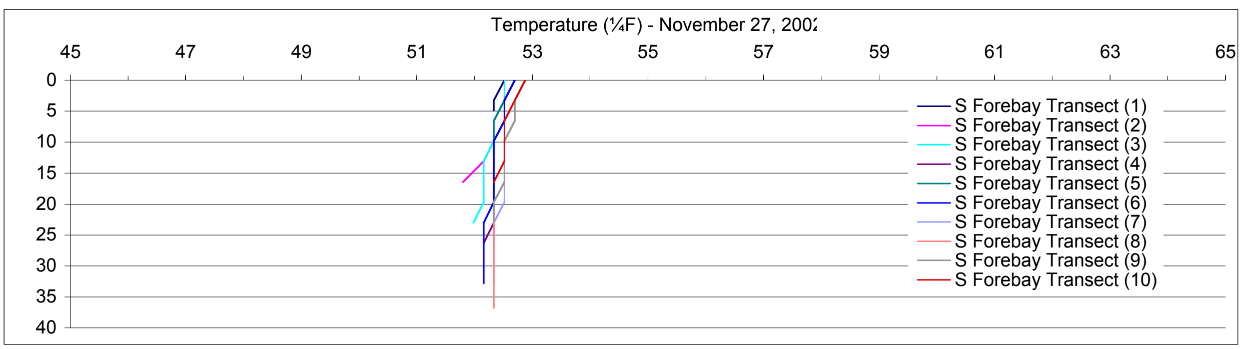

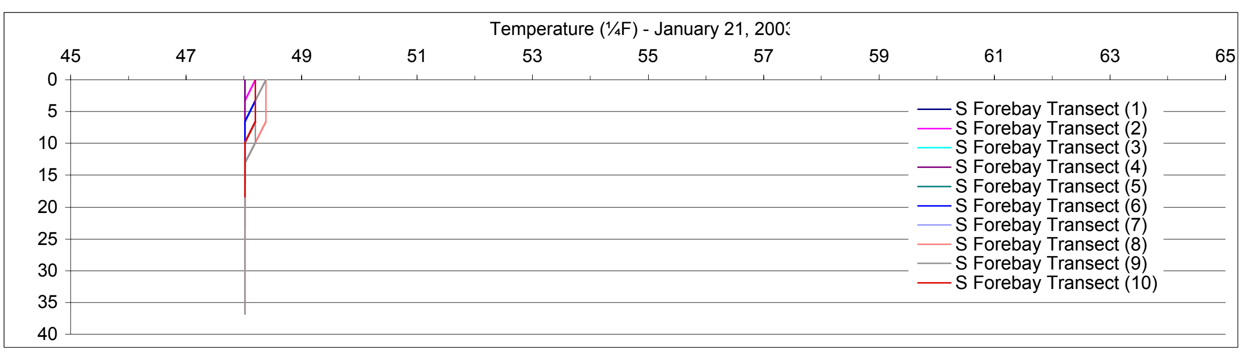

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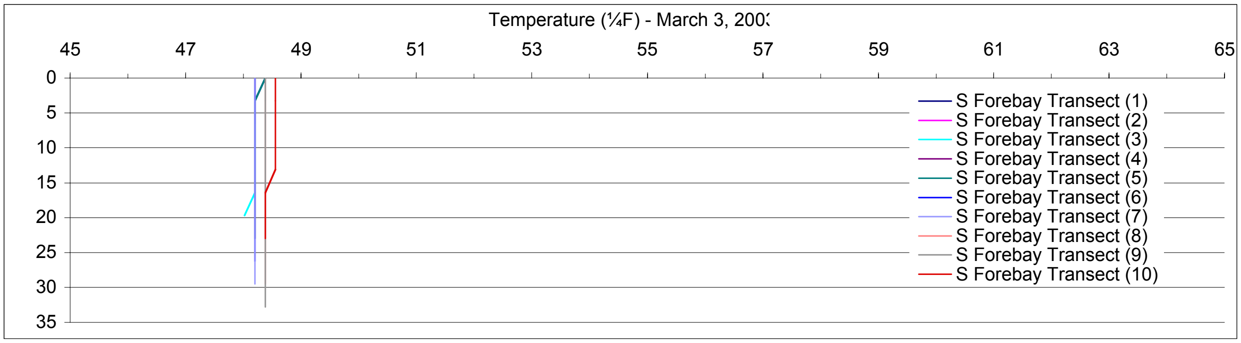

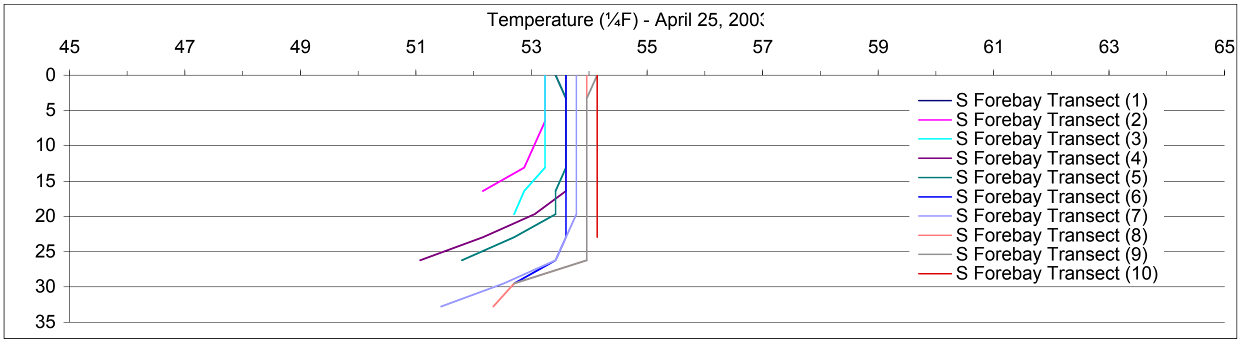

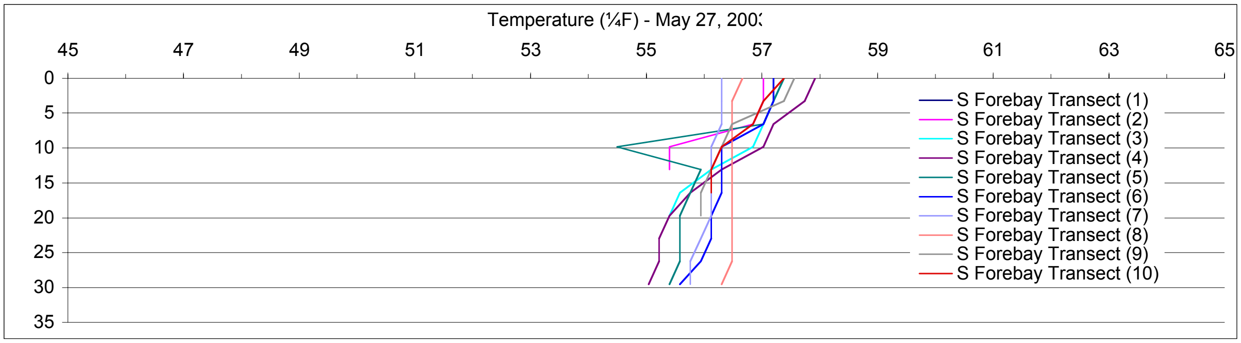

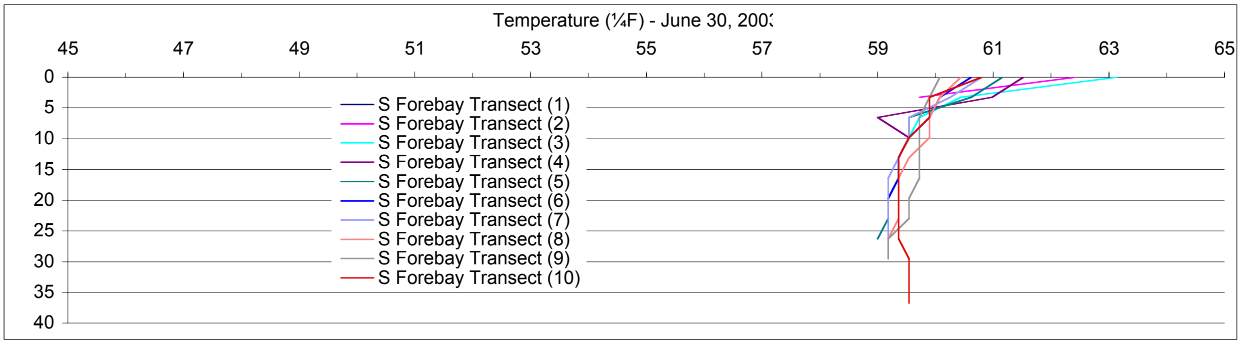

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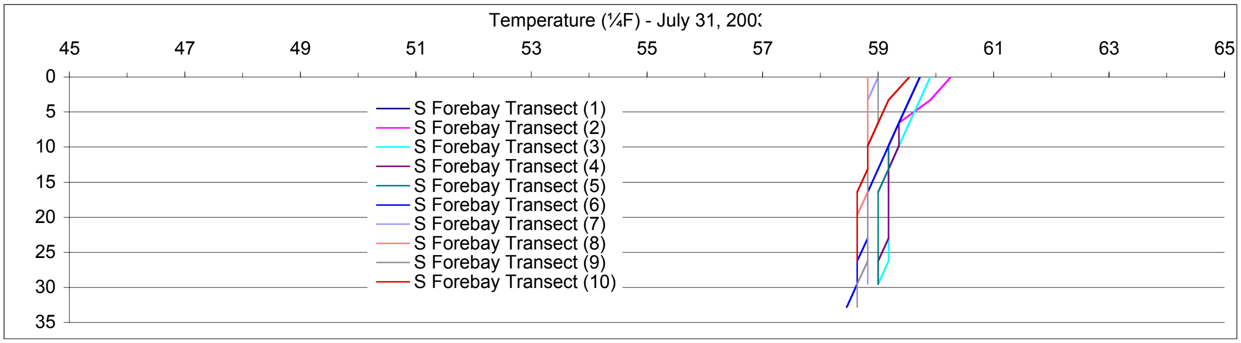

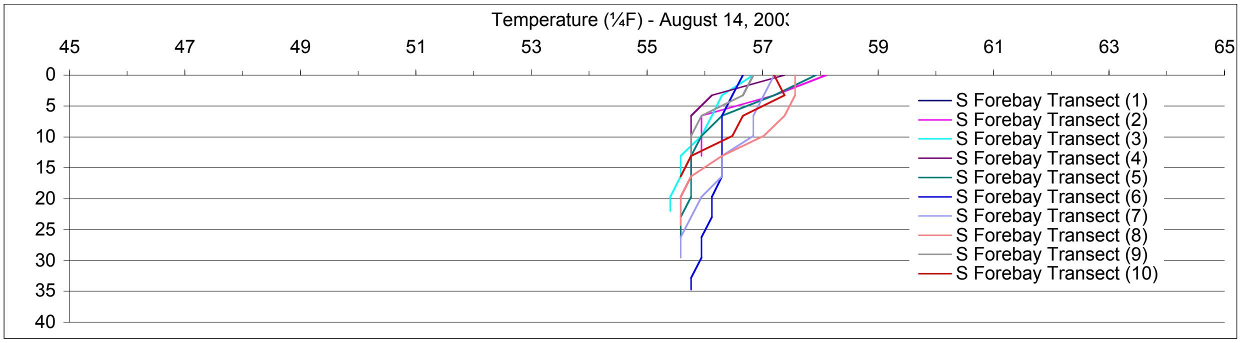

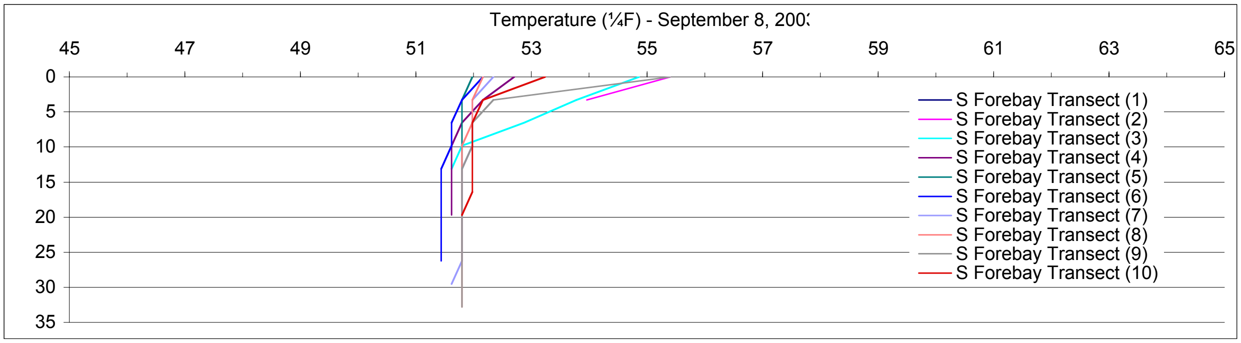

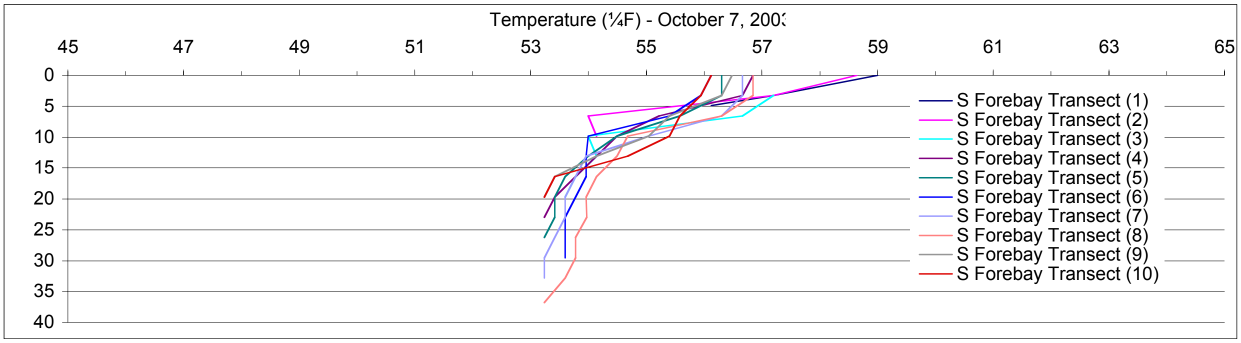

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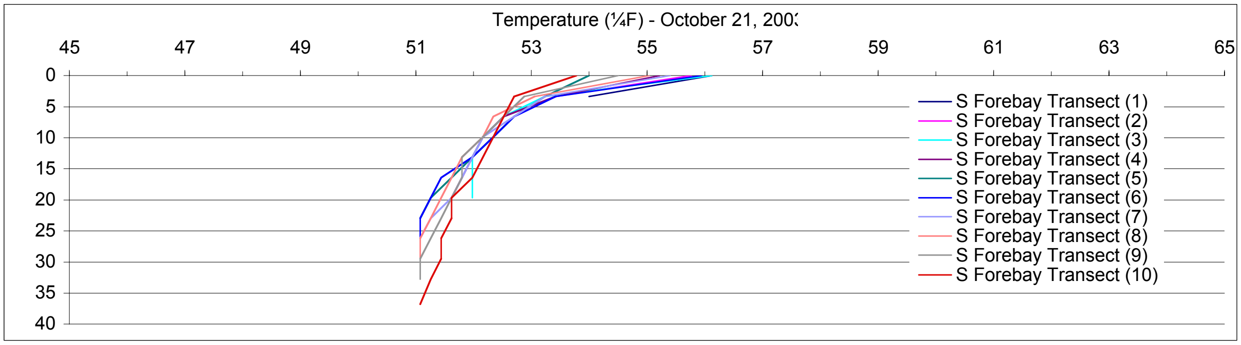
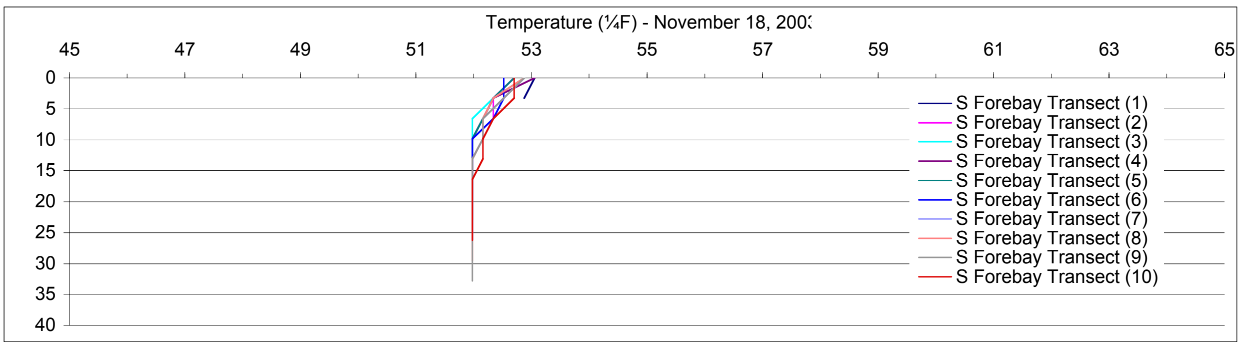
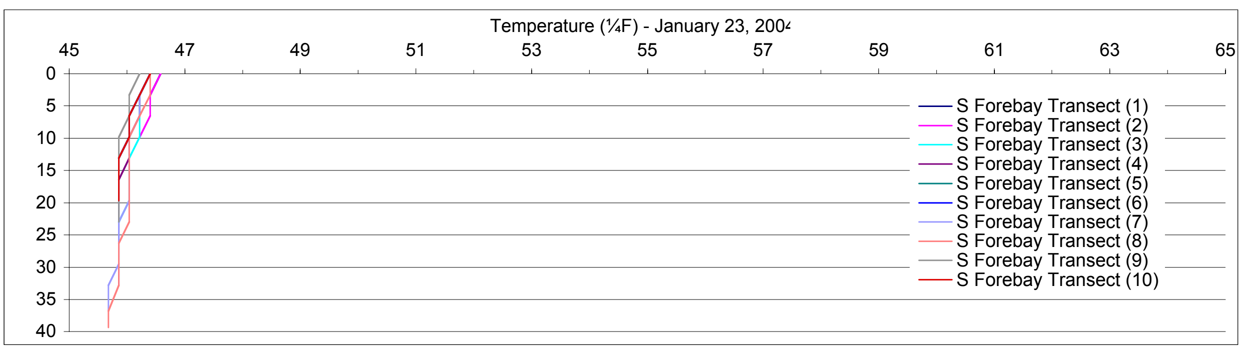
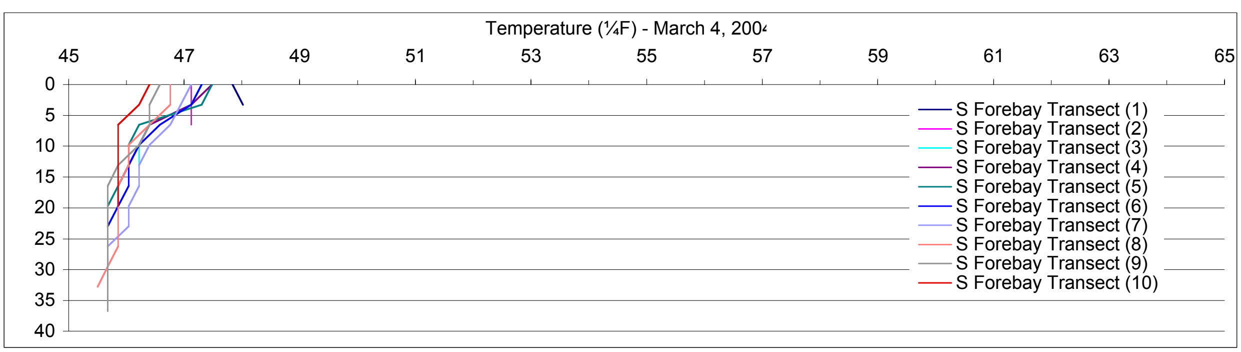
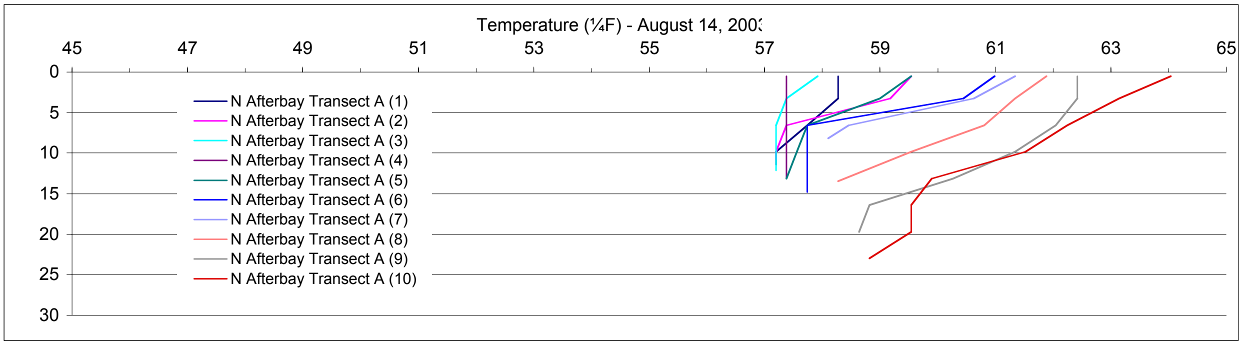


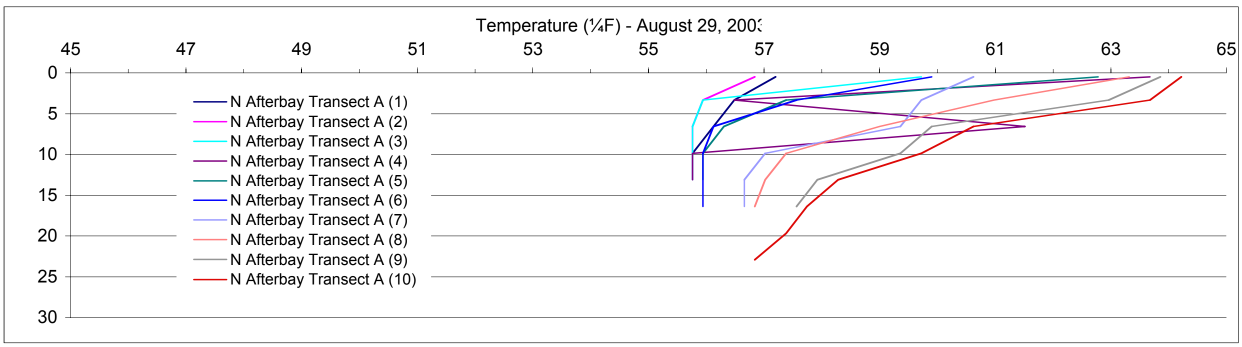


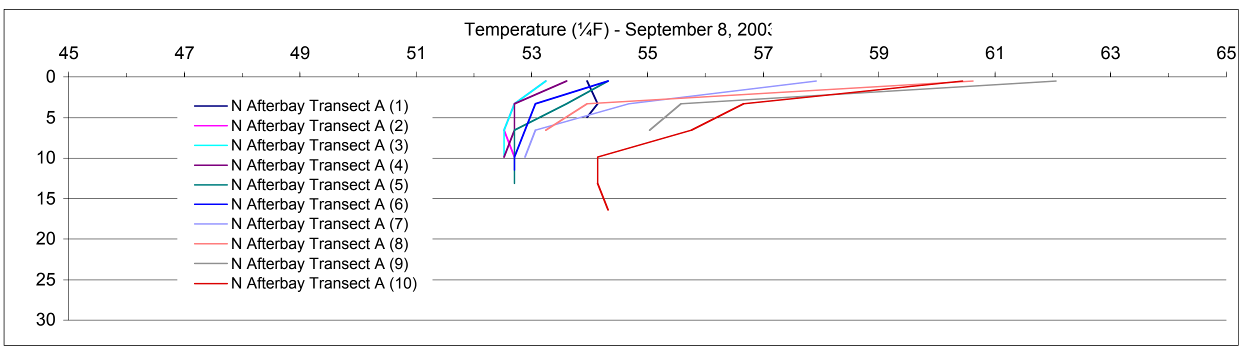


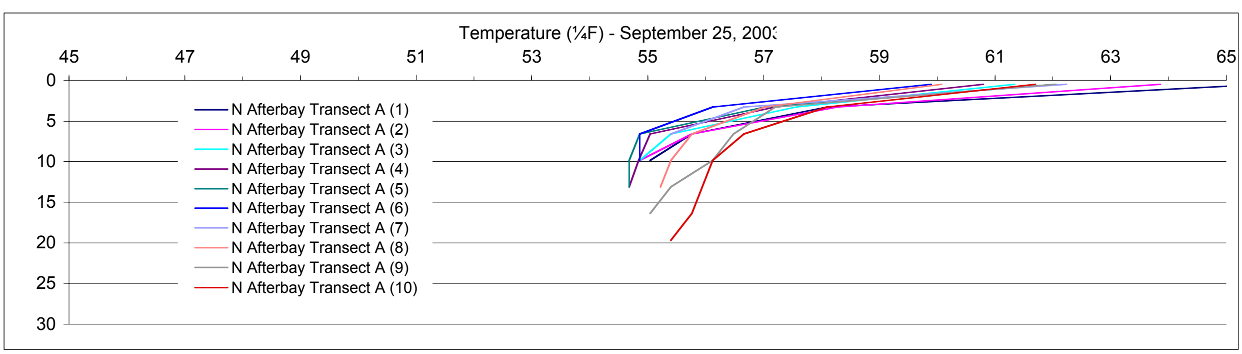


Appendix 4a. Water temperatures along Transect A in the North Thermalito Afterbay.









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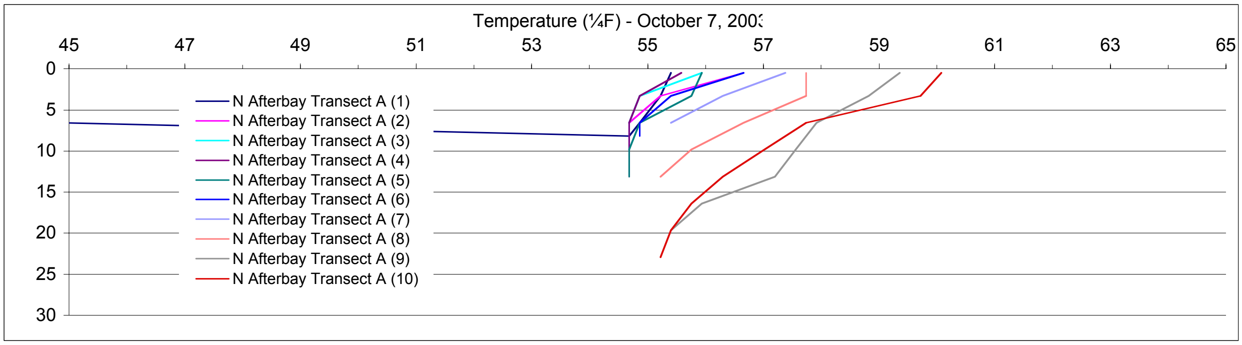

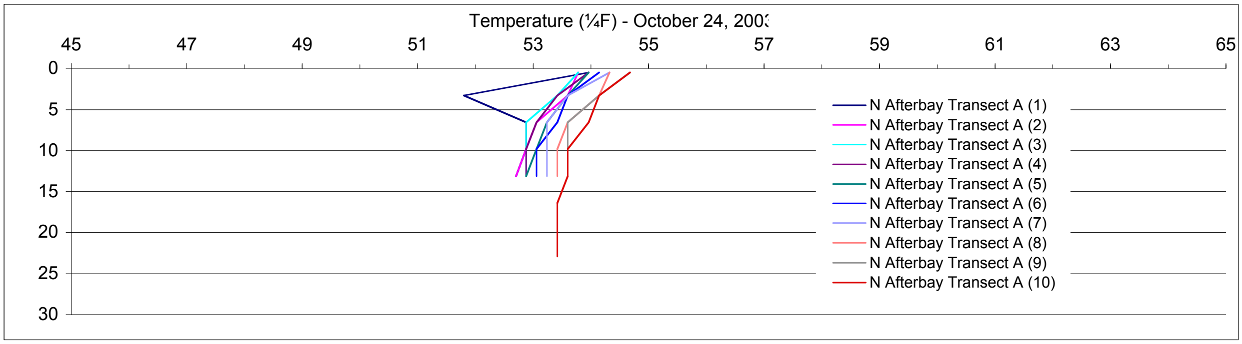

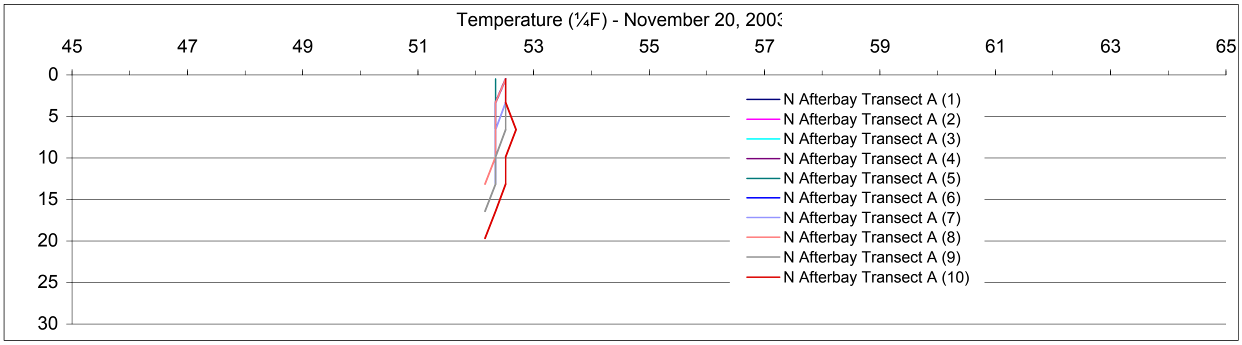

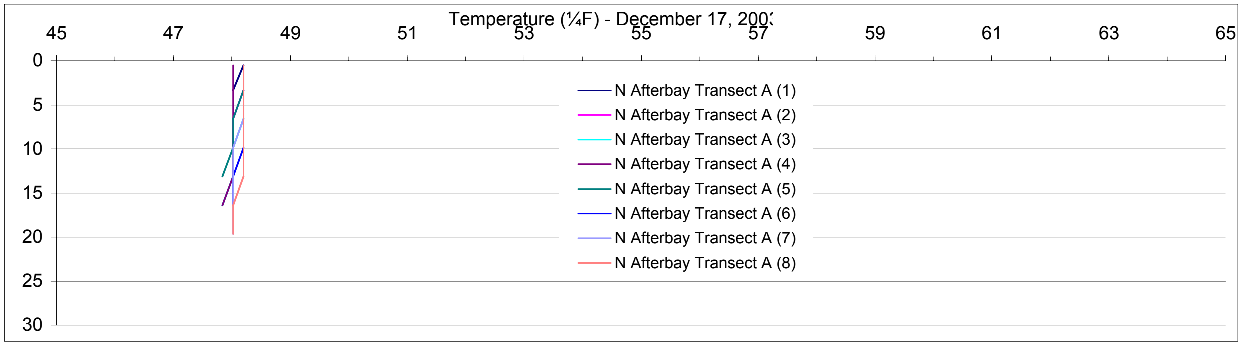

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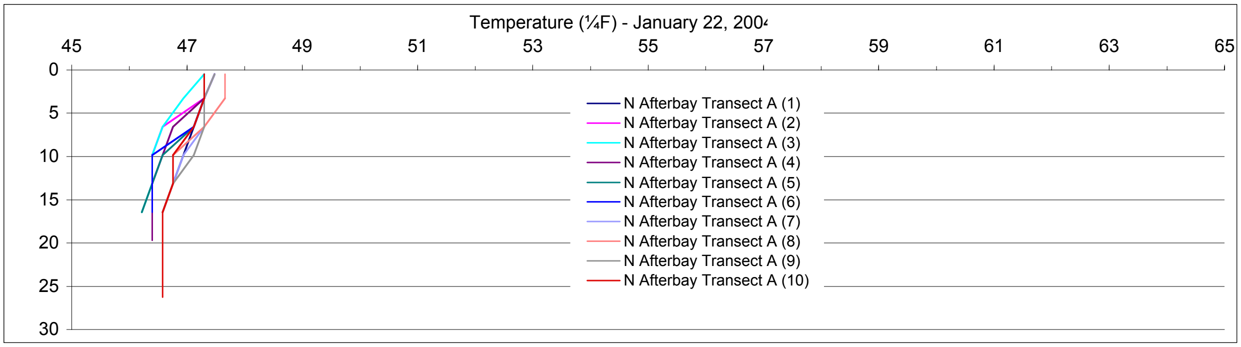
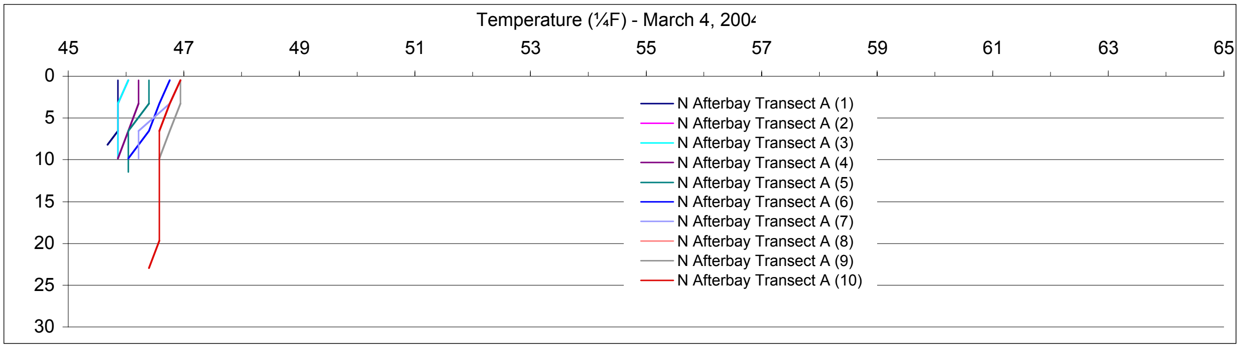
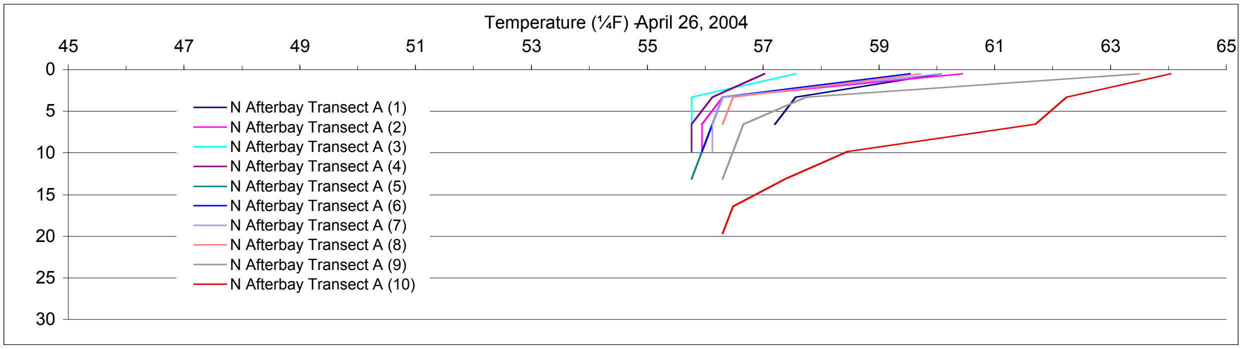
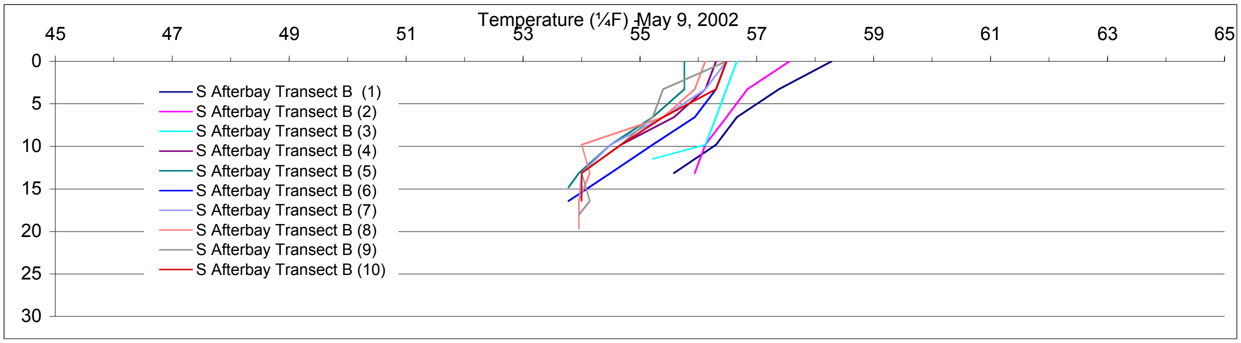
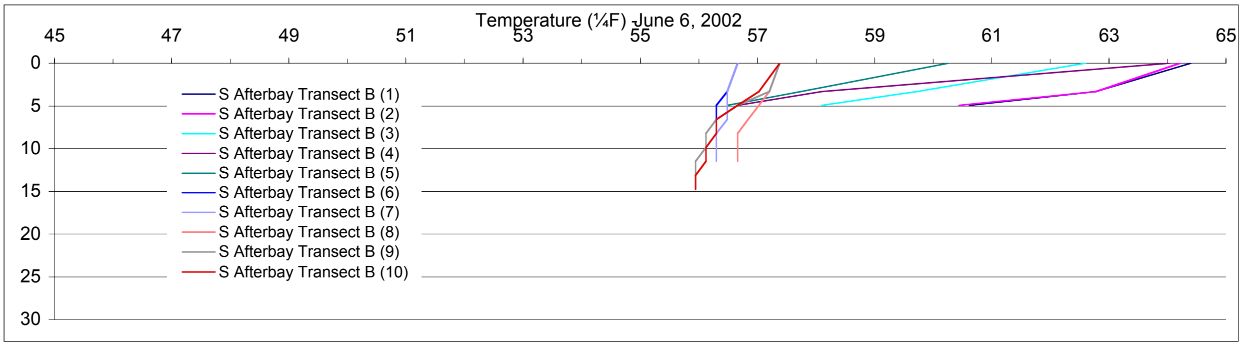


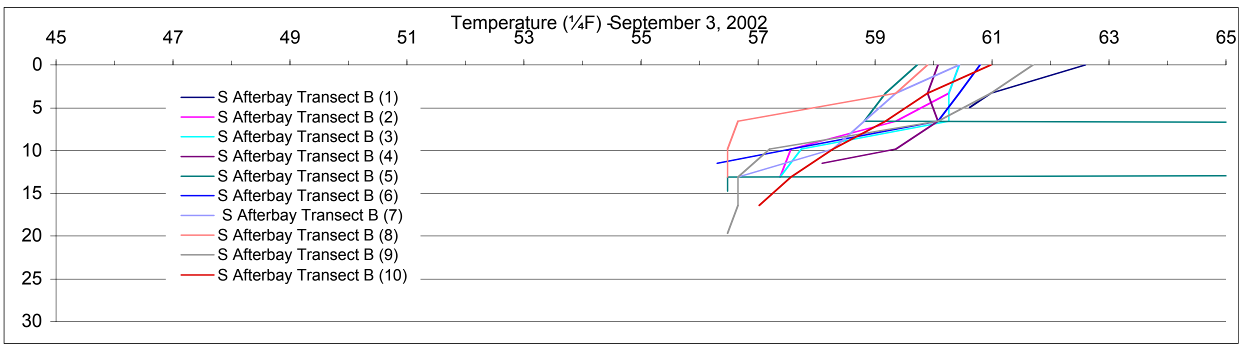


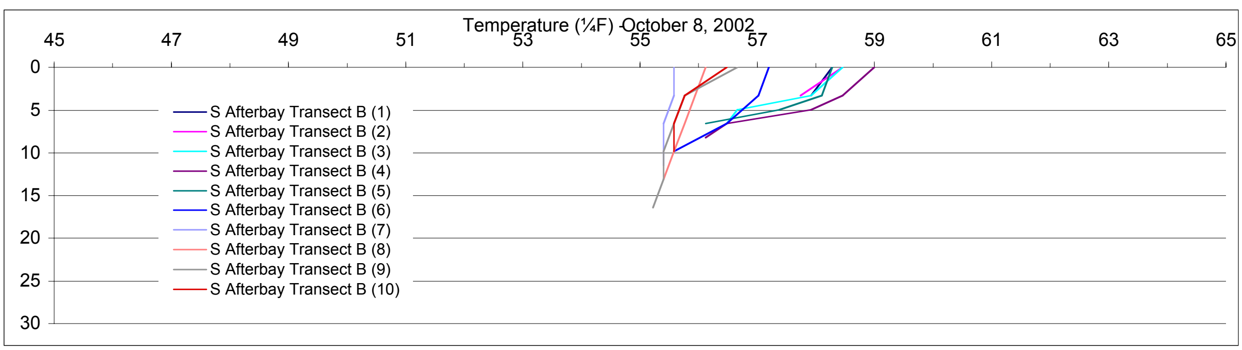


Appendix 4b. Water temperatures along Transect B in the South Thermalito Afterbay.









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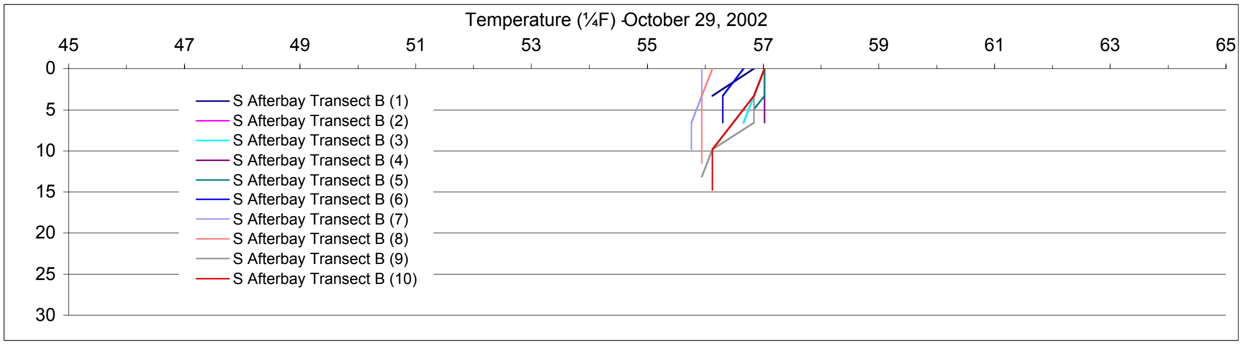

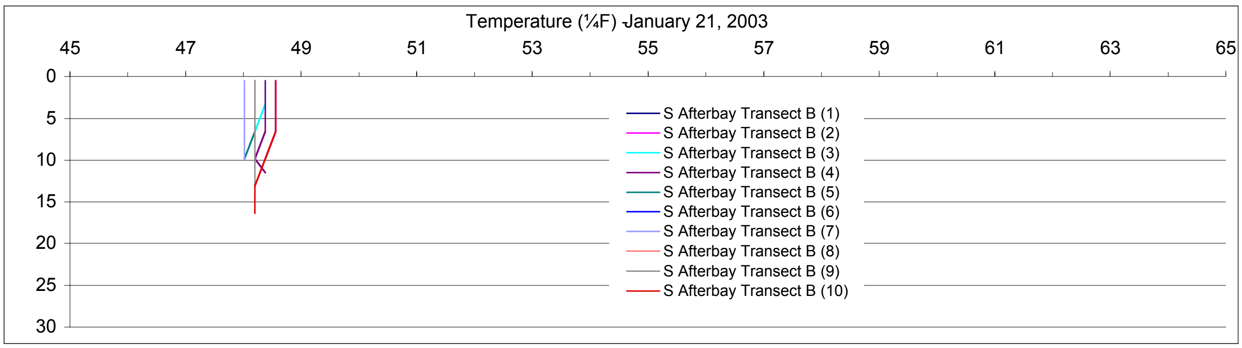

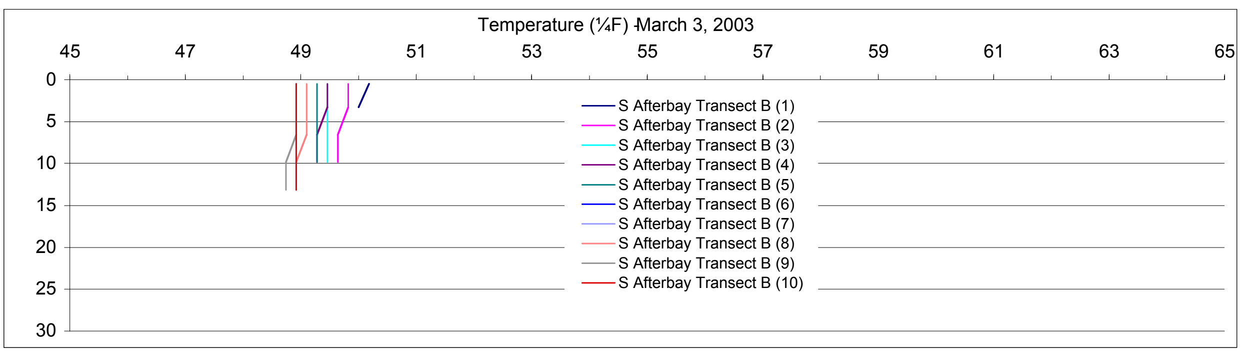

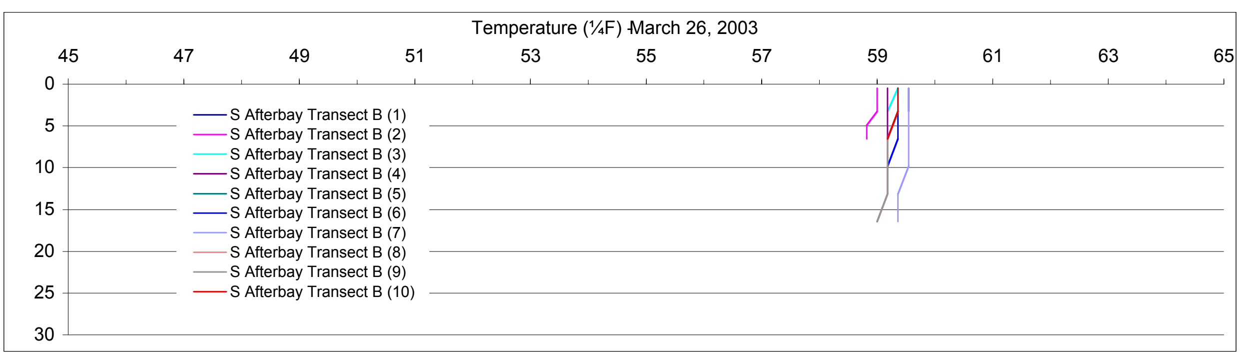

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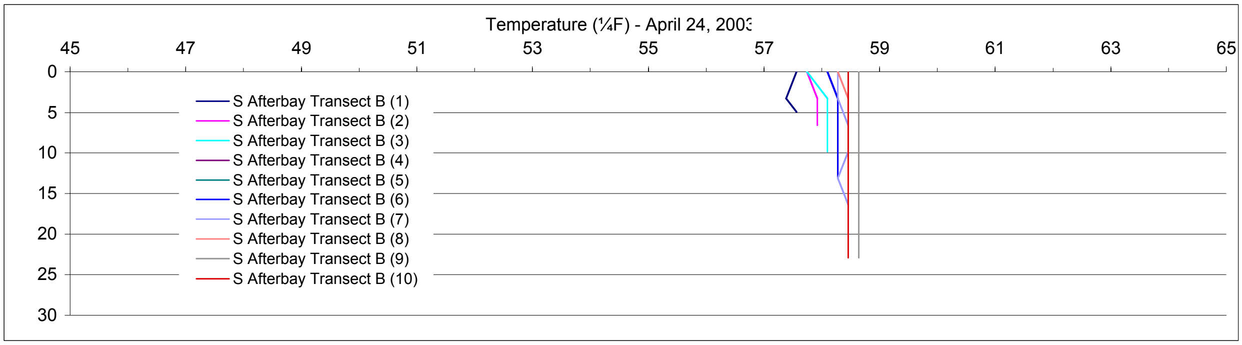

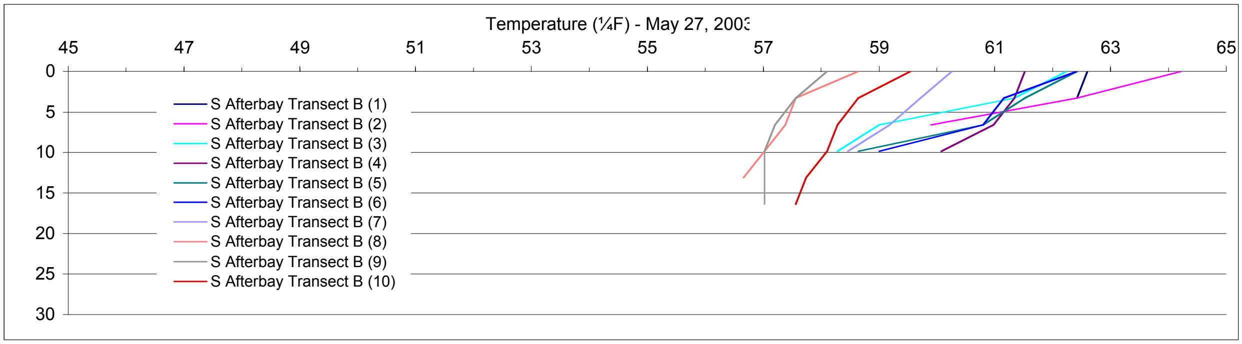

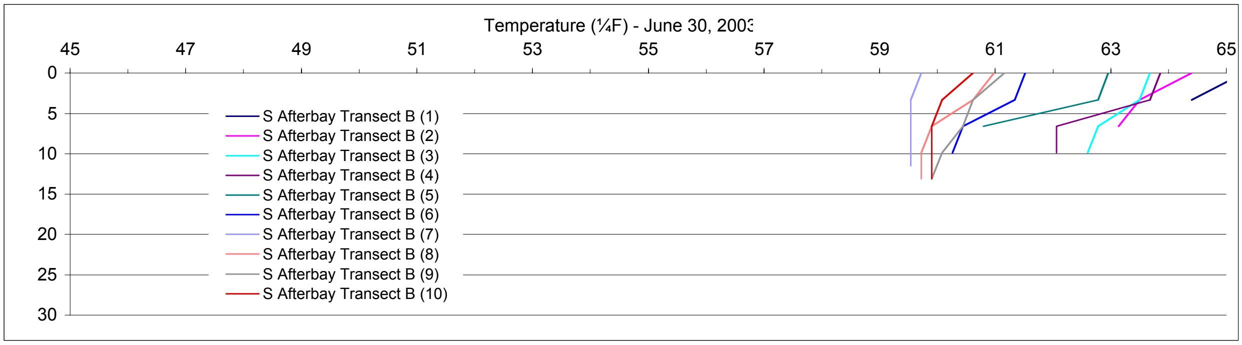

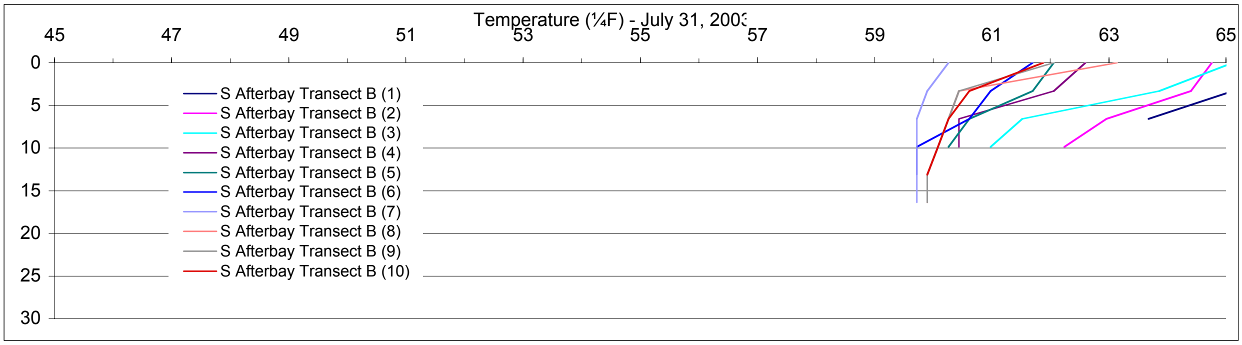

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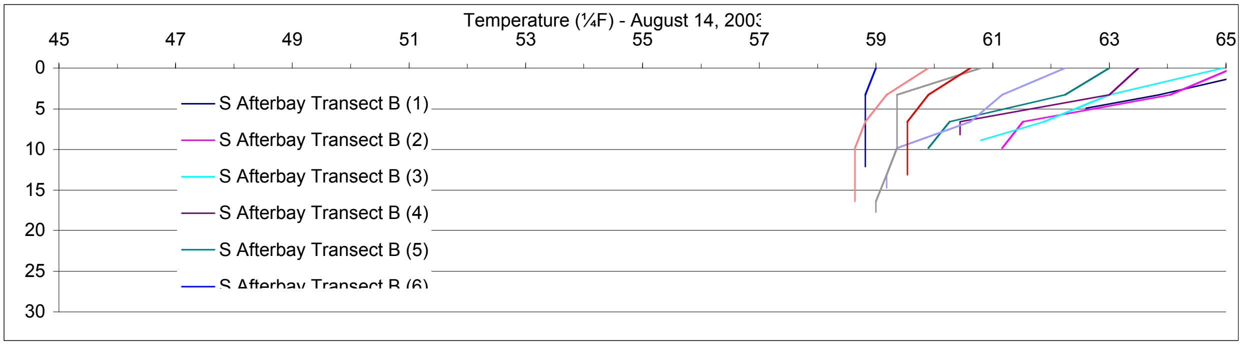

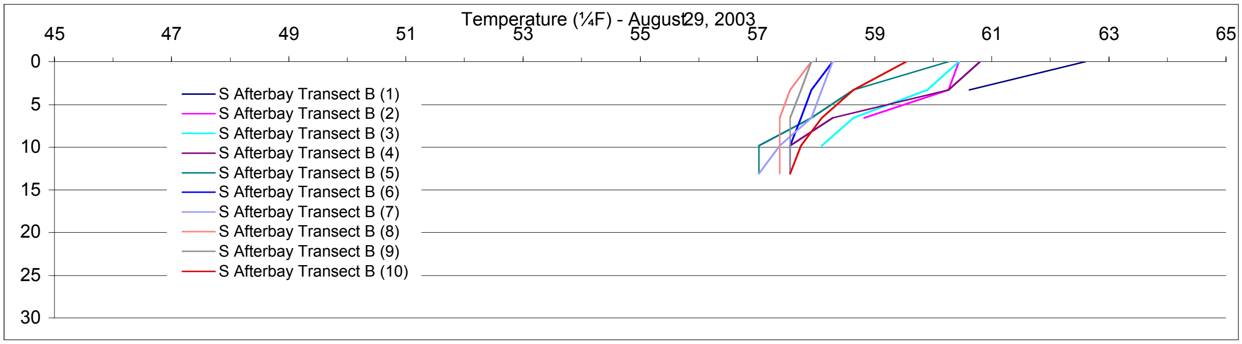

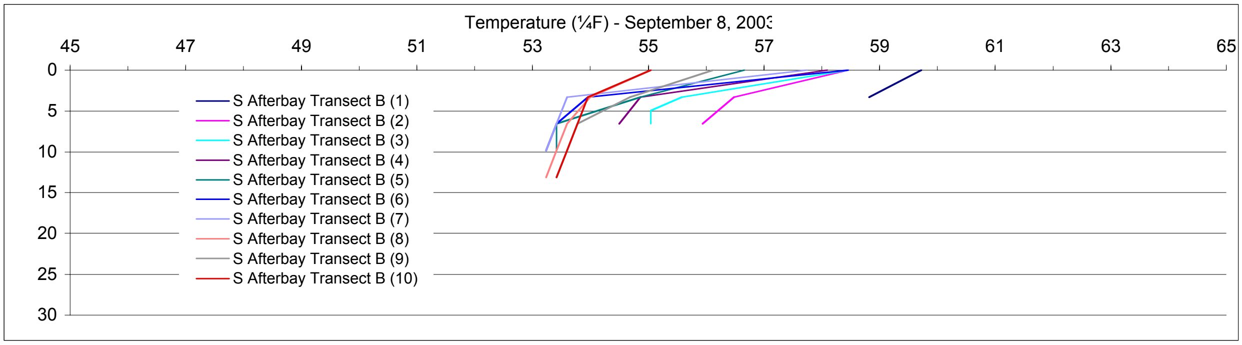

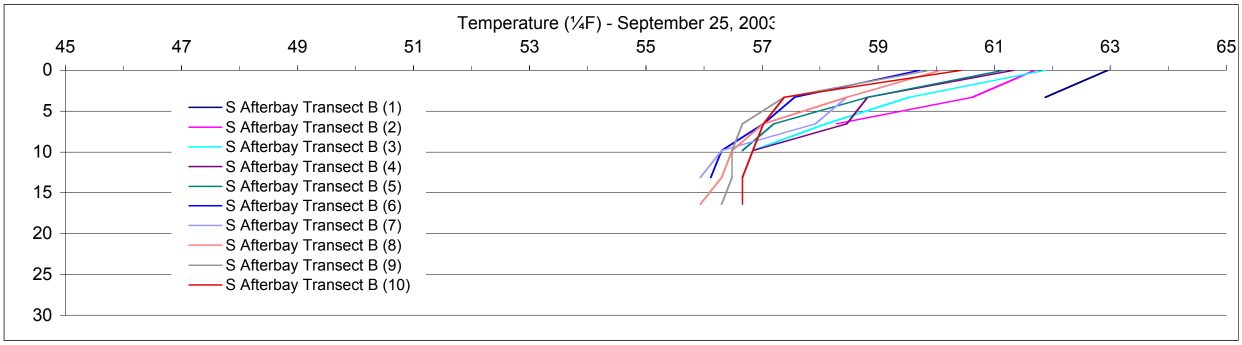

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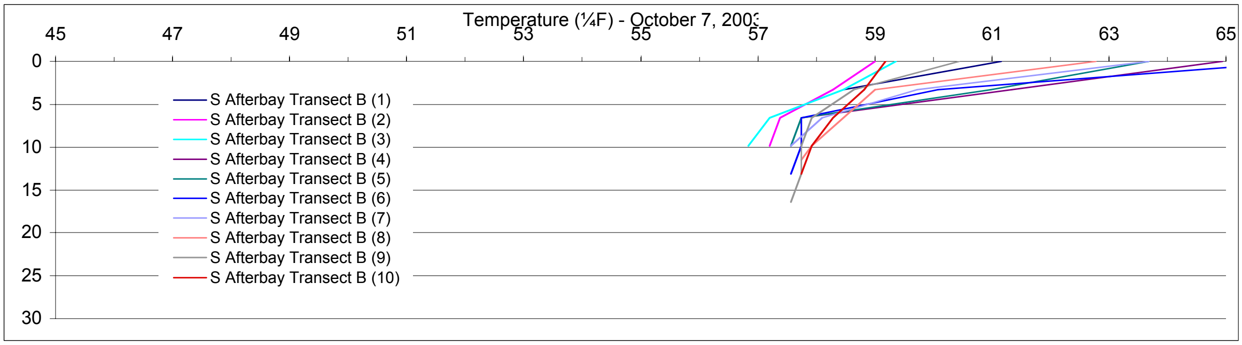

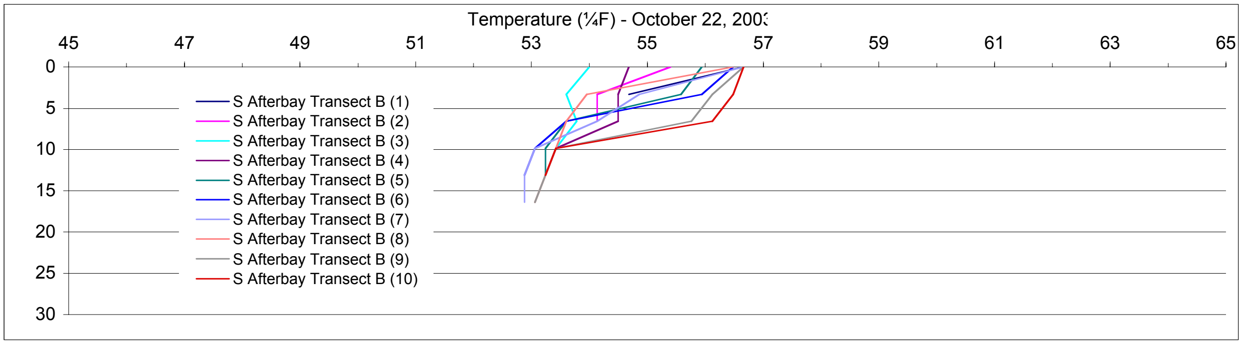

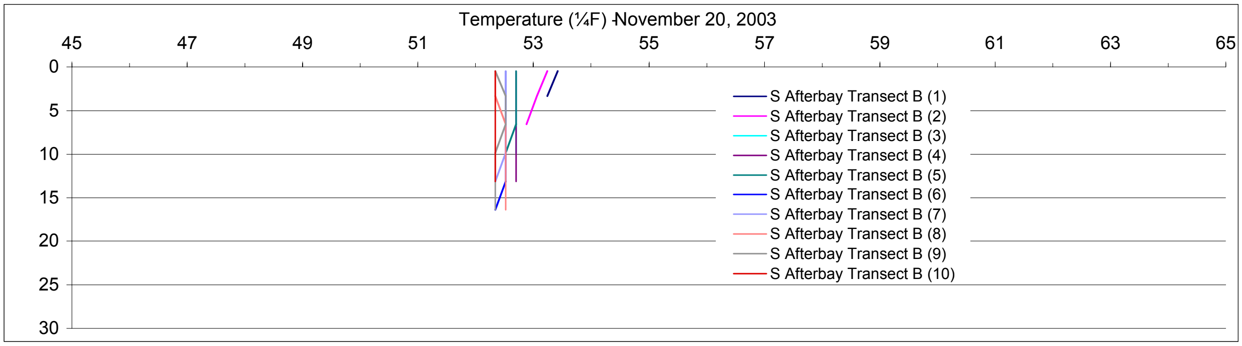

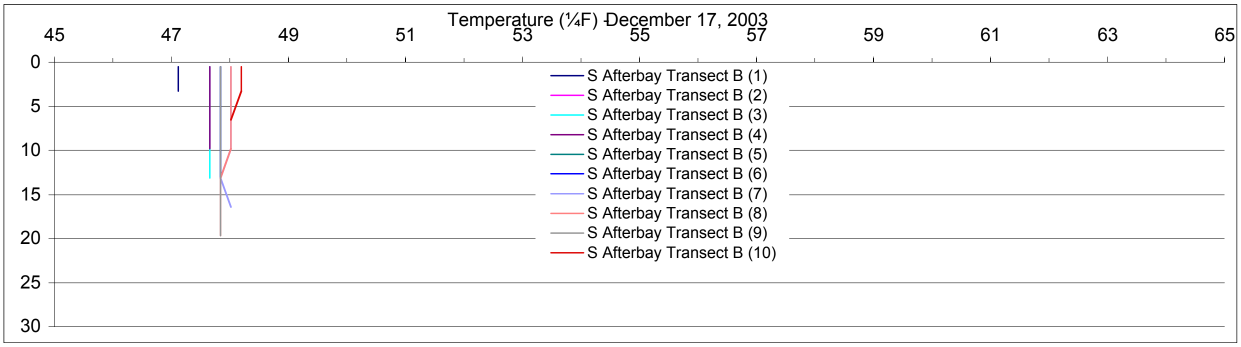

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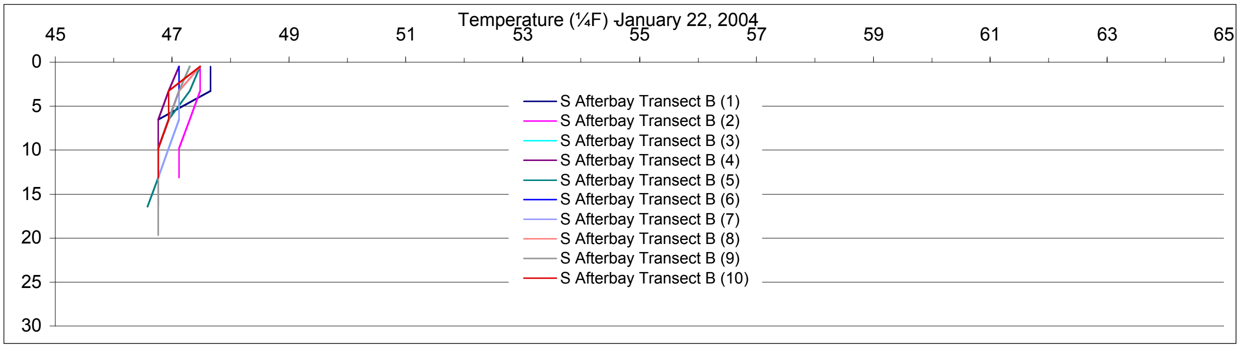
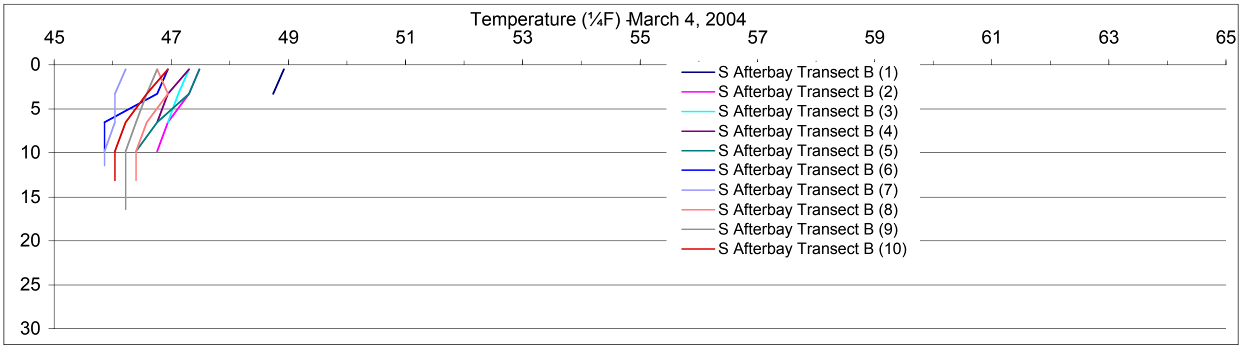
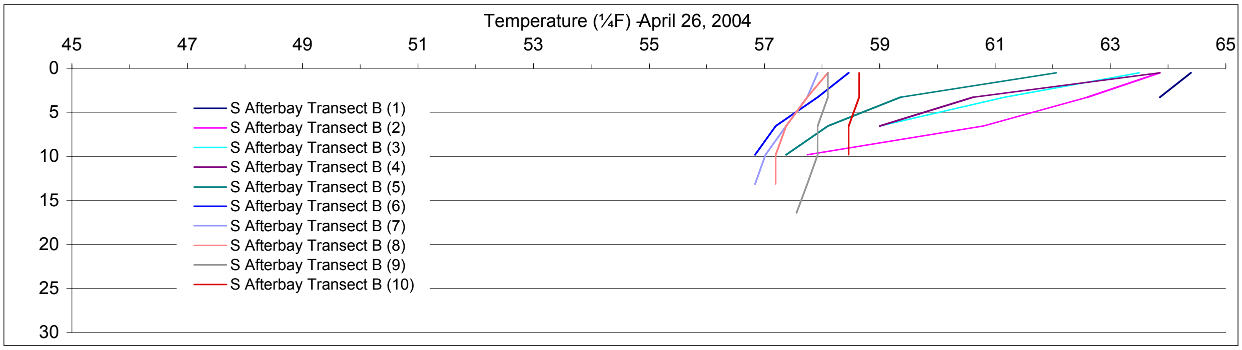
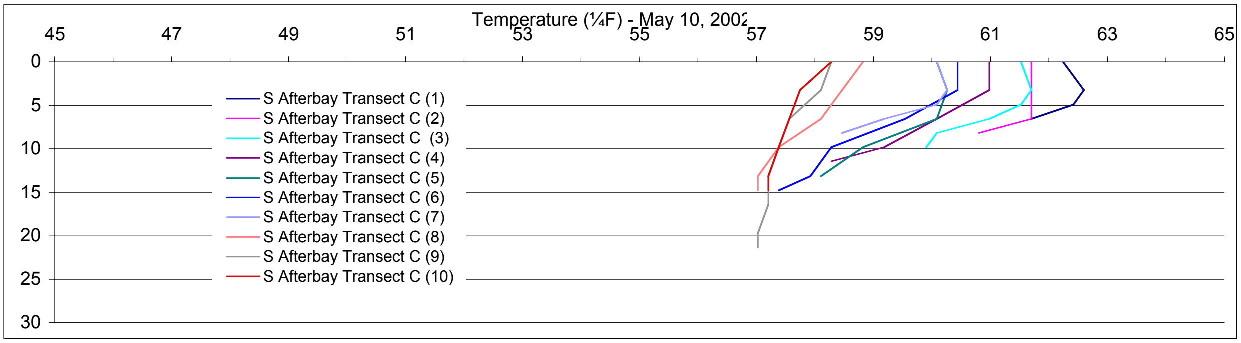
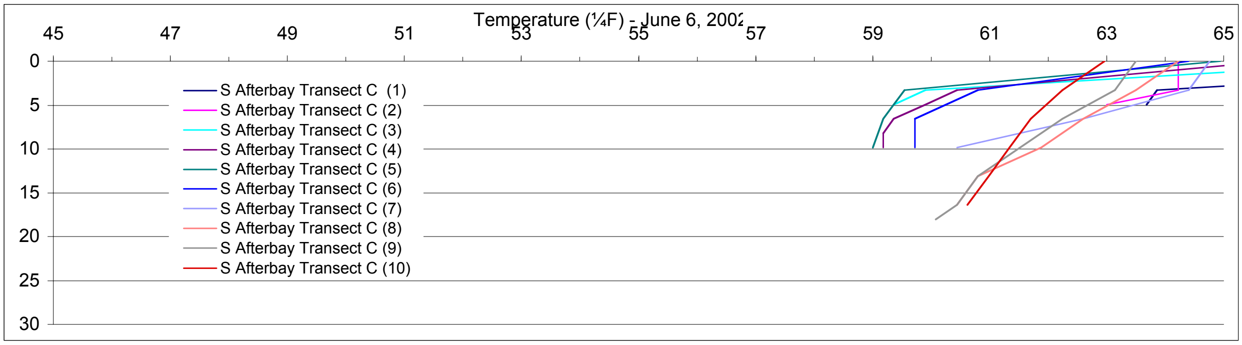


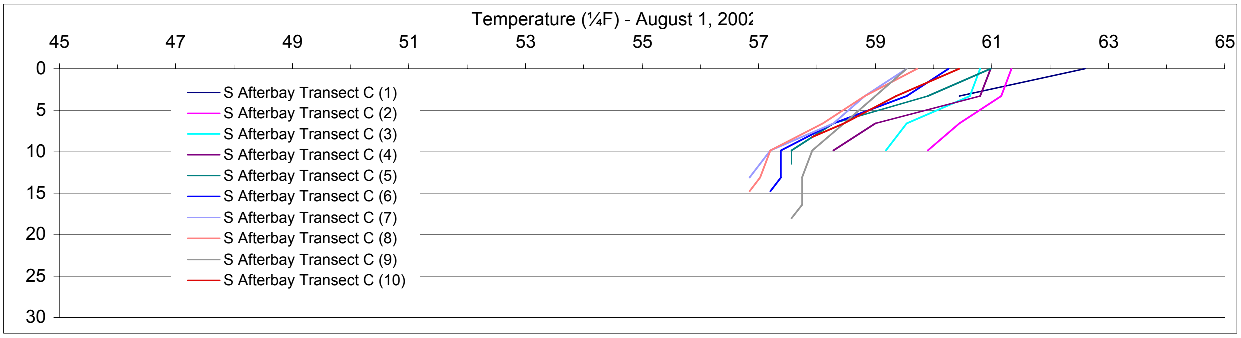


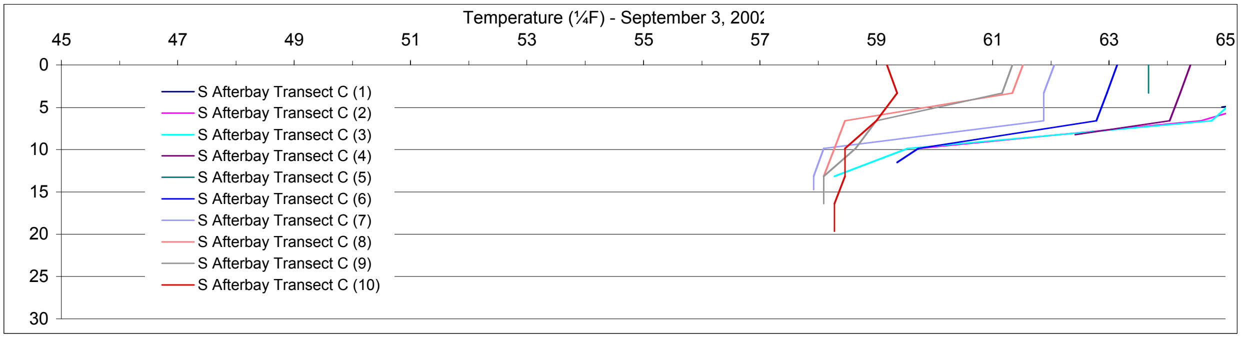


Appendix 4c. Water temperatures along Transect C in the South Thermalito Afterbay.









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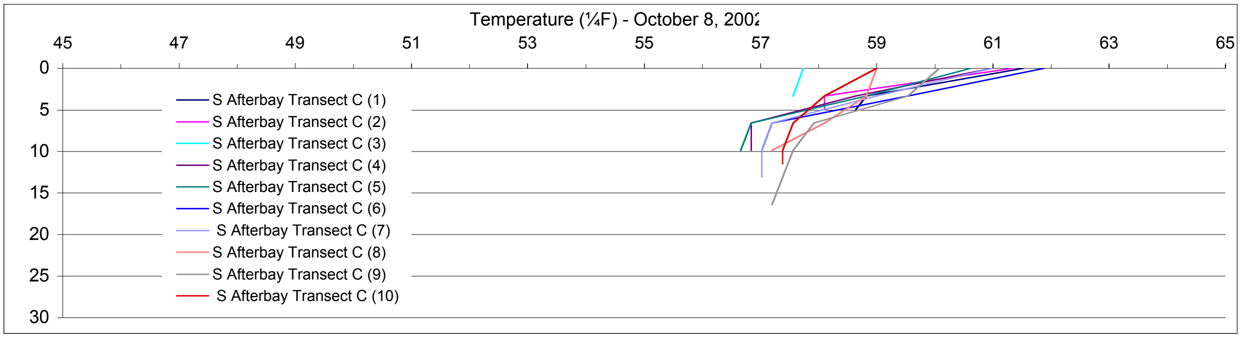
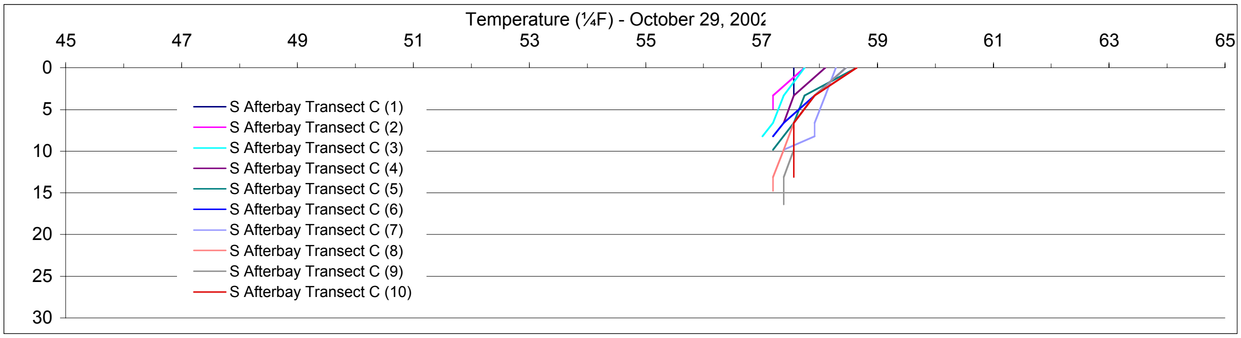
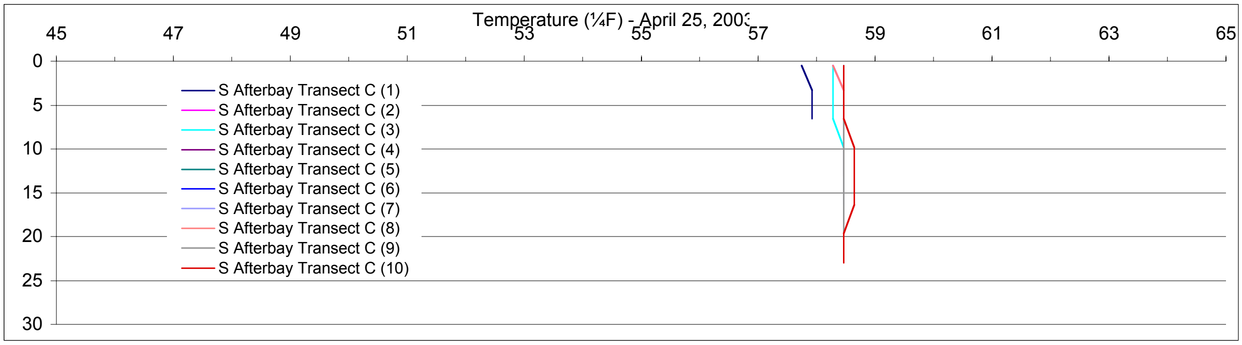
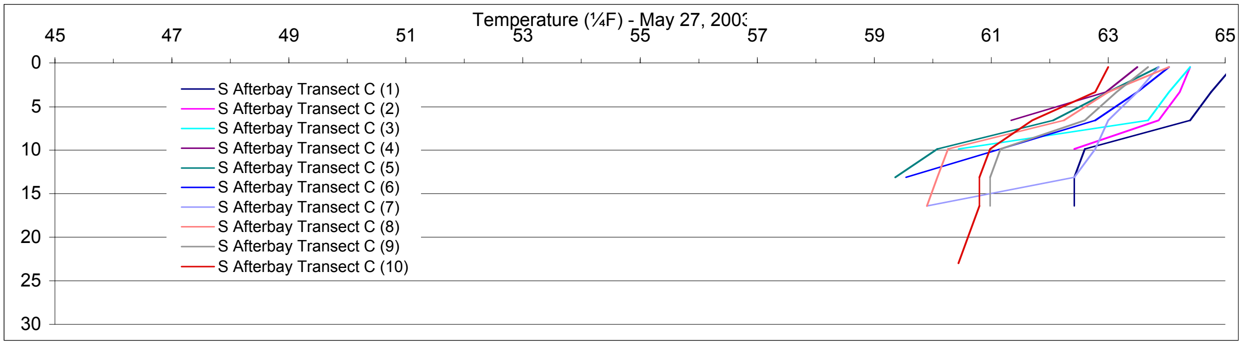
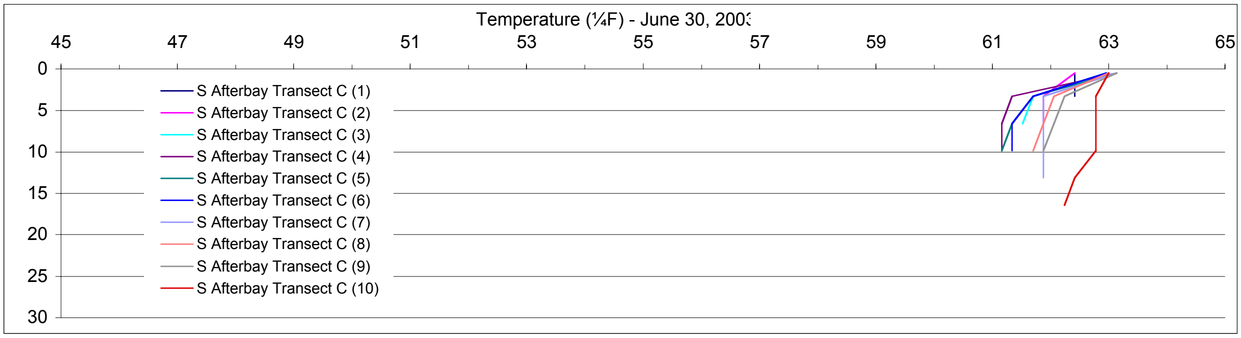


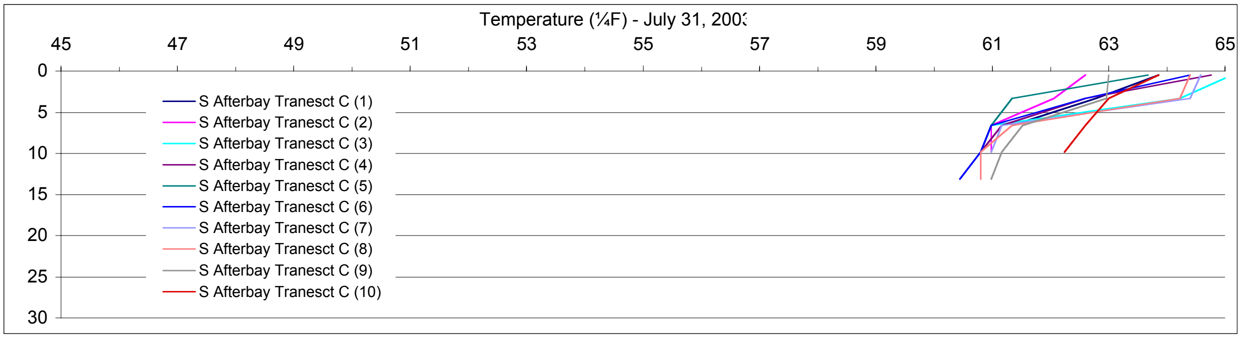


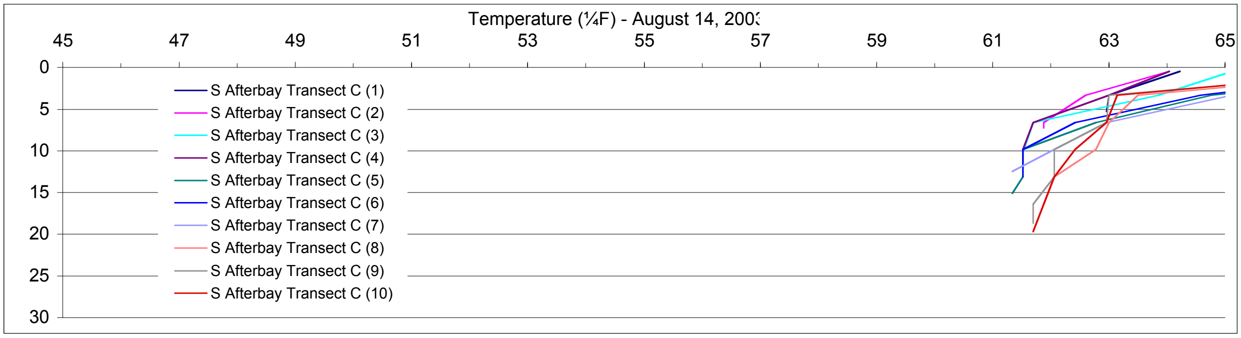


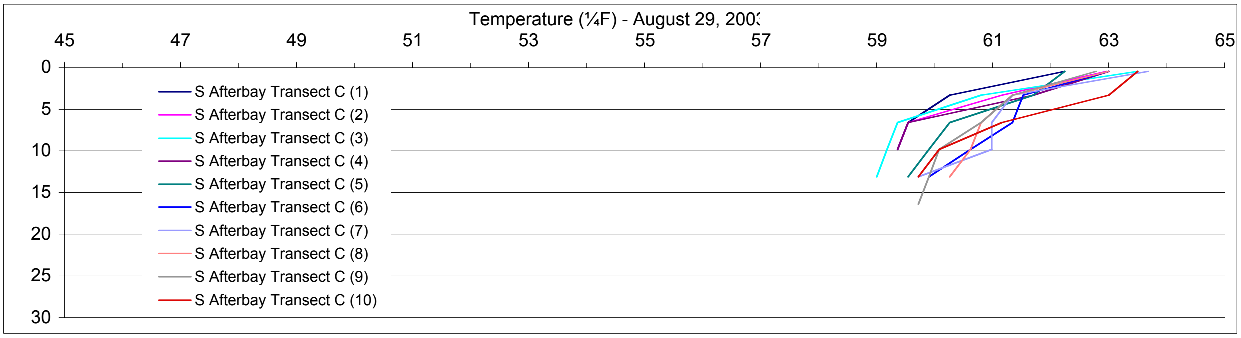


Appendix 4c. Continued.

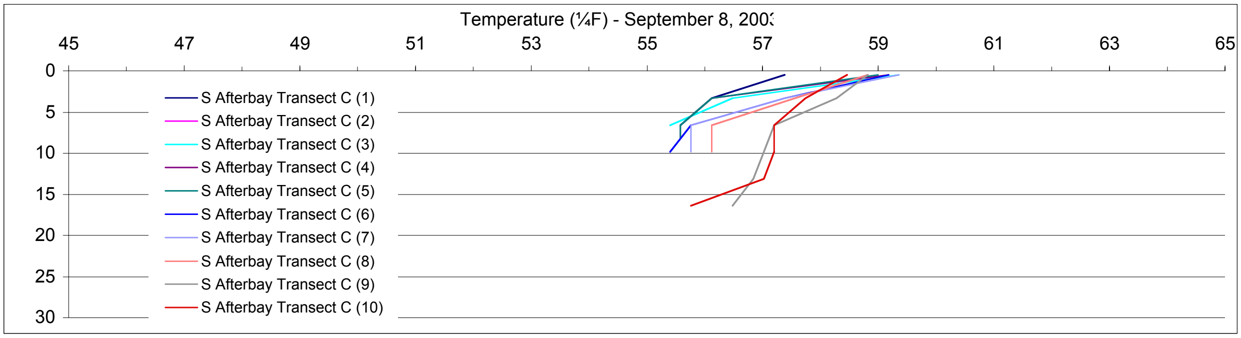


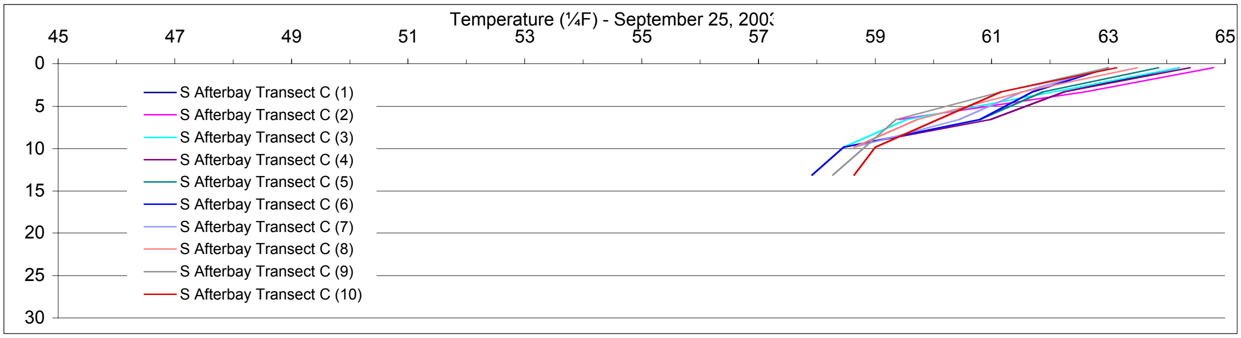


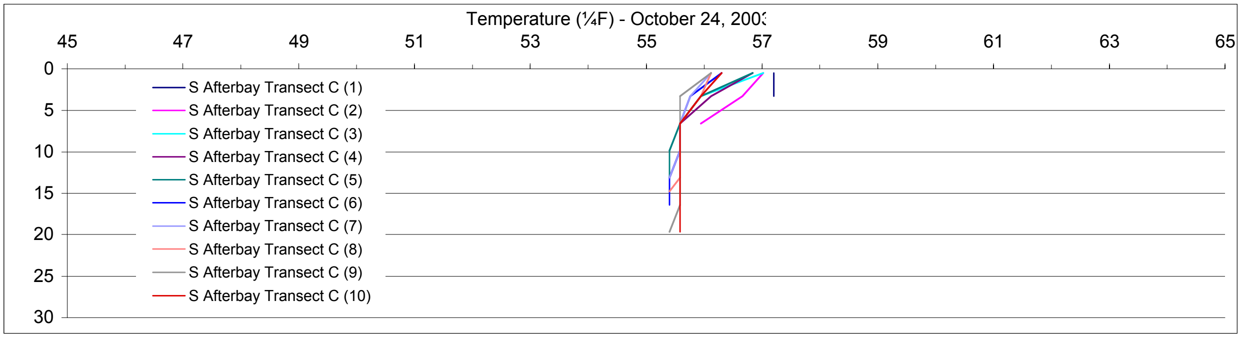


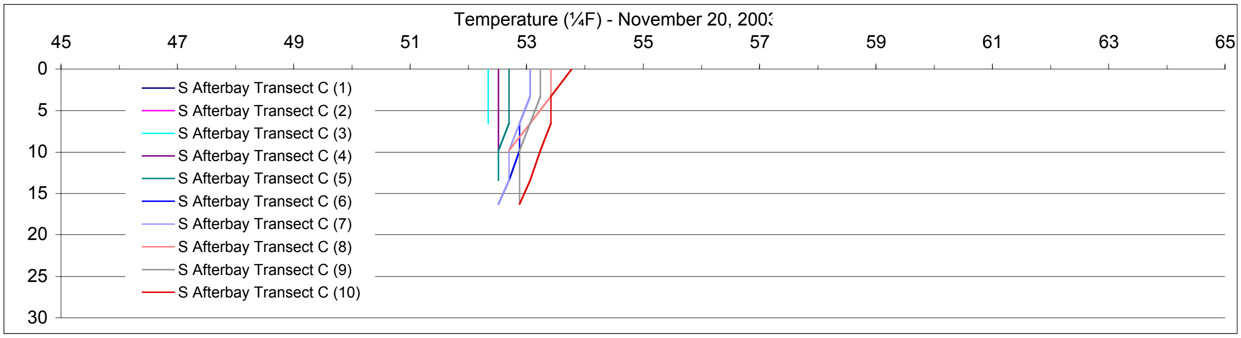


Appendix 4c. Continued.









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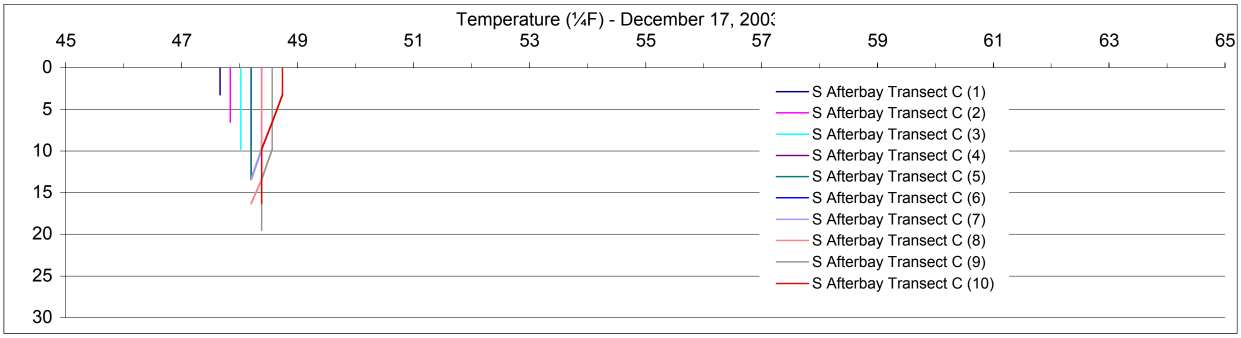
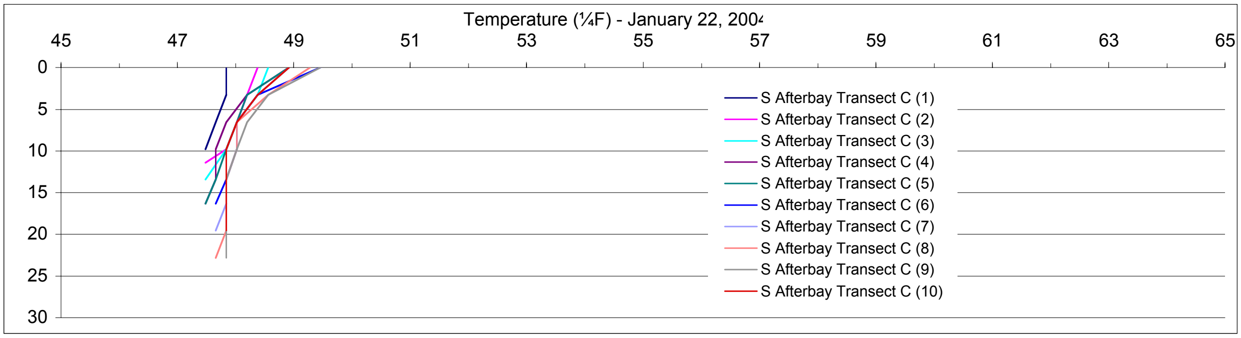
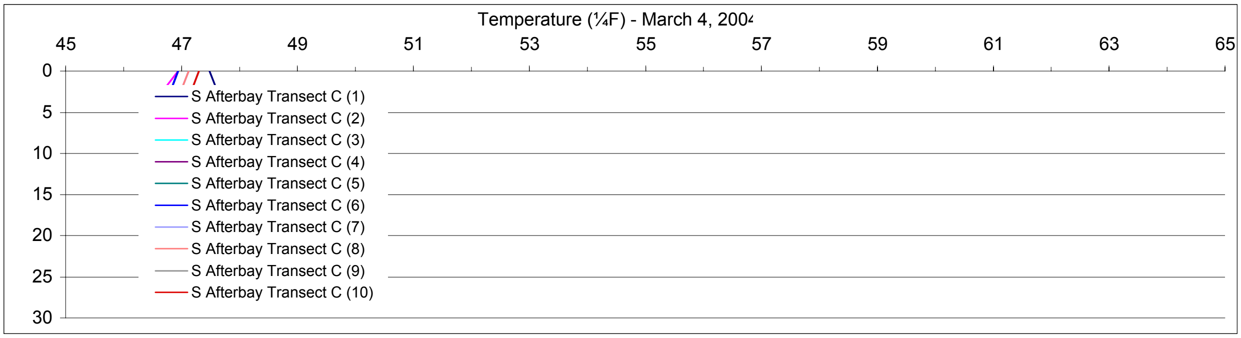
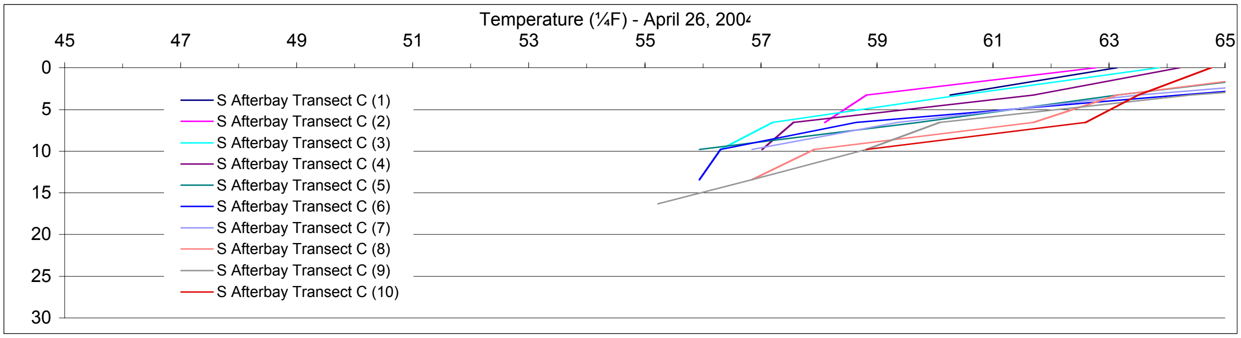
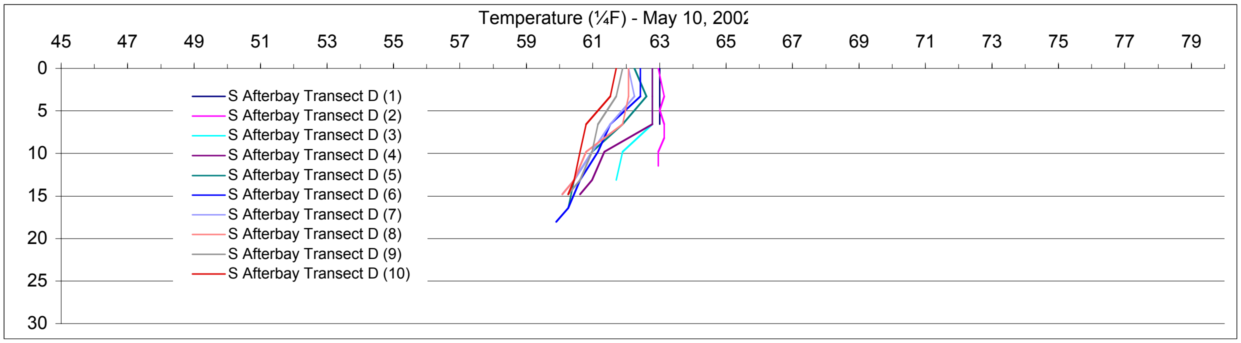


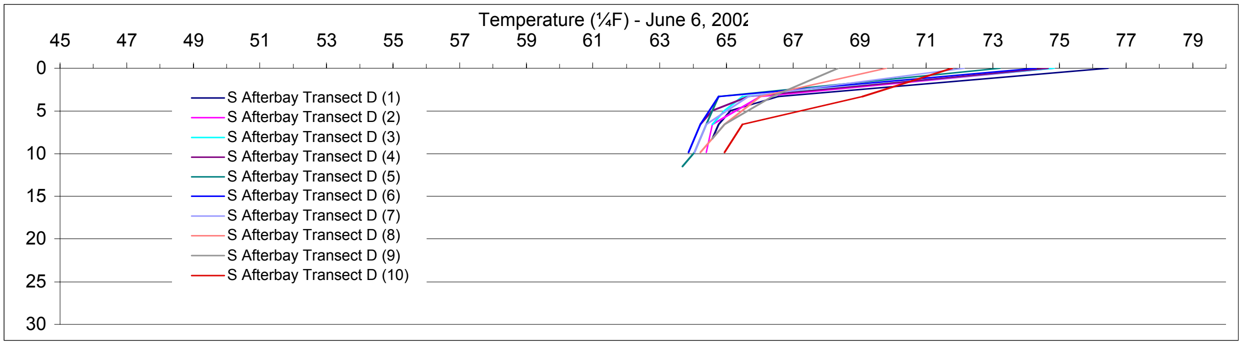


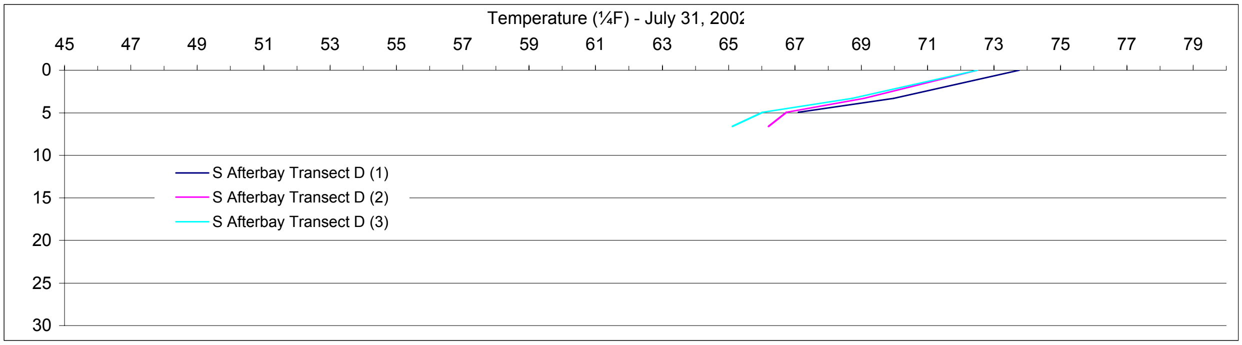


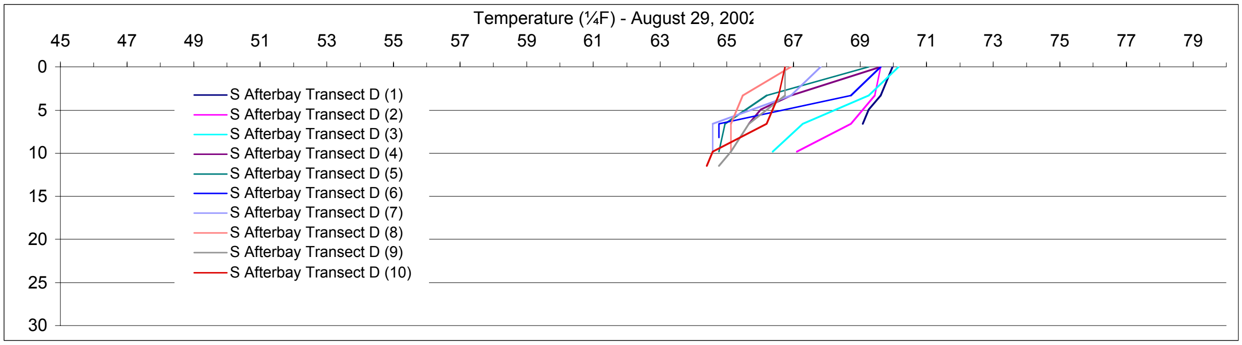


Appendix 4d. Water temperatures along Transect D in the South Thermalito Afterbay.









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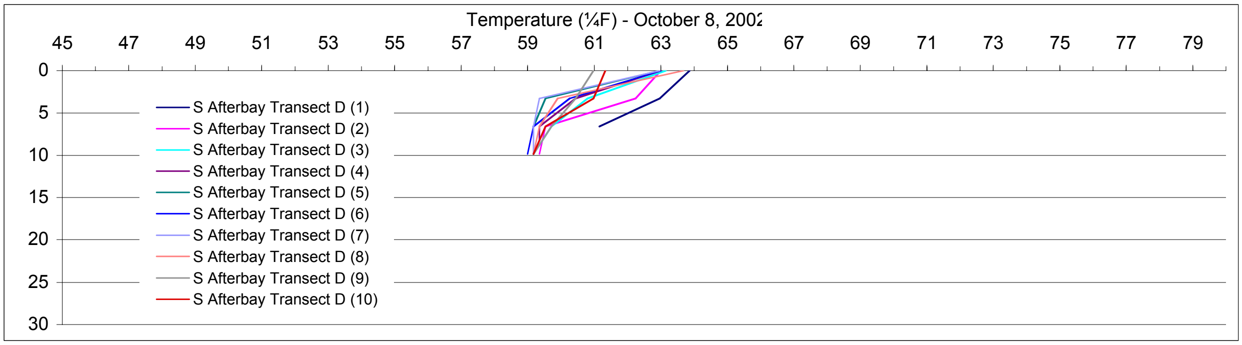

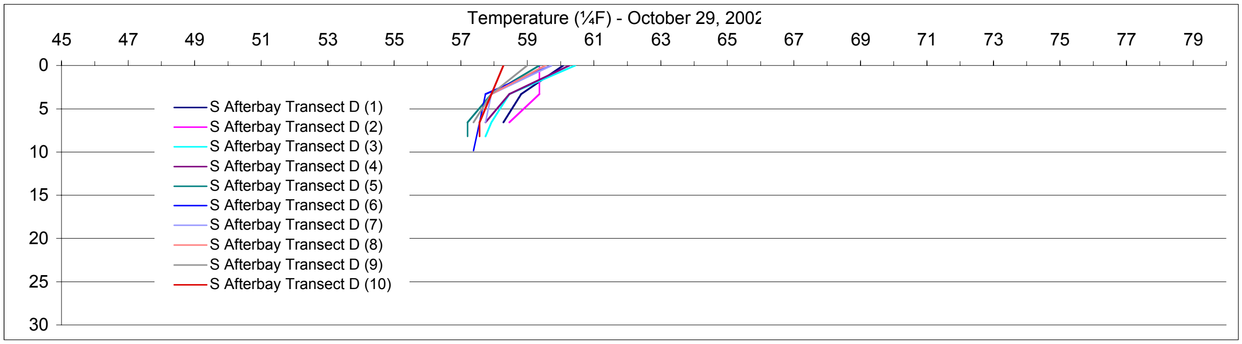

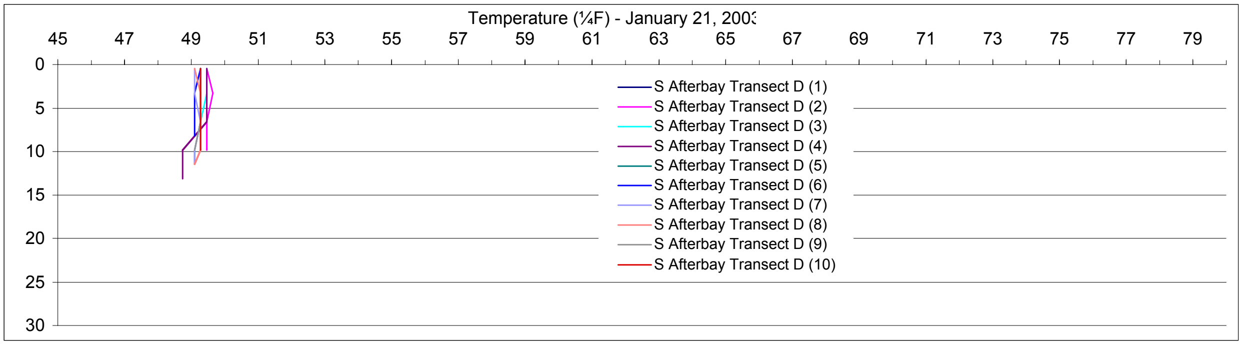

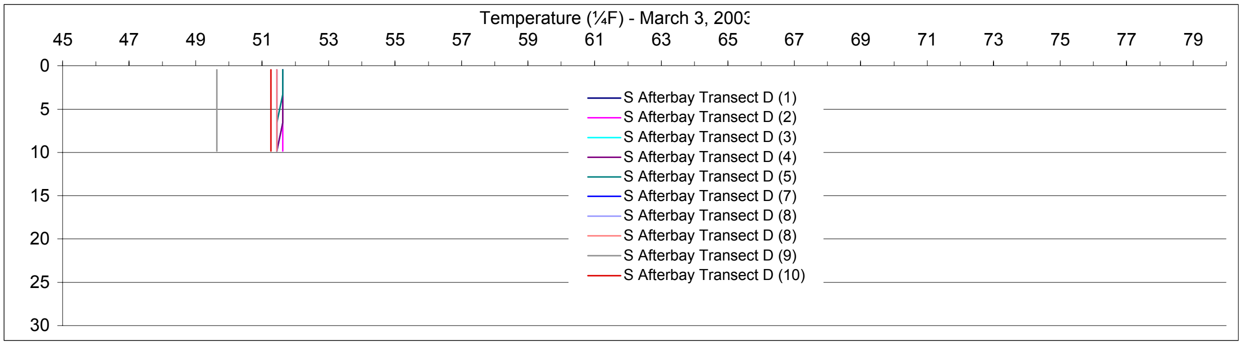

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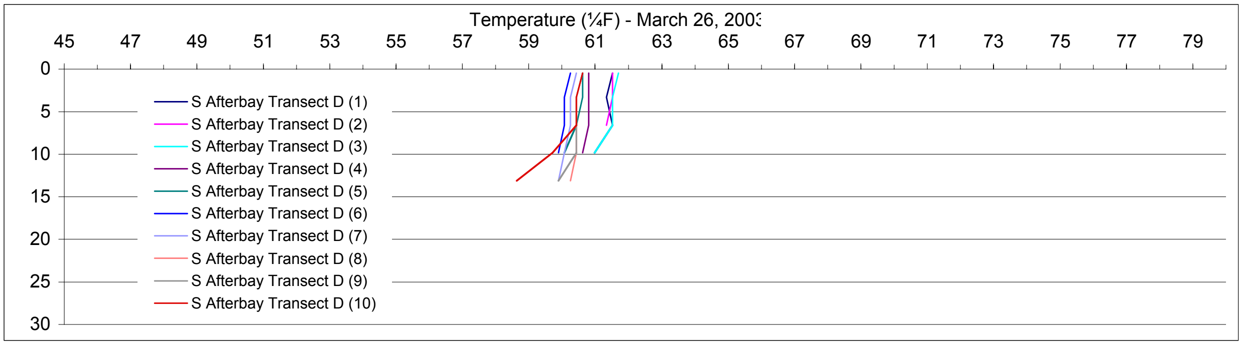

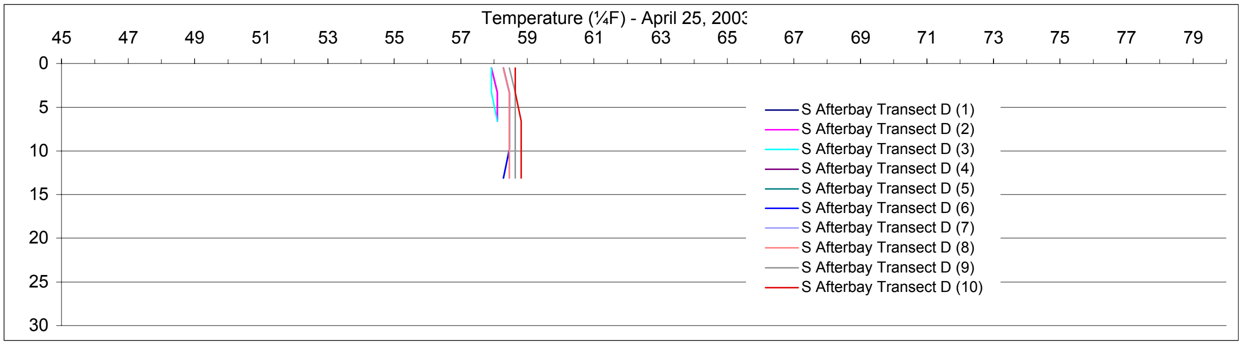

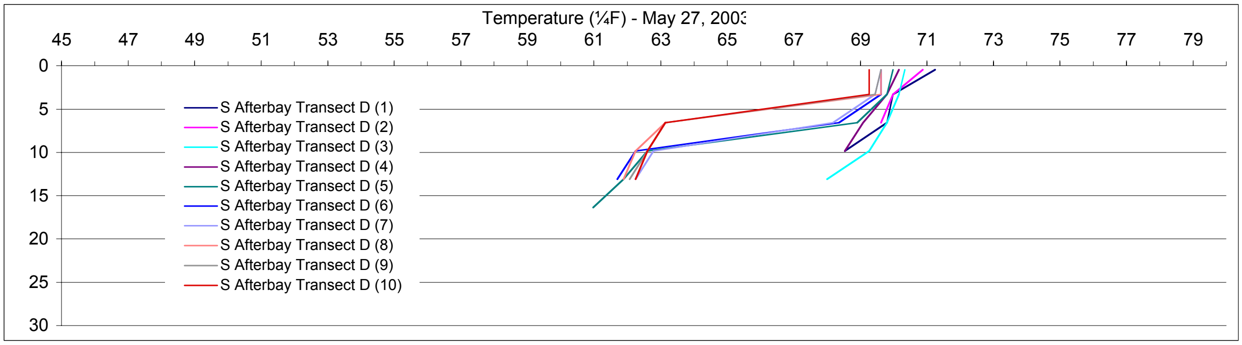

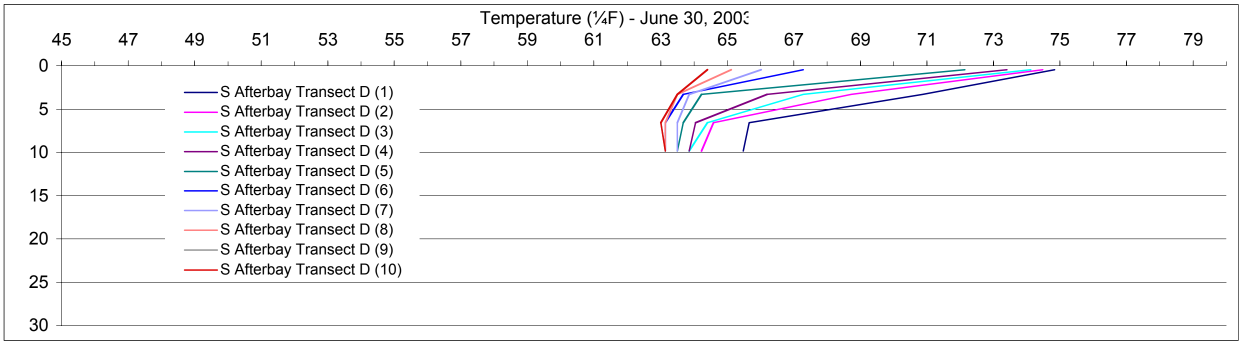

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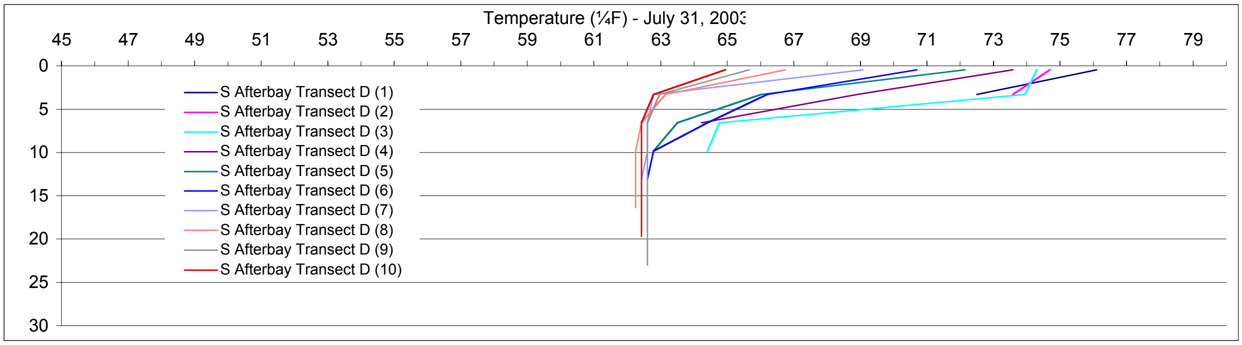

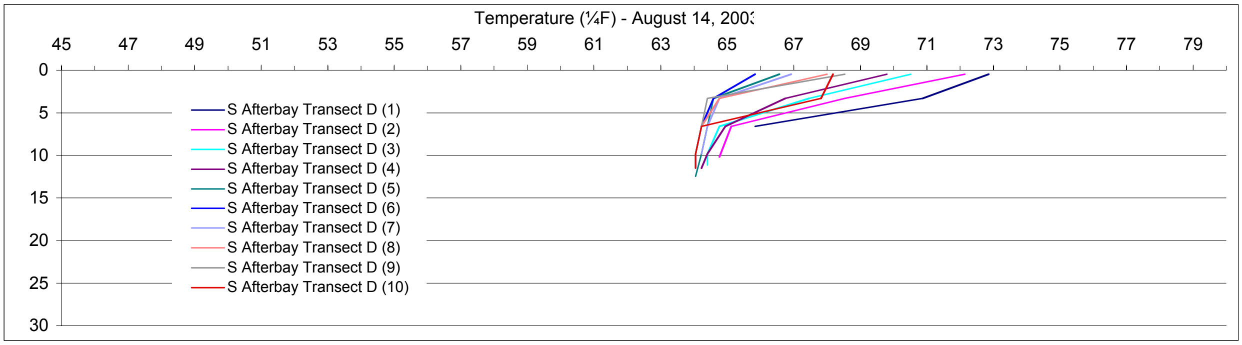

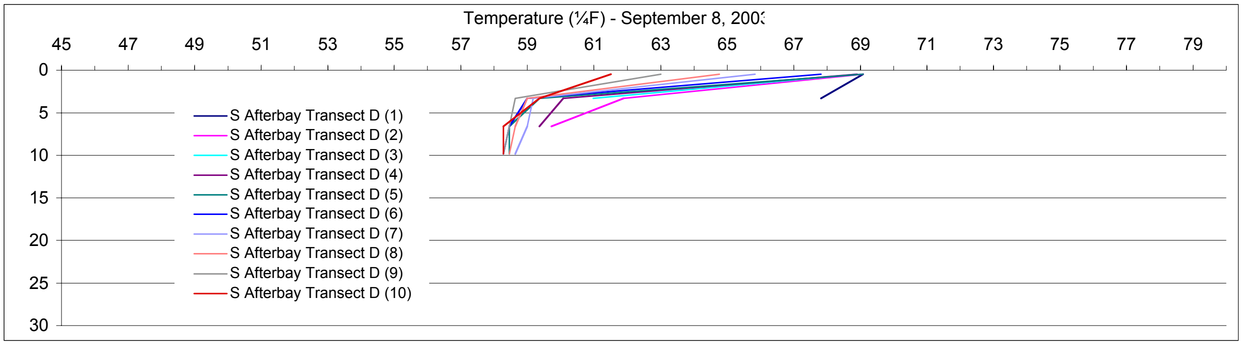

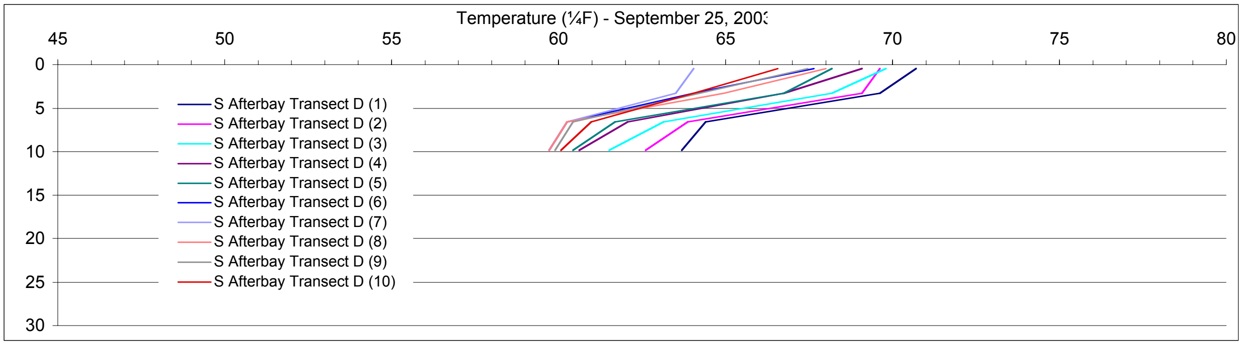

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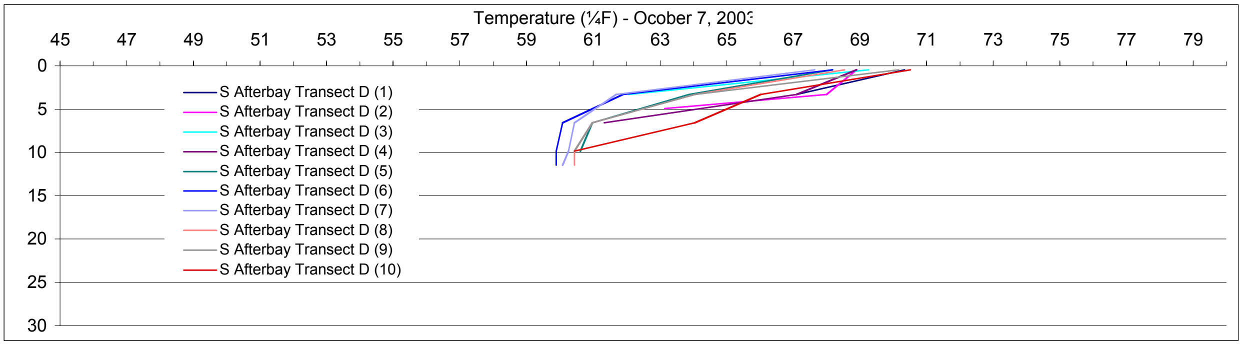

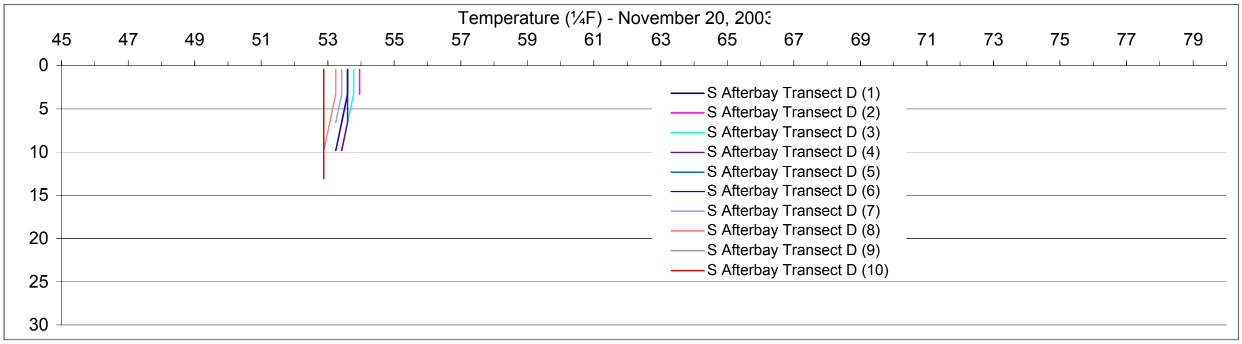

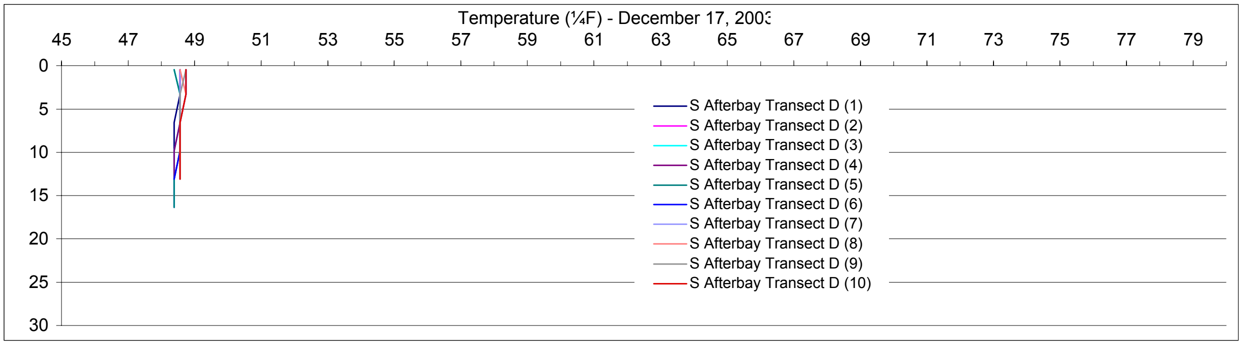

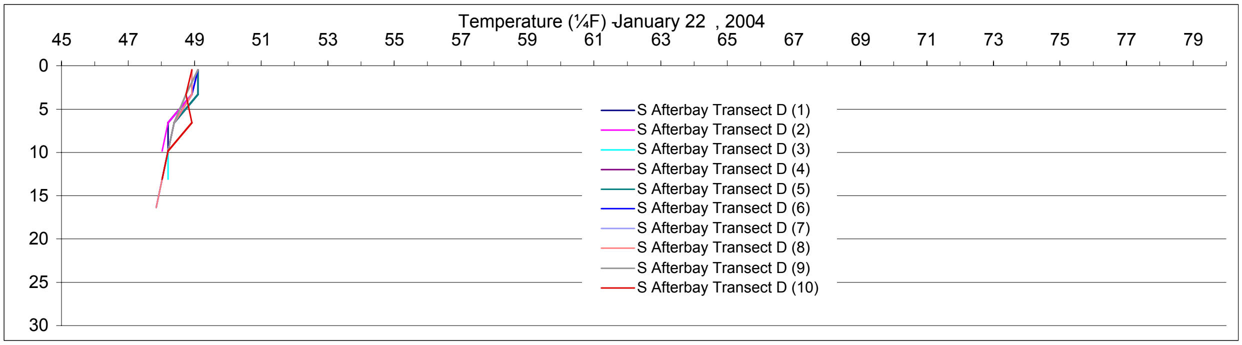

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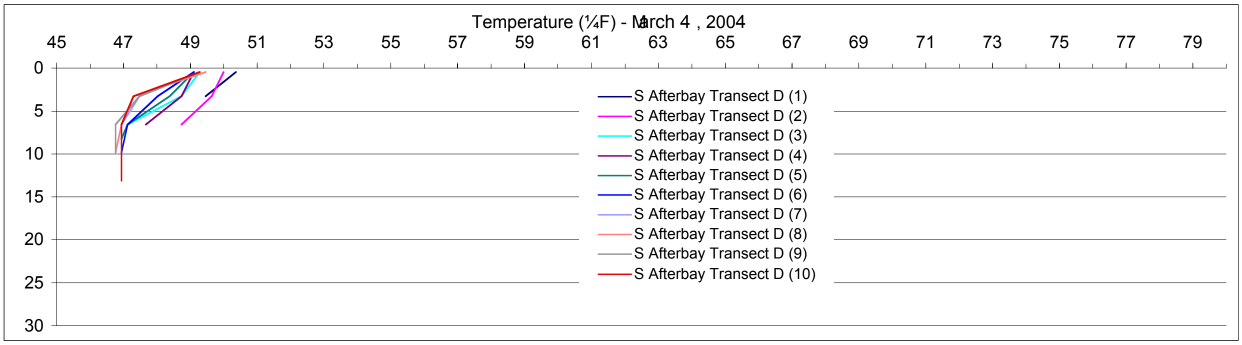
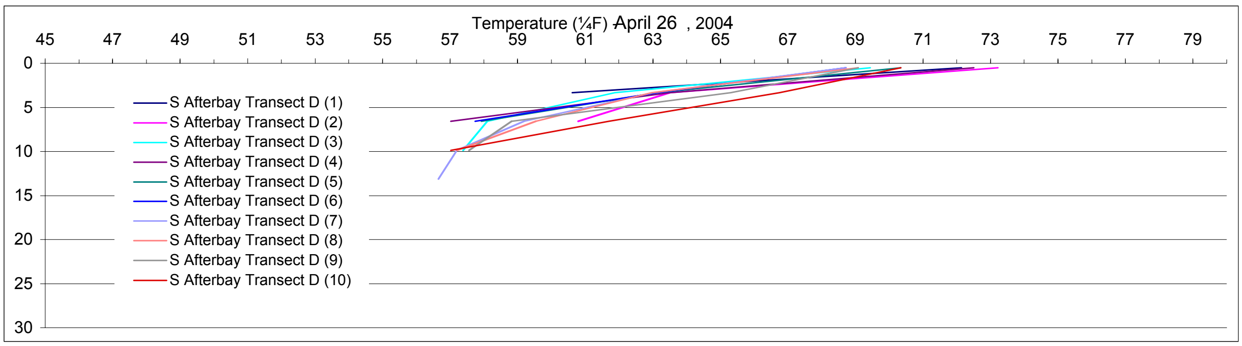
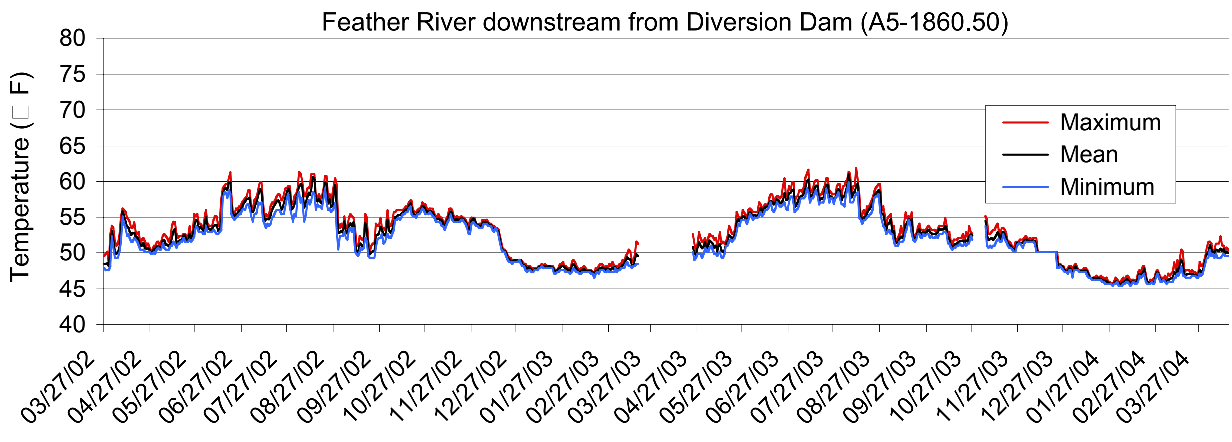
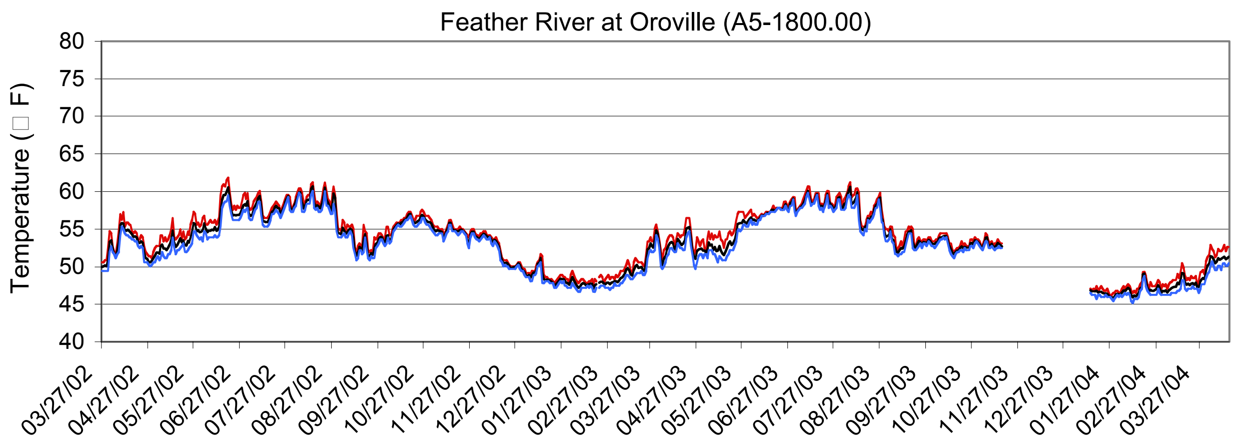
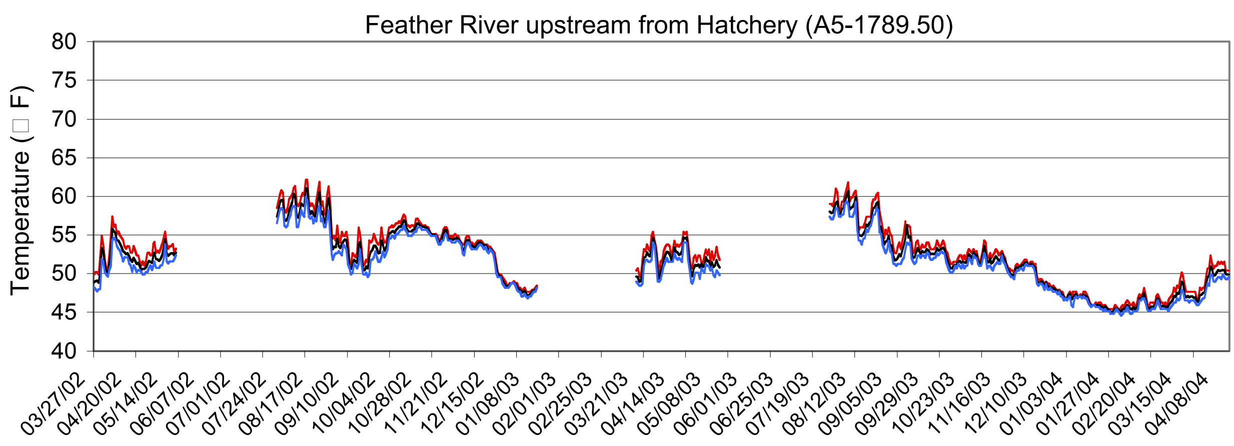




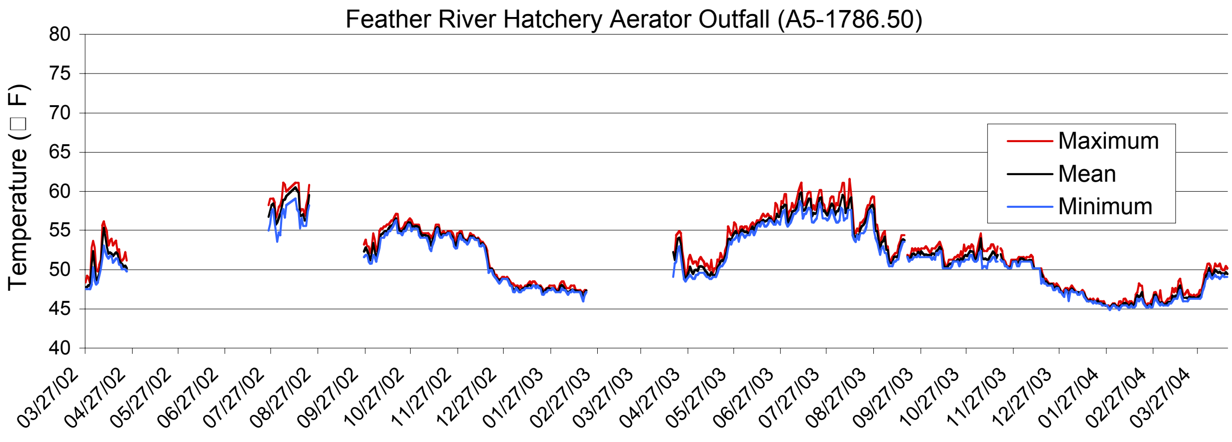
Appendix 5a. Water temperatures in the lower Feather River.

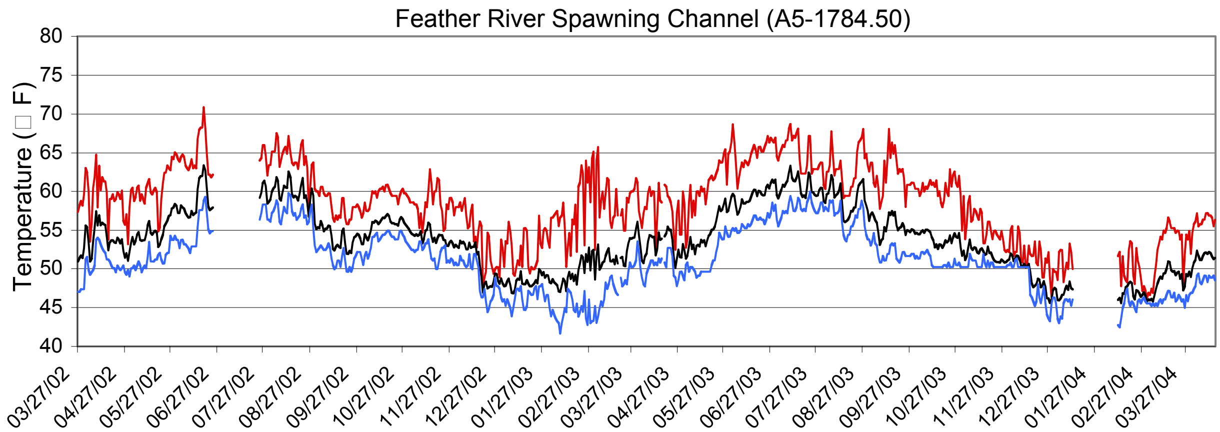


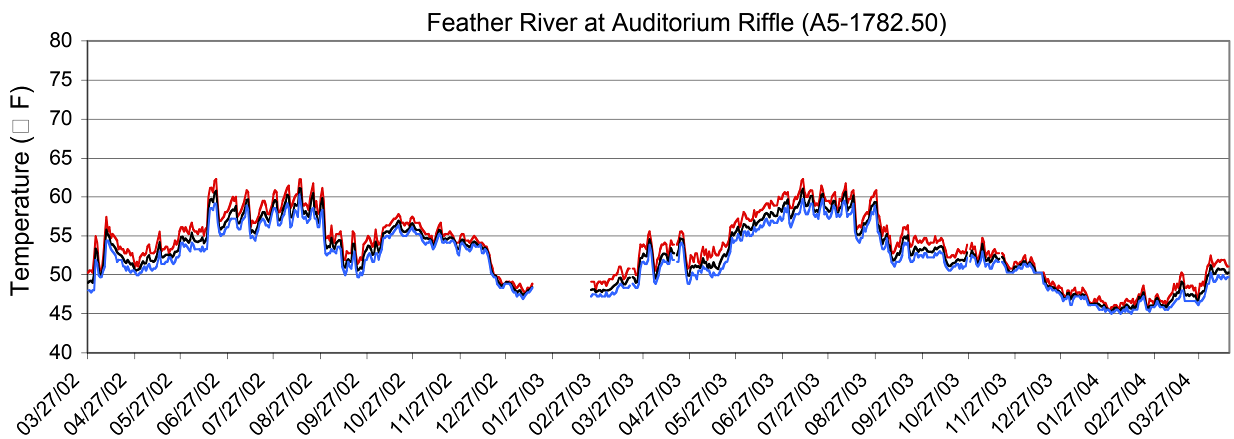




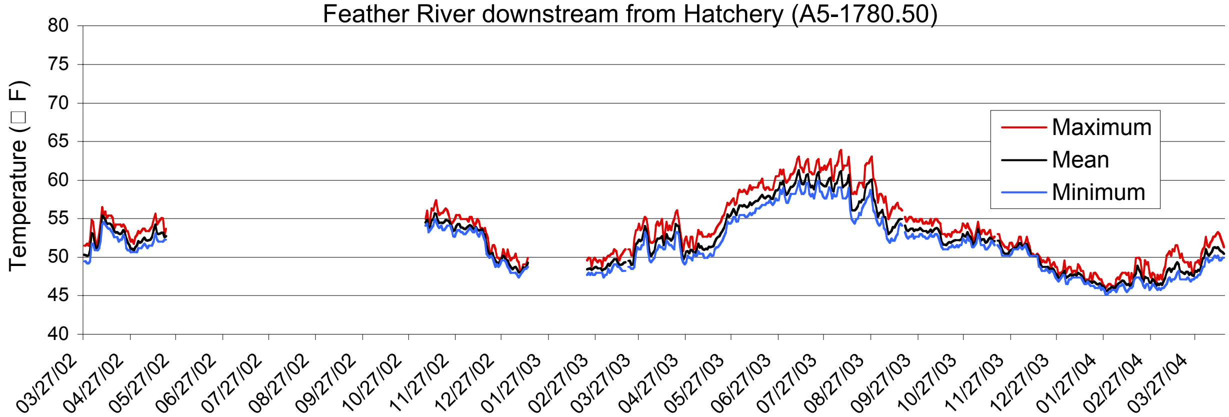
Appendix 5a. Continued.

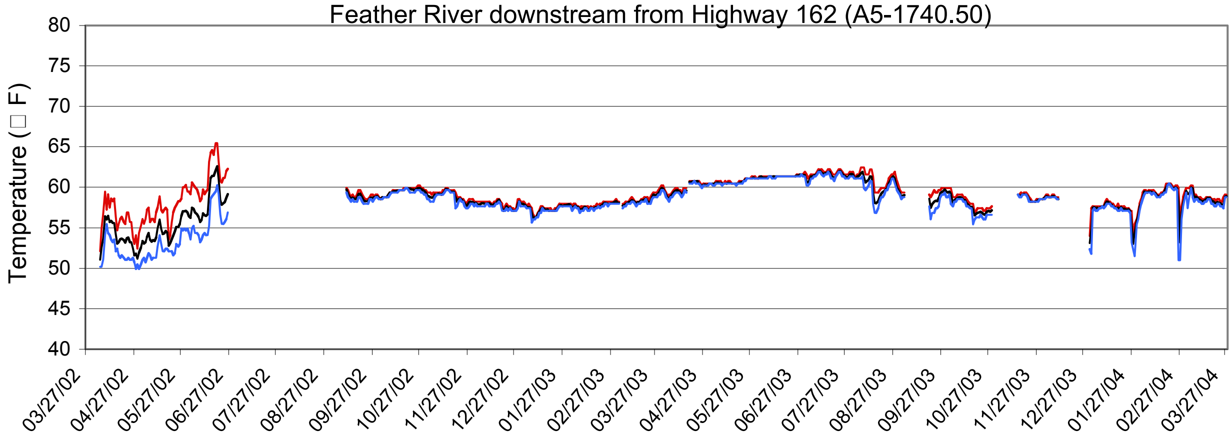


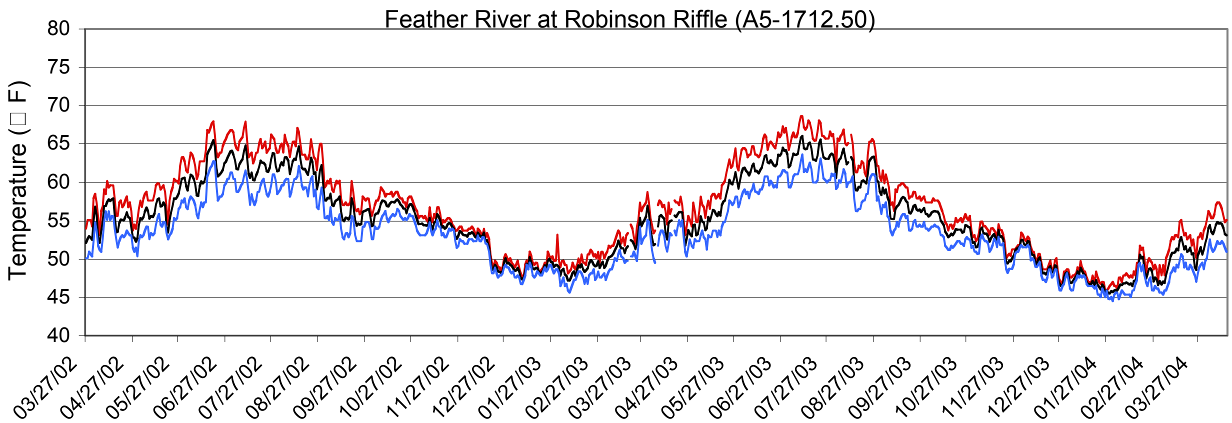




Appendix 5a. Continued.







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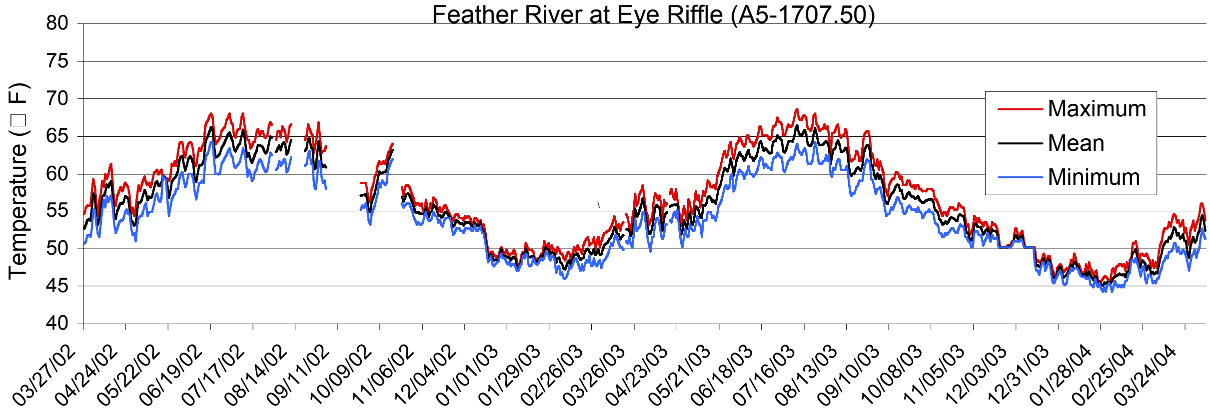

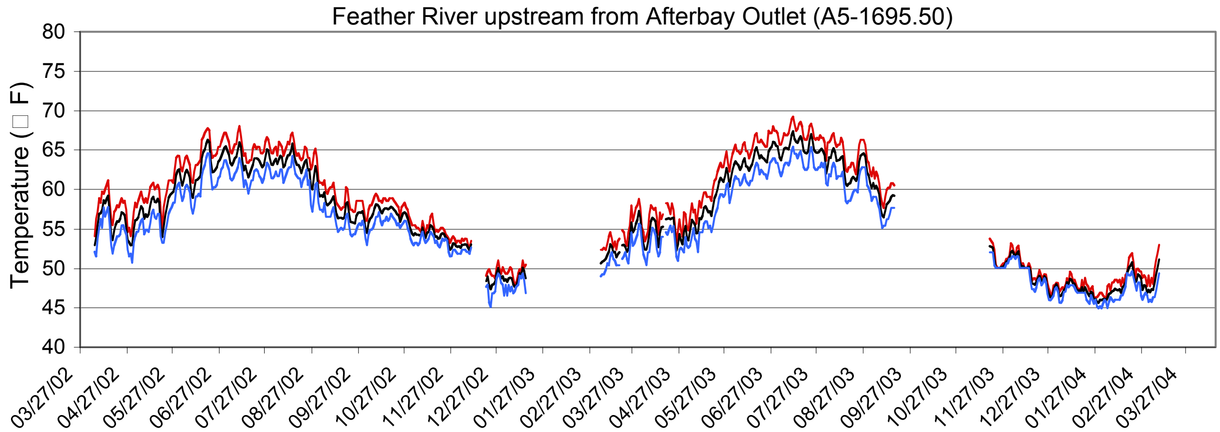

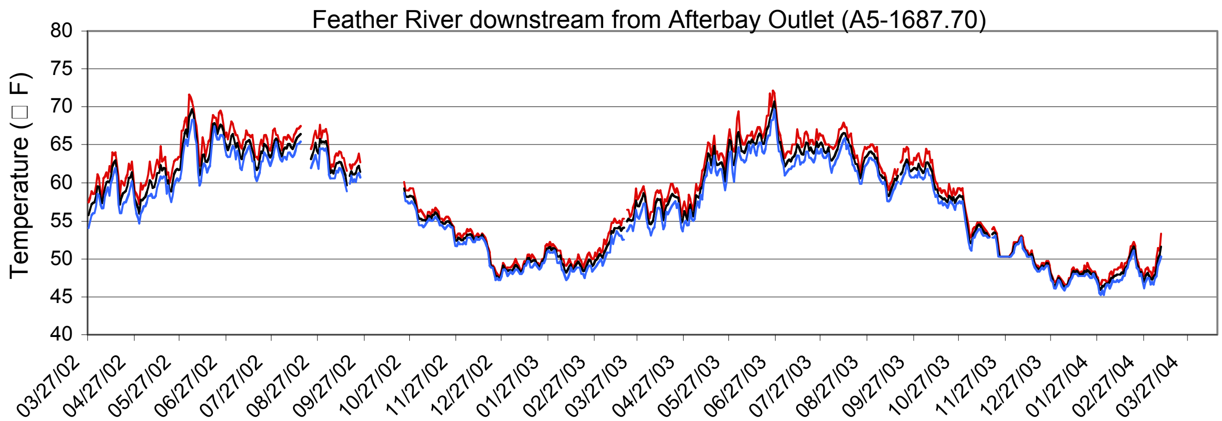

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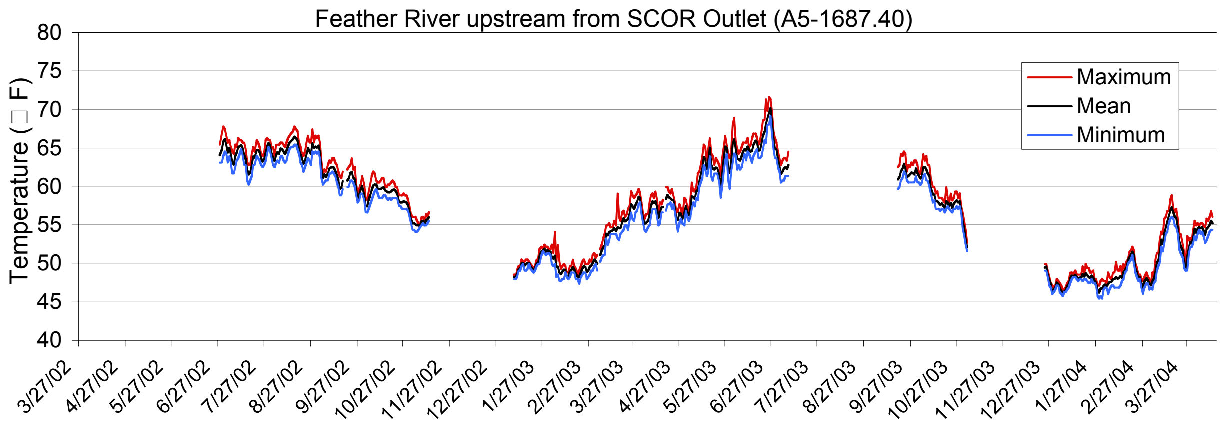

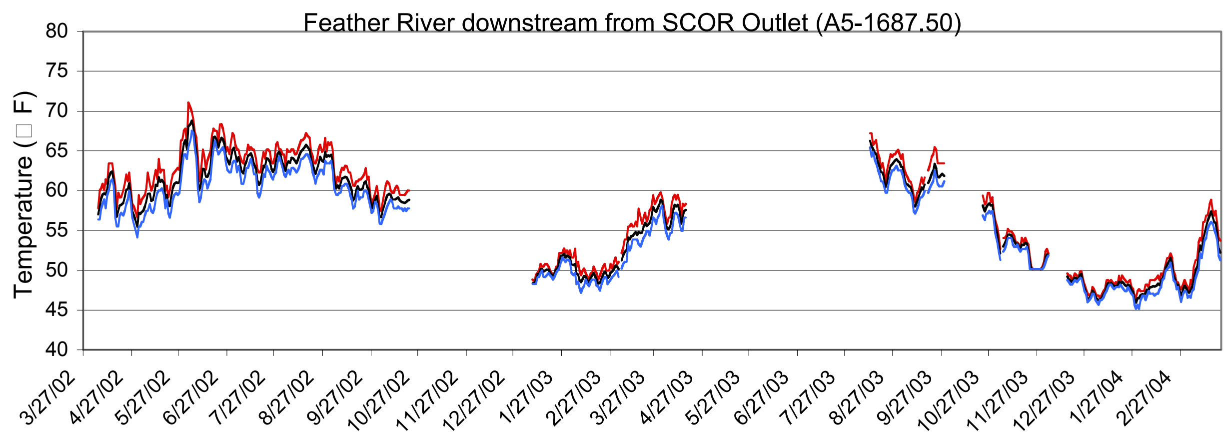

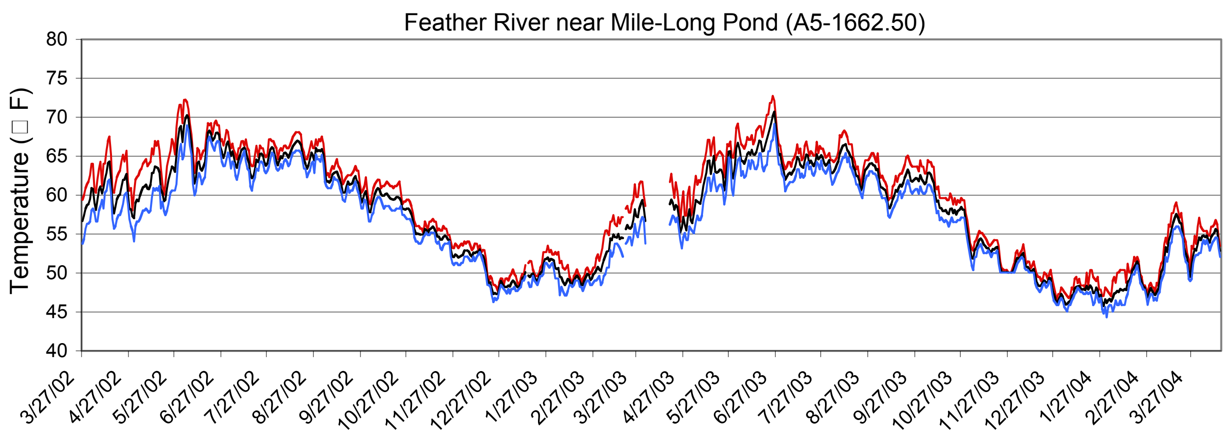

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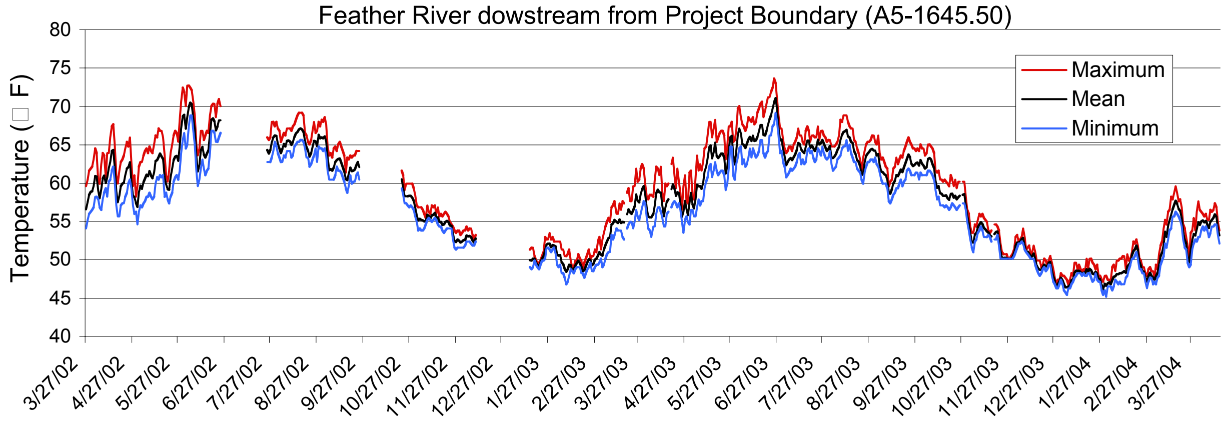

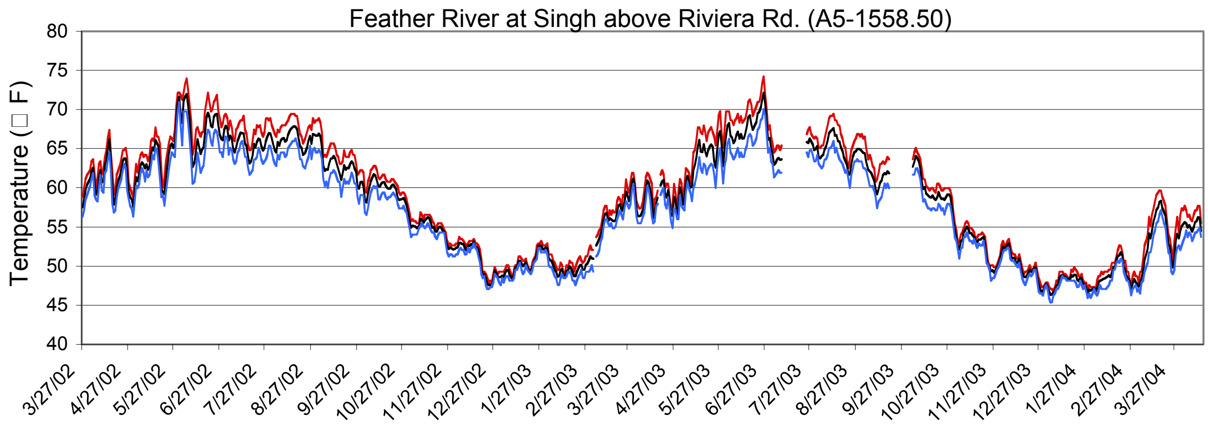

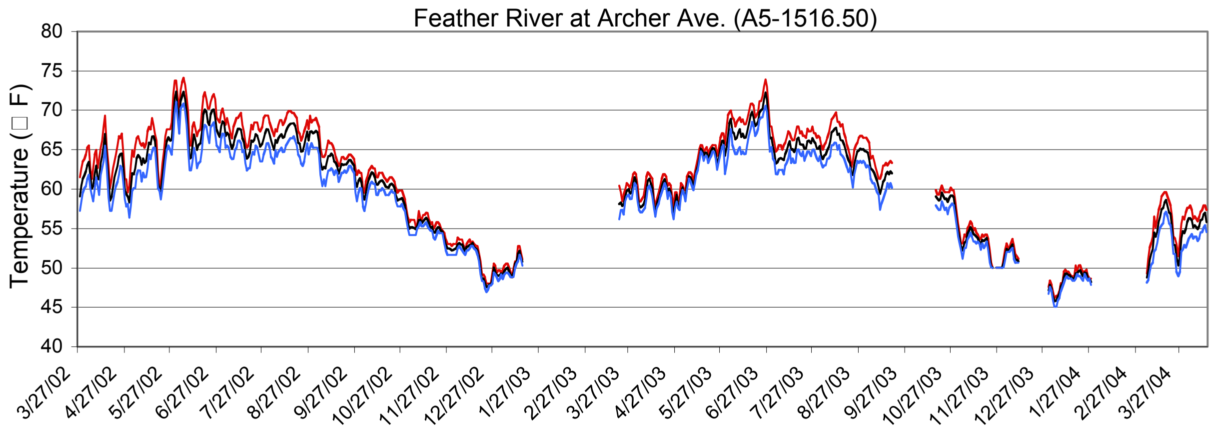

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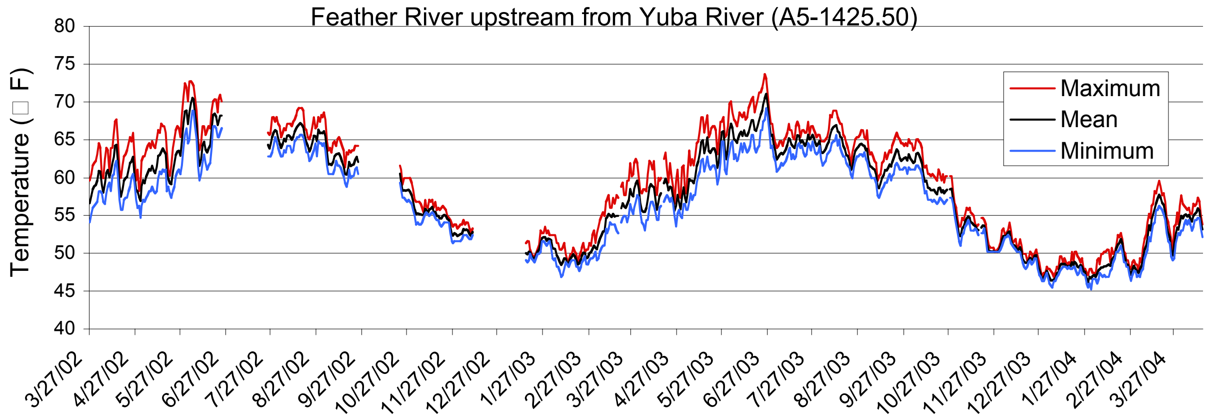

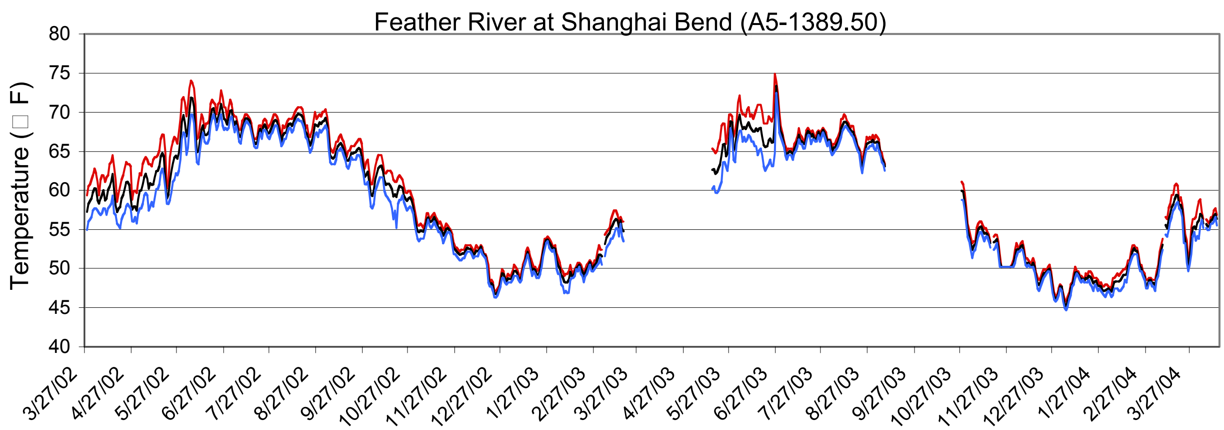

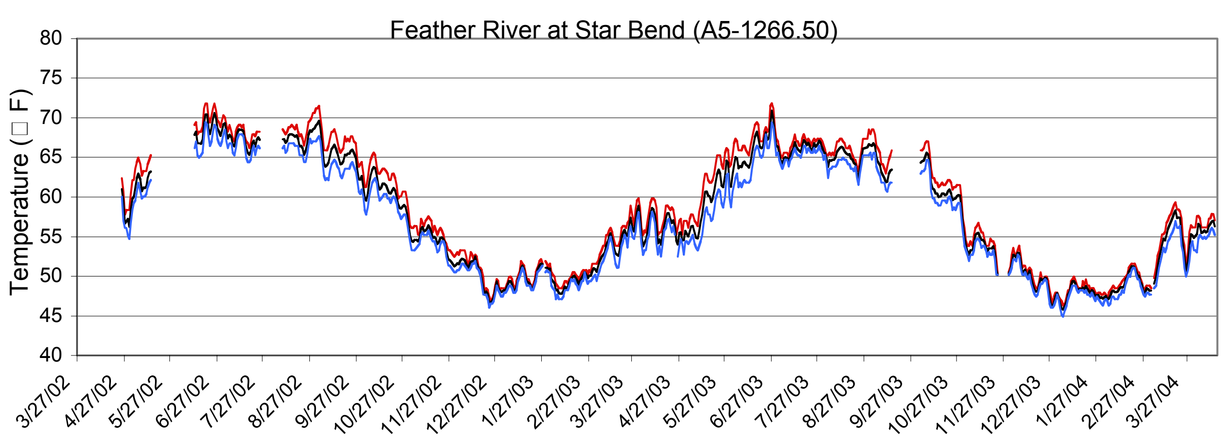

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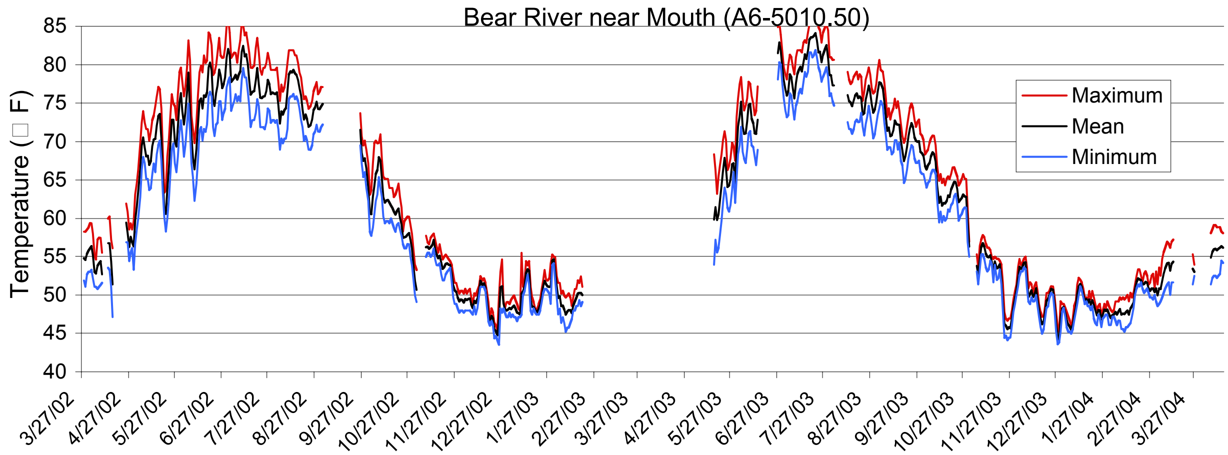

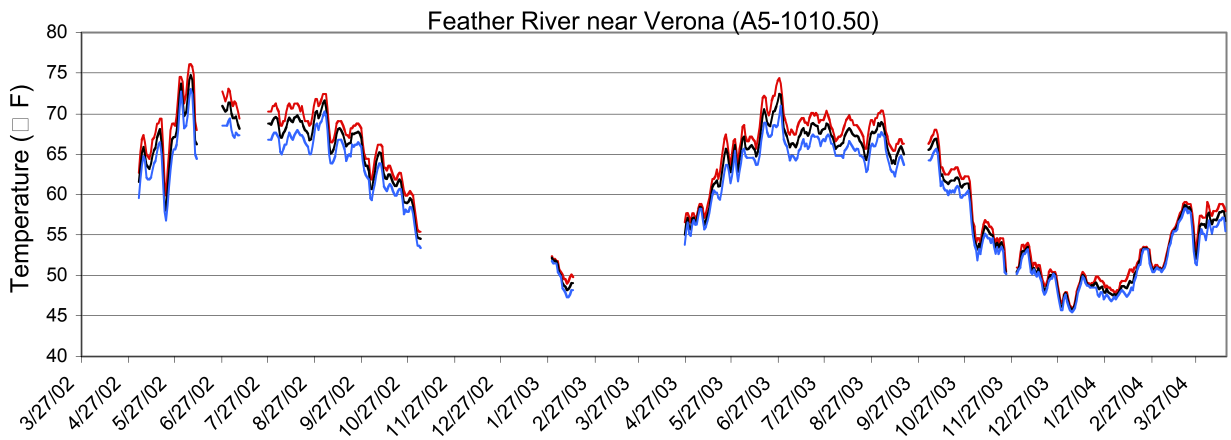

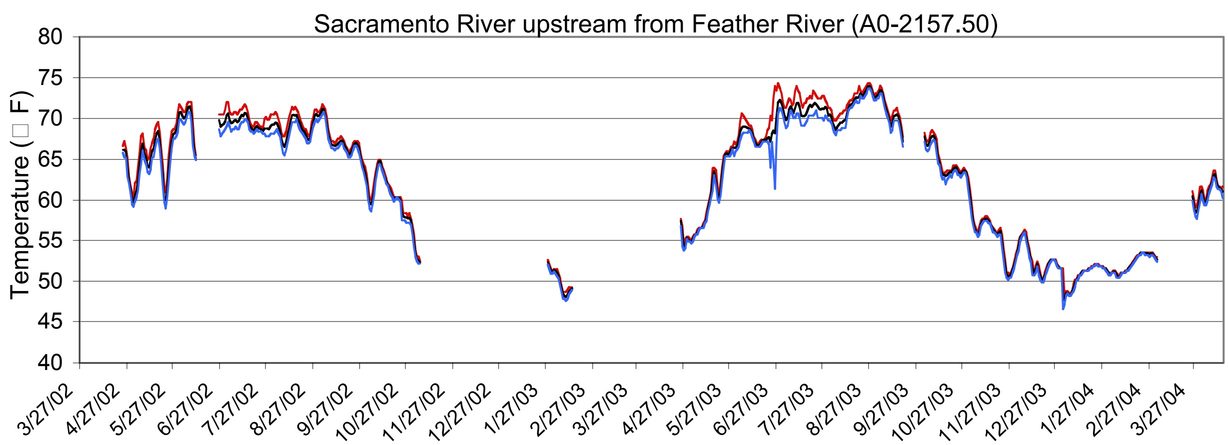

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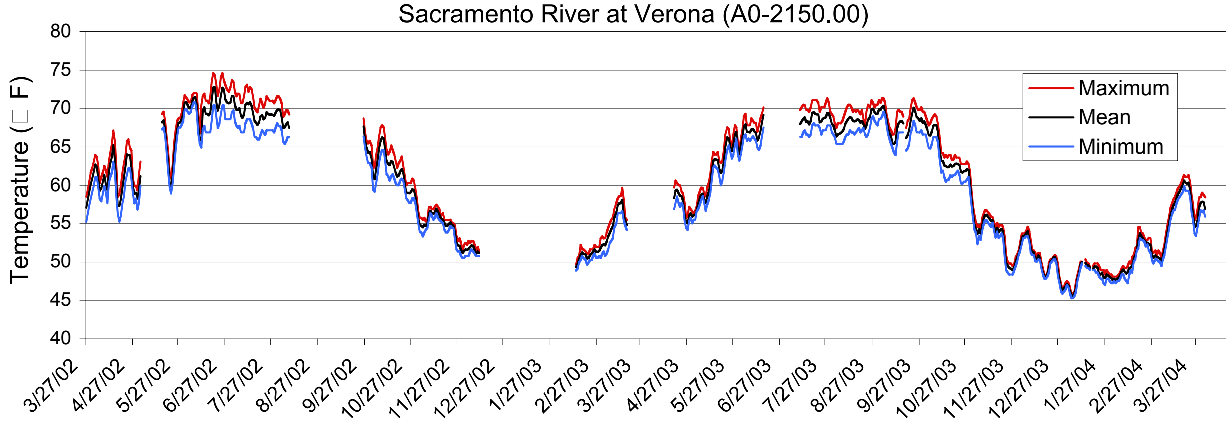
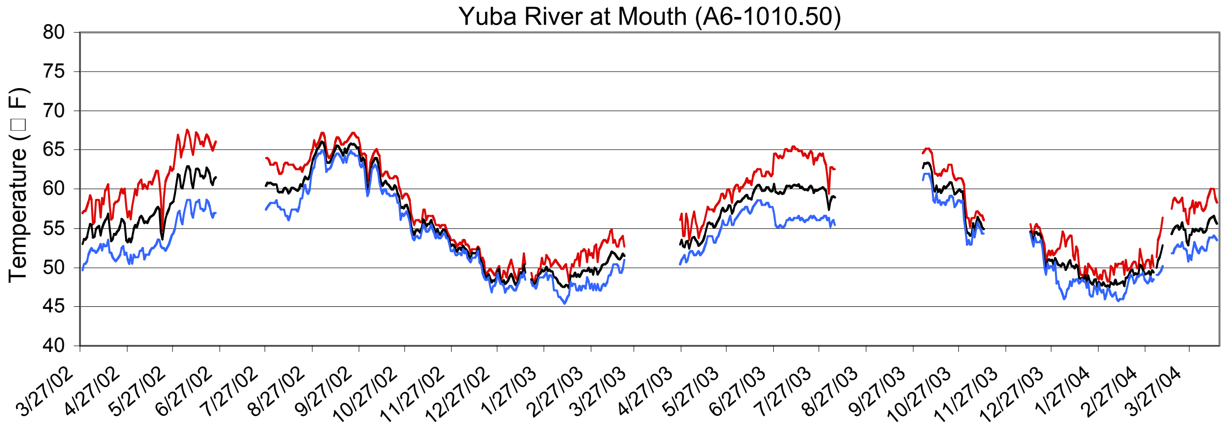
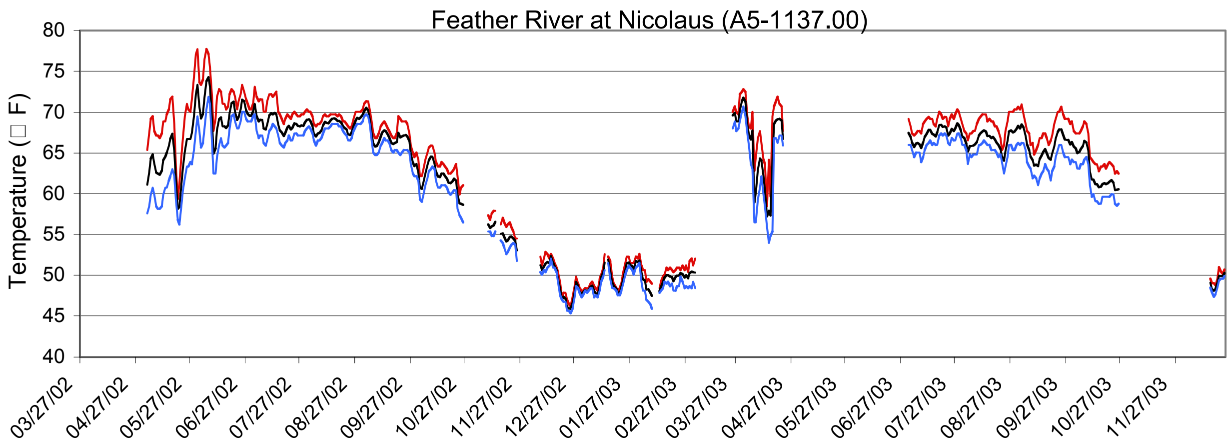
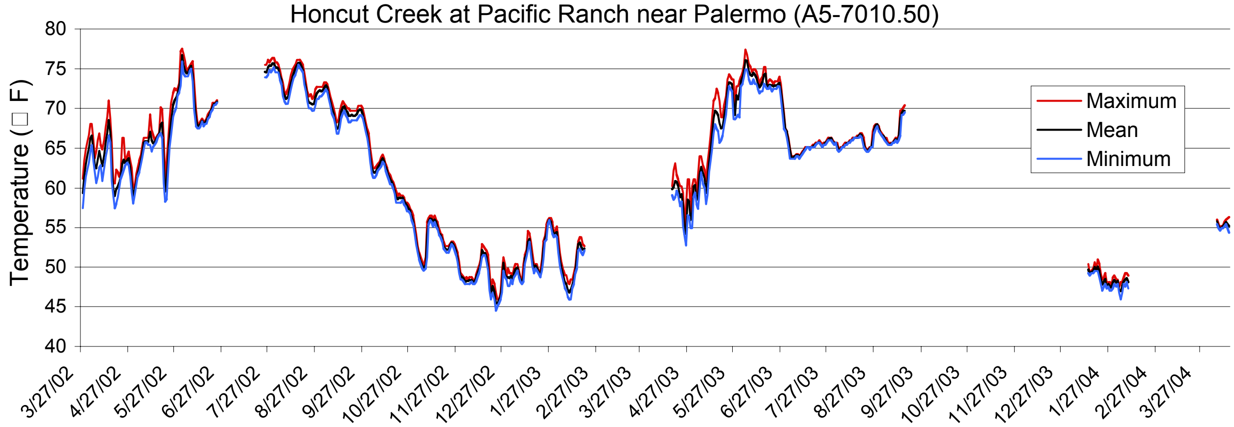
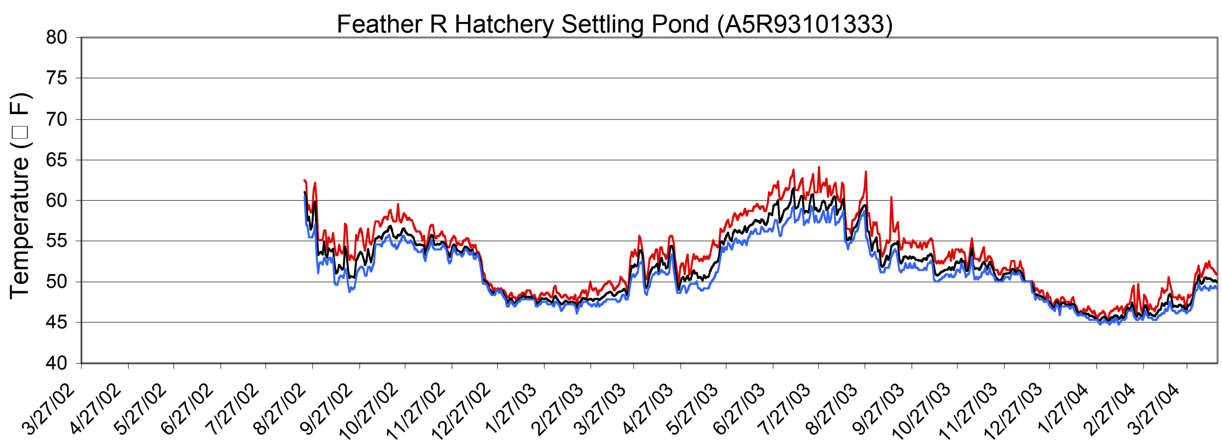




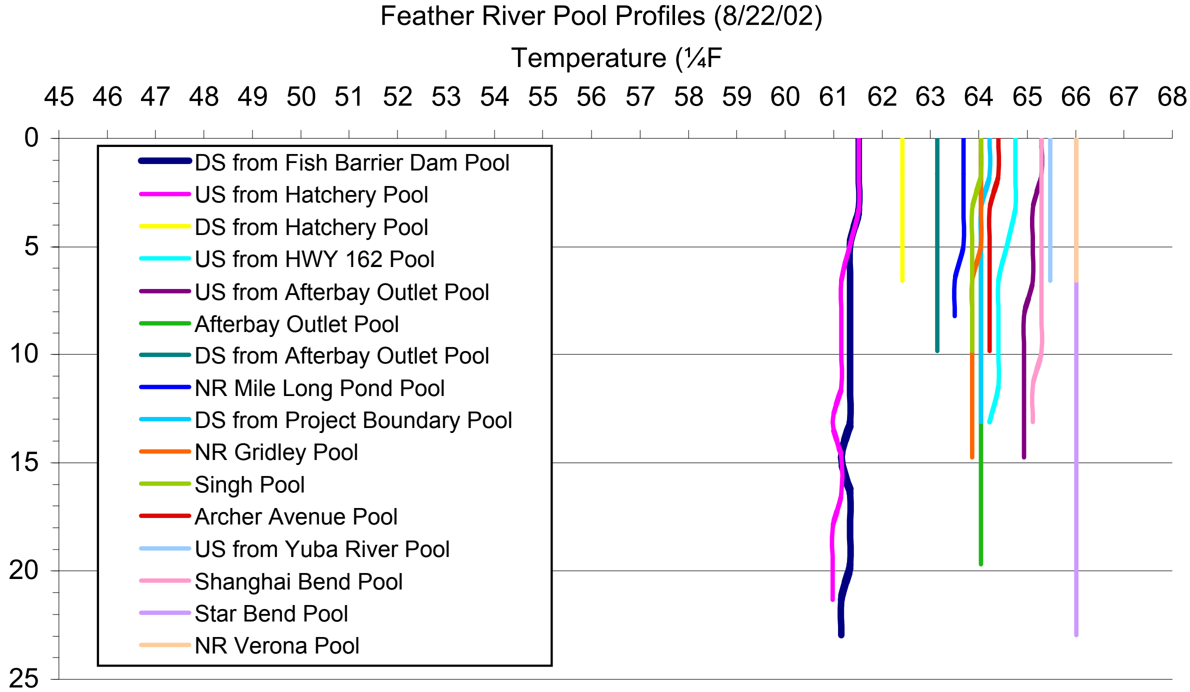


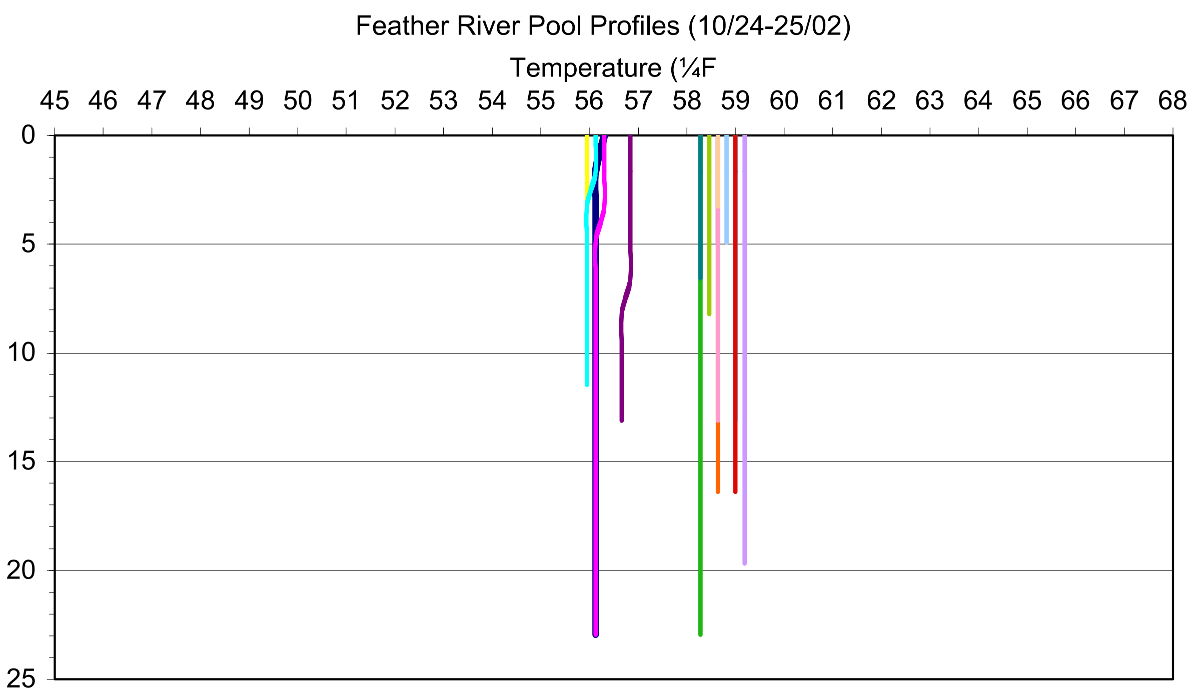
Appendix 5a. Continued.





Appendix 5b. Water temperatures in pools in the lower Feather River.





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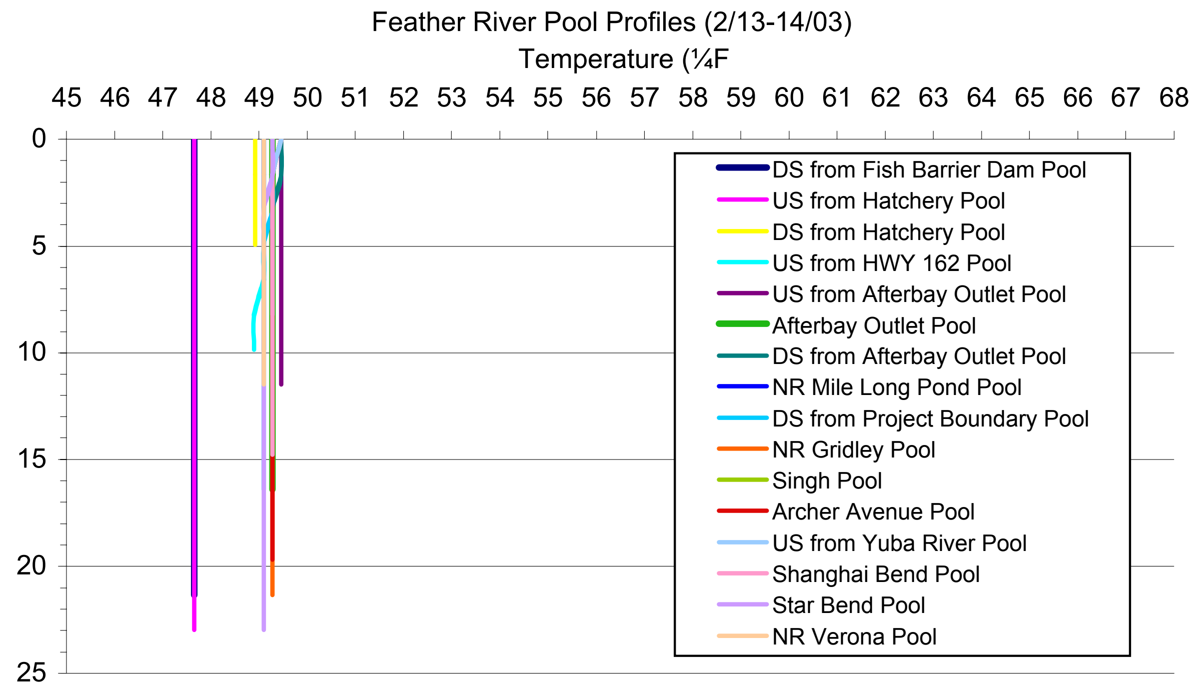

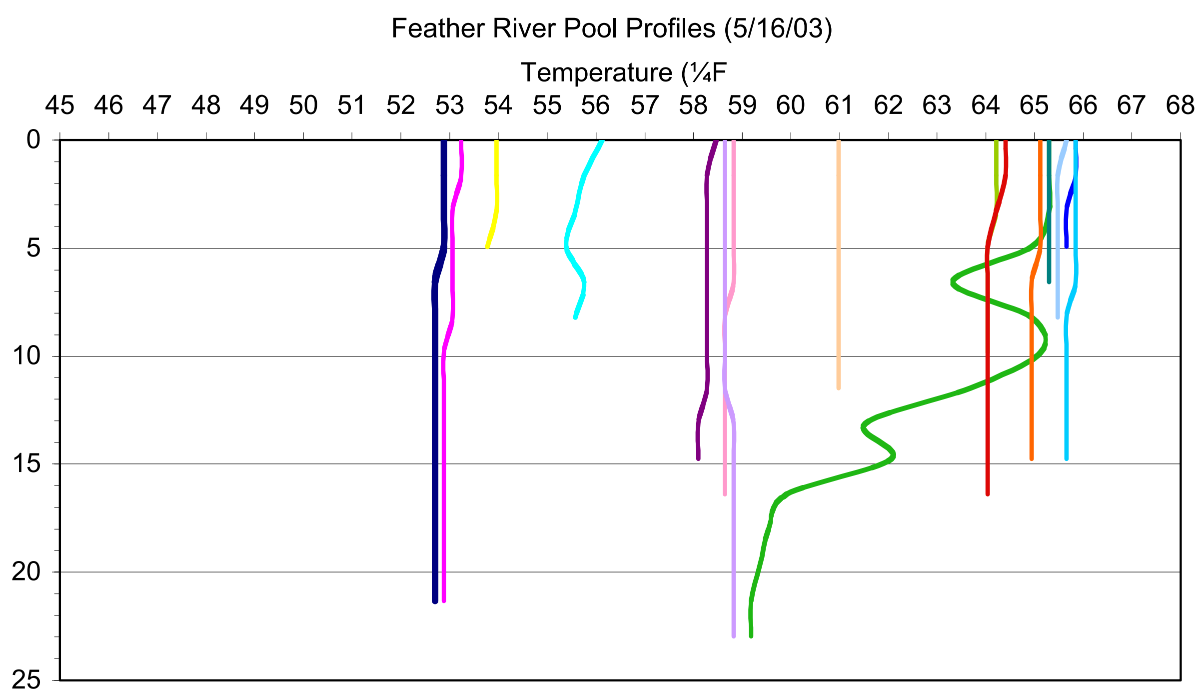

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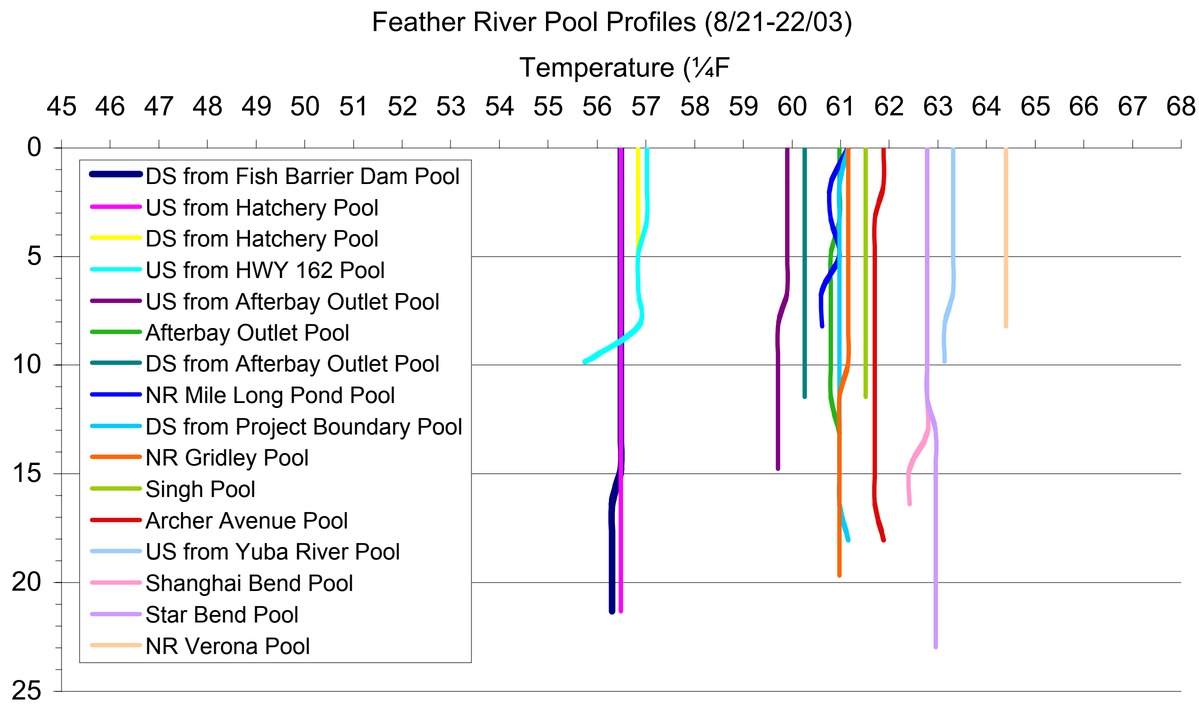

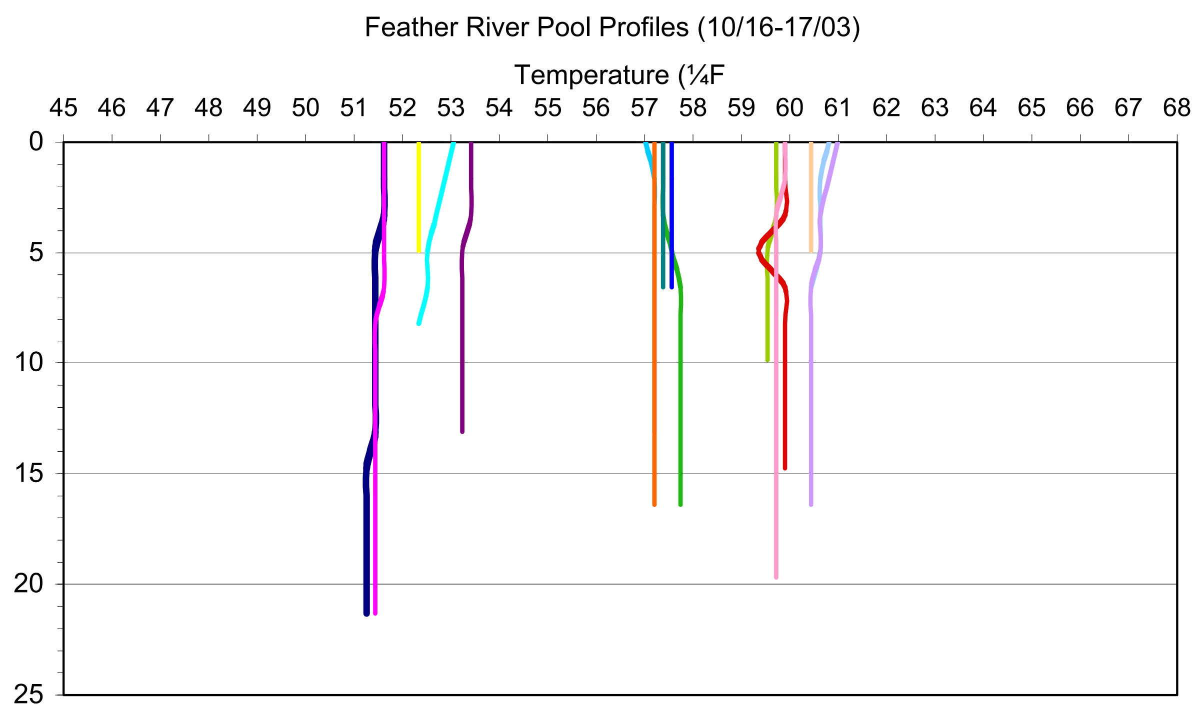

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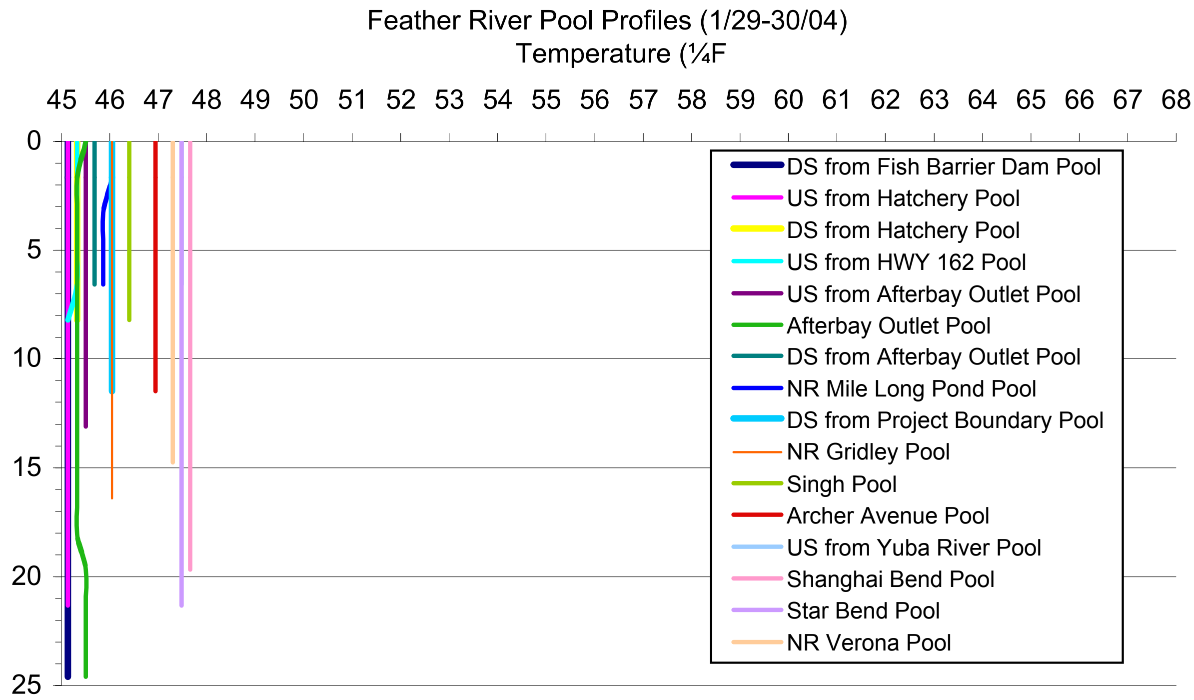
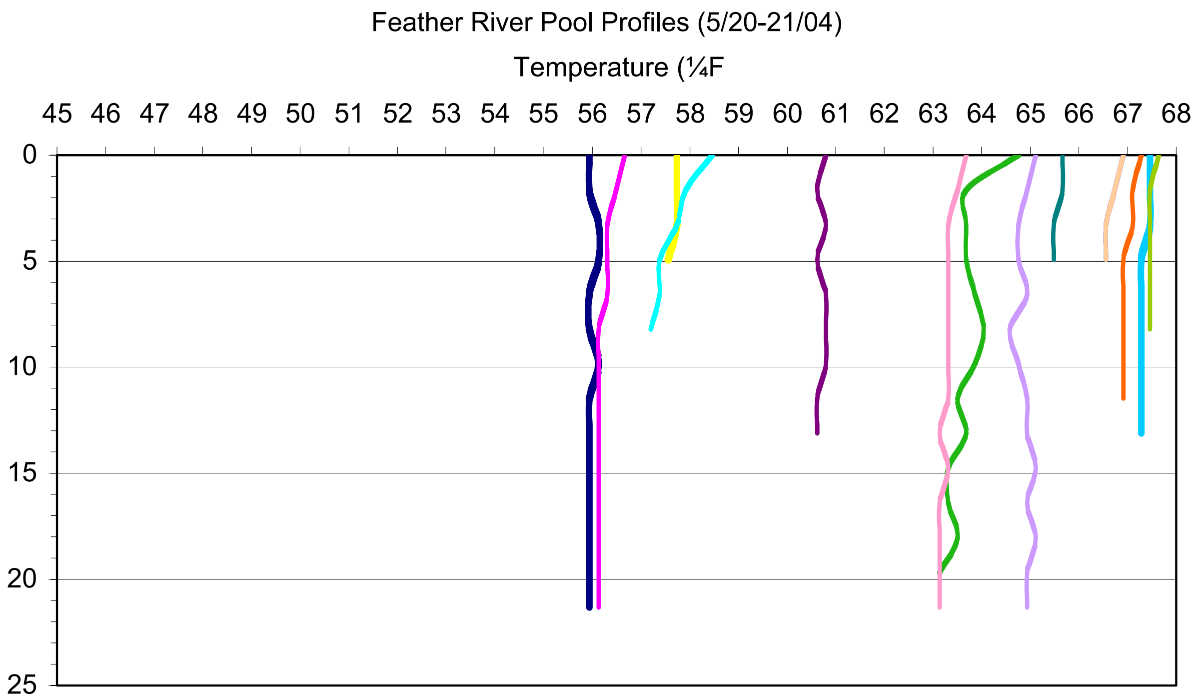
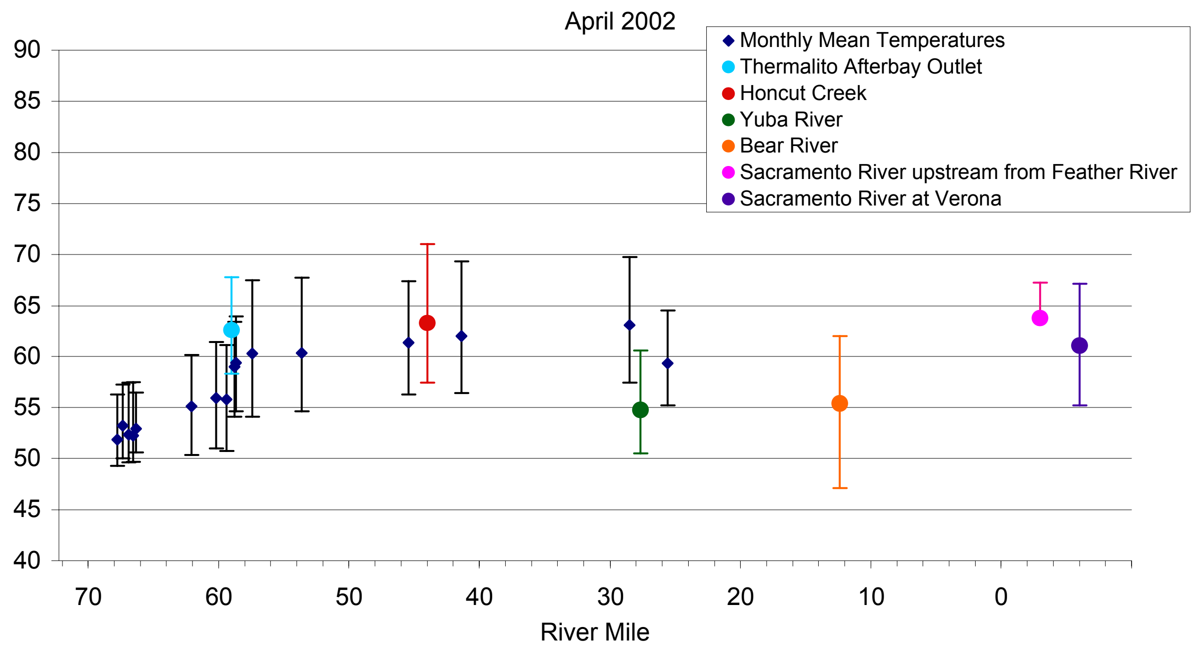
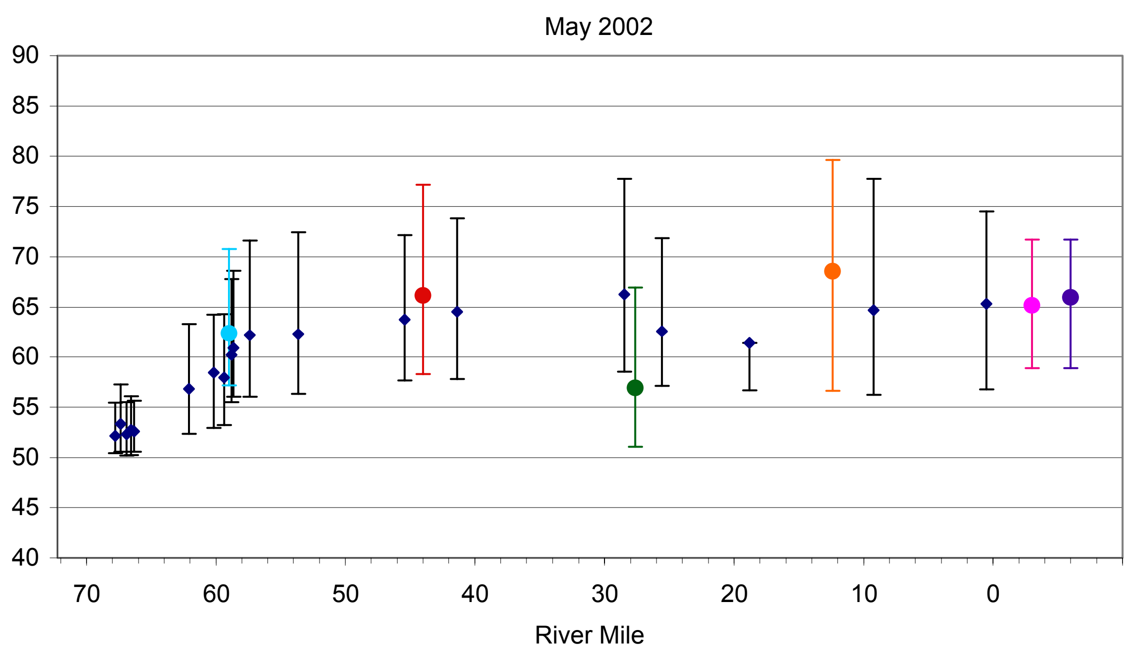




Appendix 5c. Monthly maximum, mean, and minimum temperatures in the Feather River from Oroville Dam to the Sacramento River.





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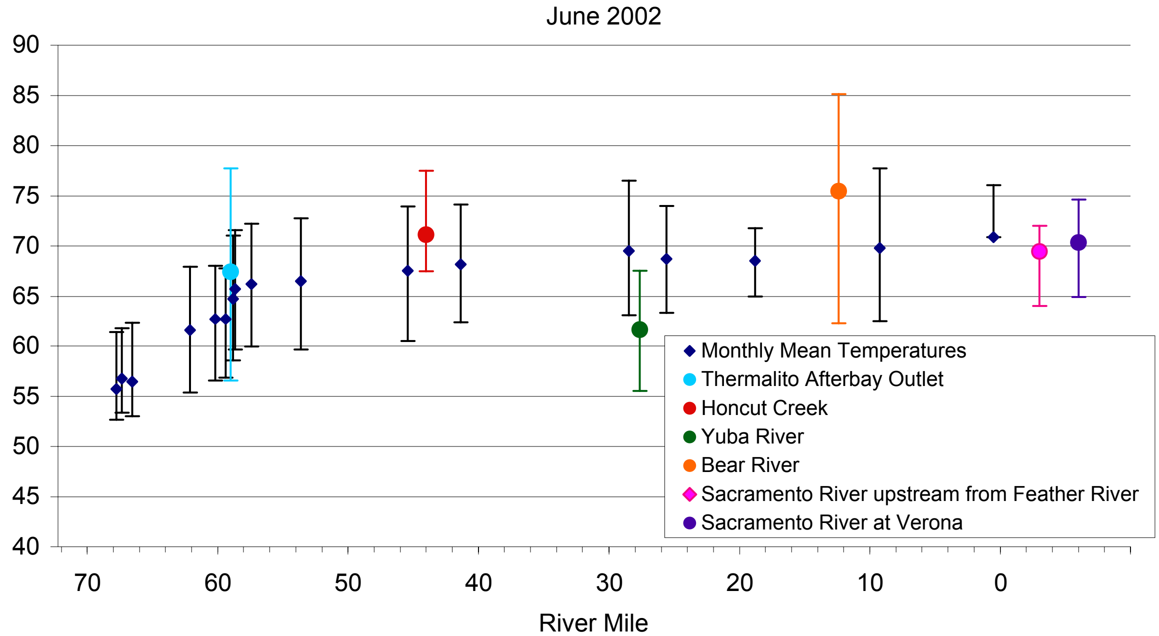

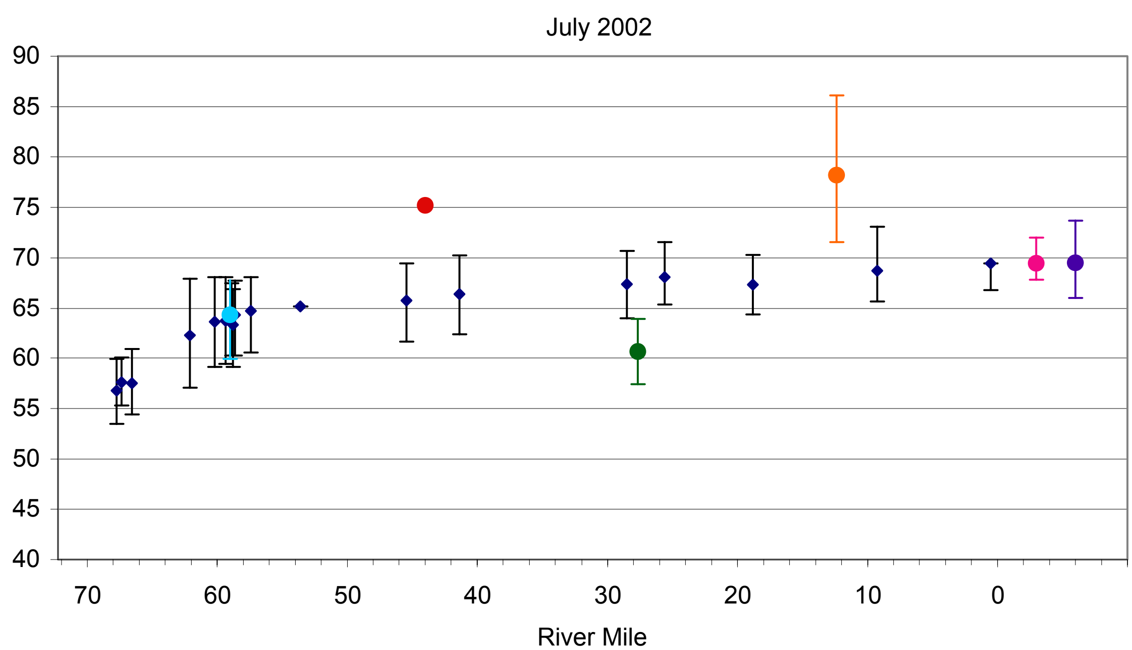

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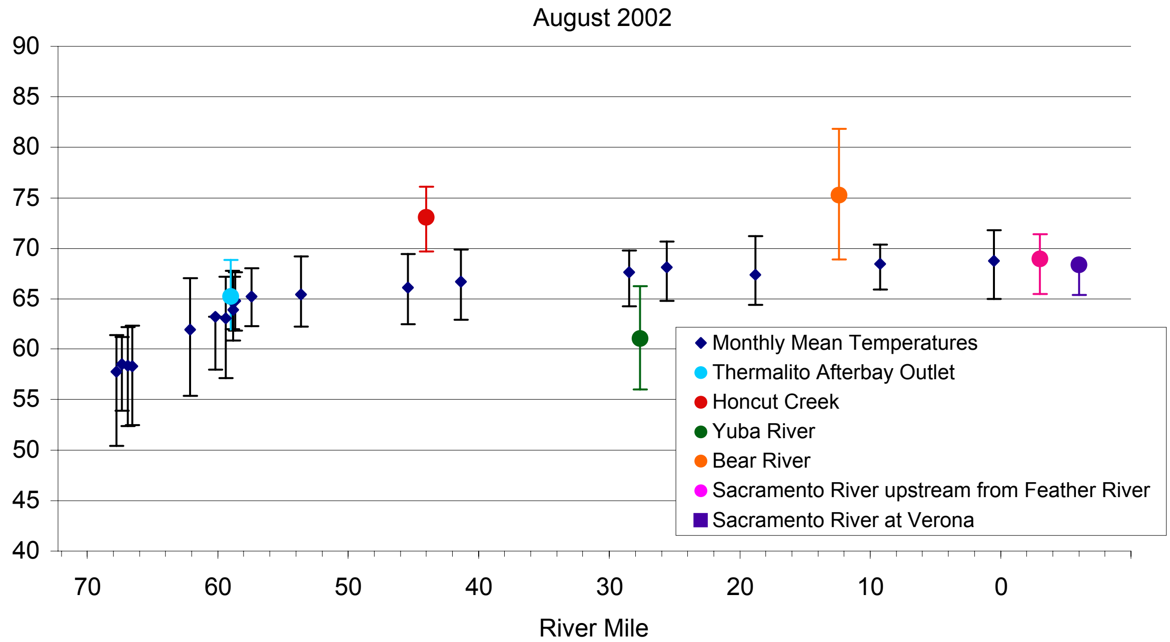

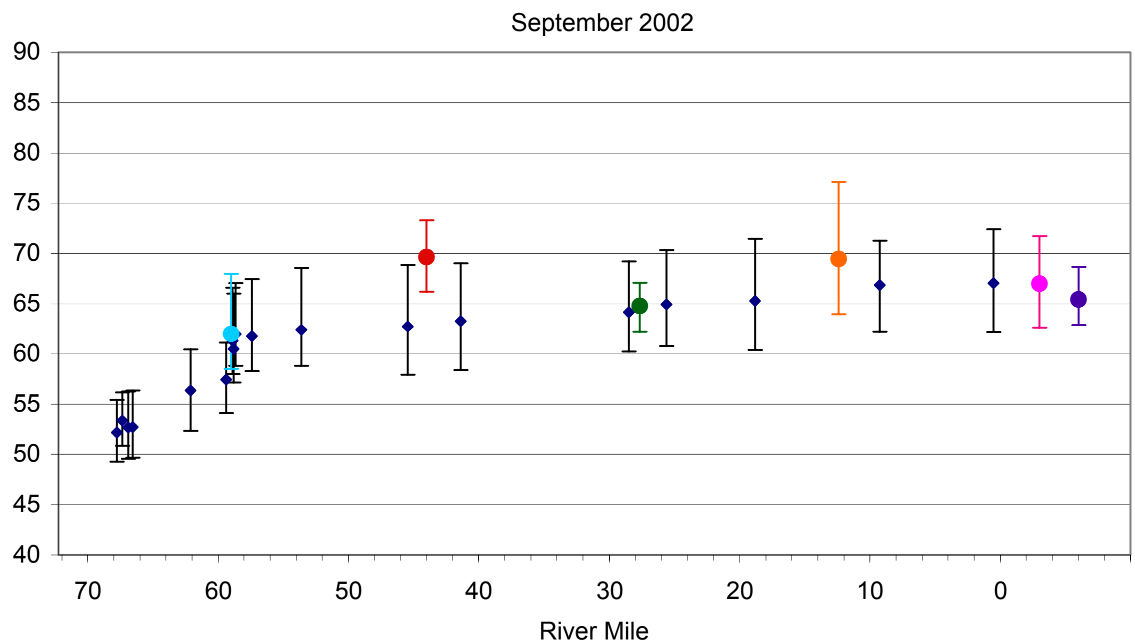

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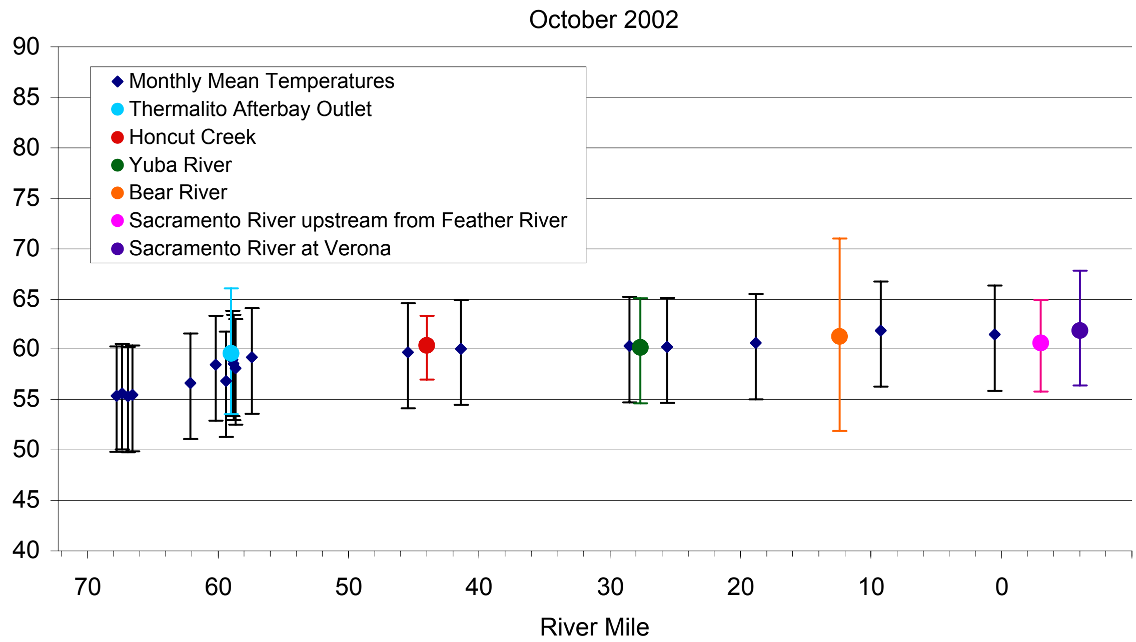

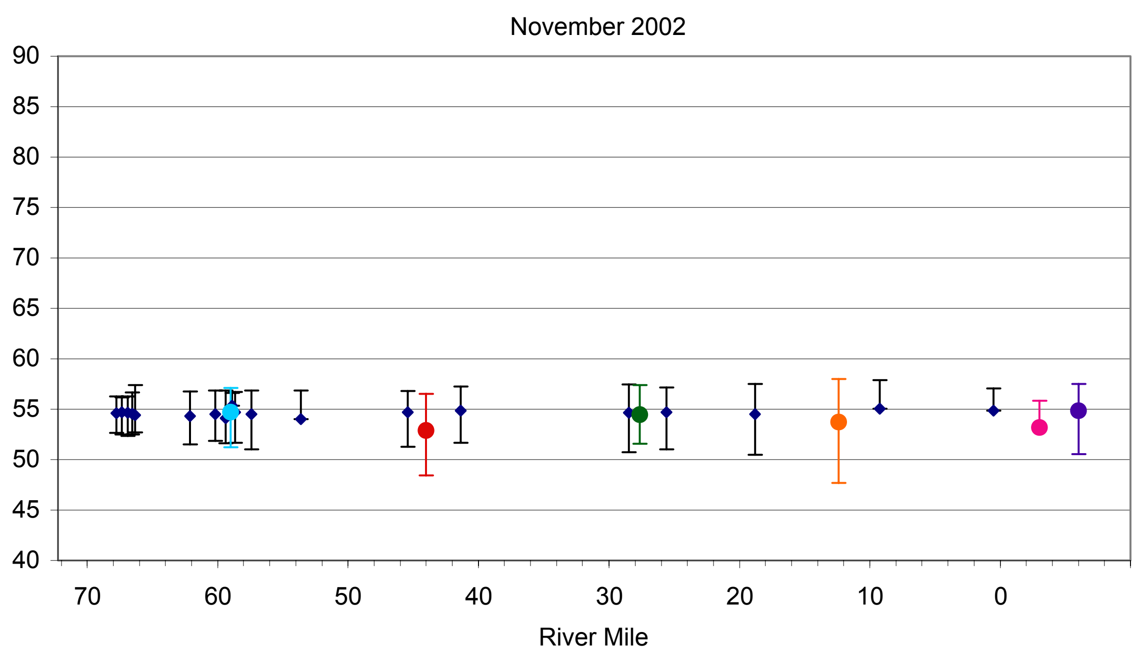

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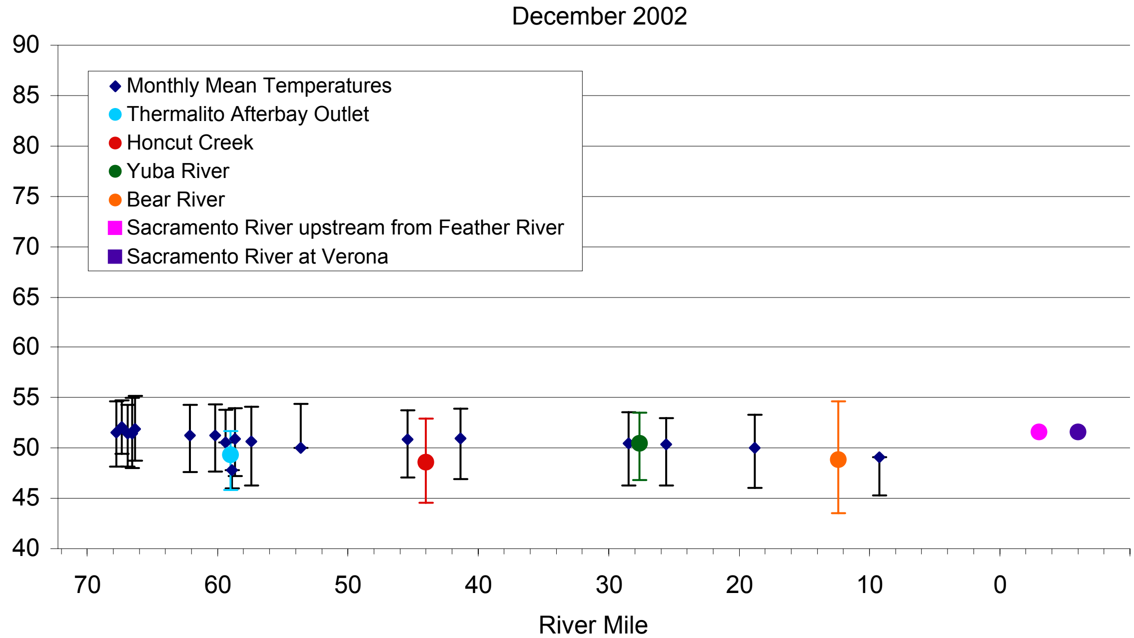

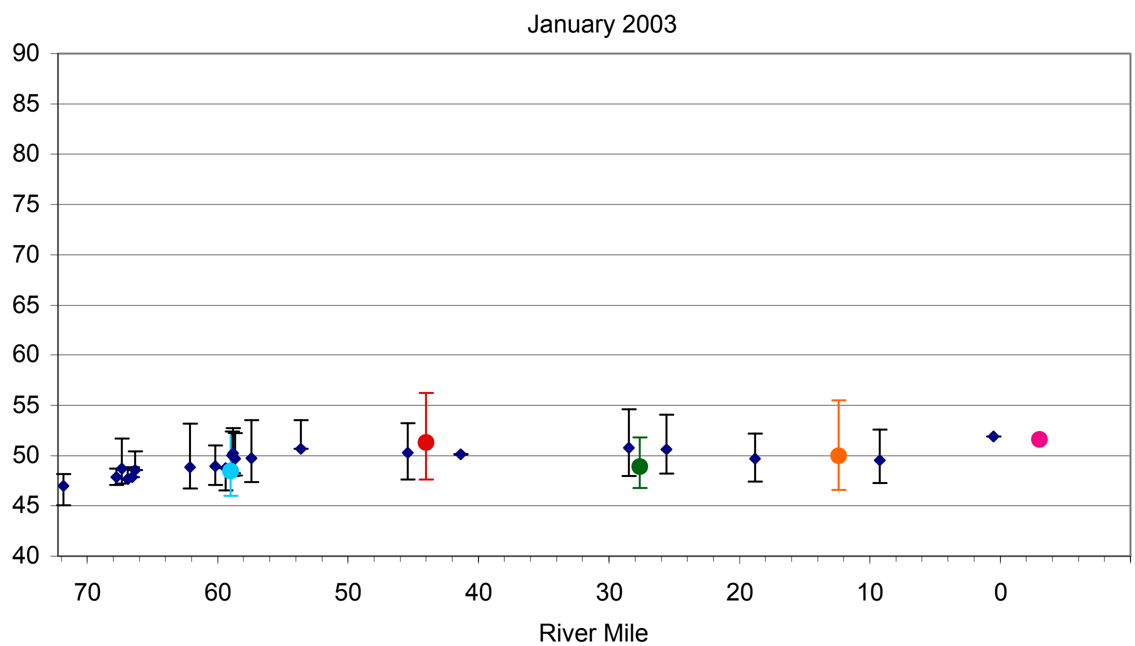

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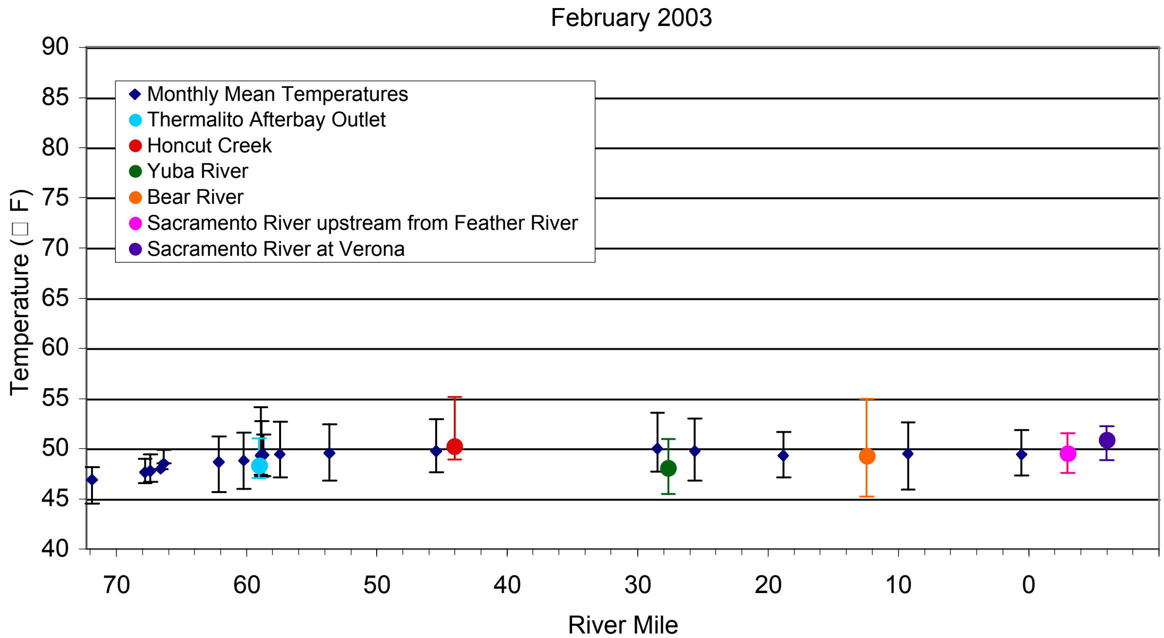

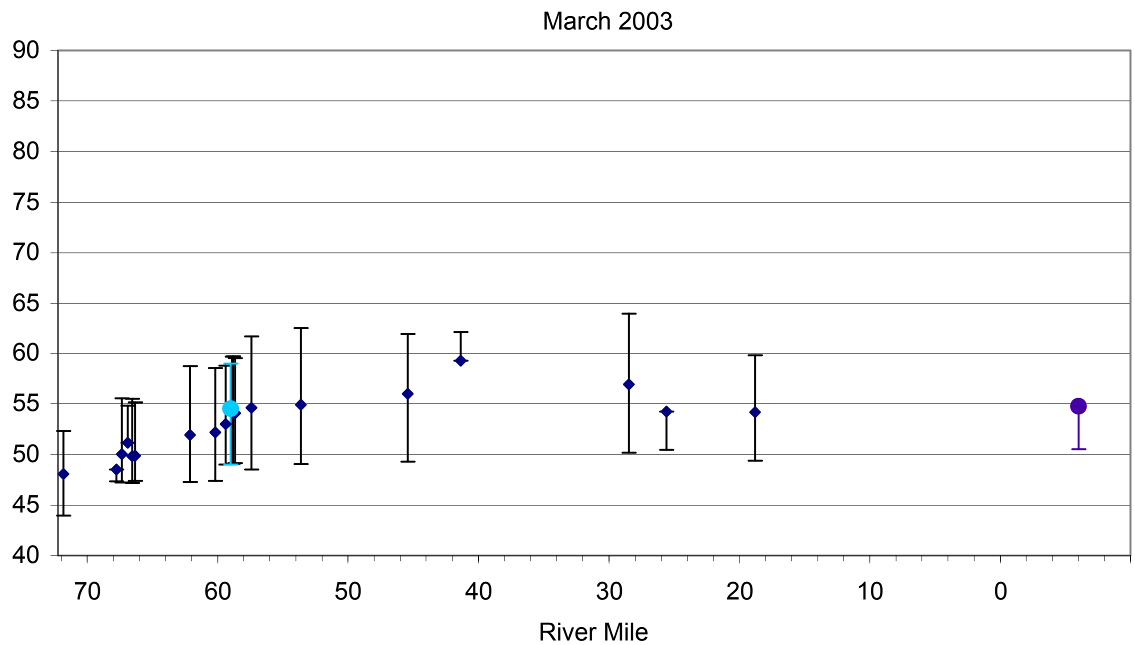

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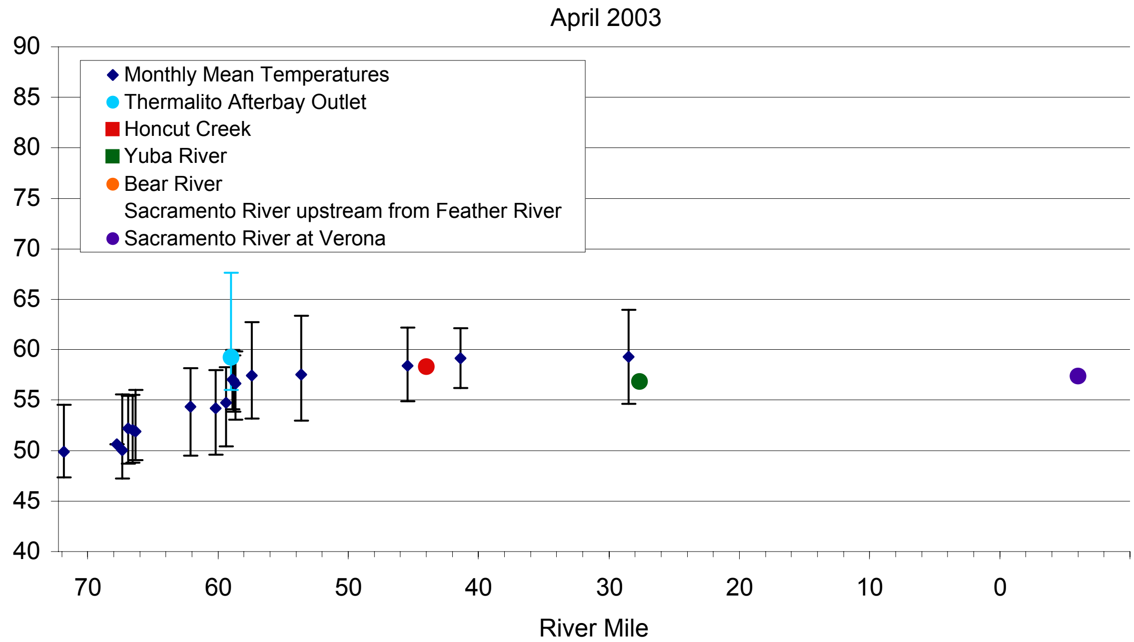

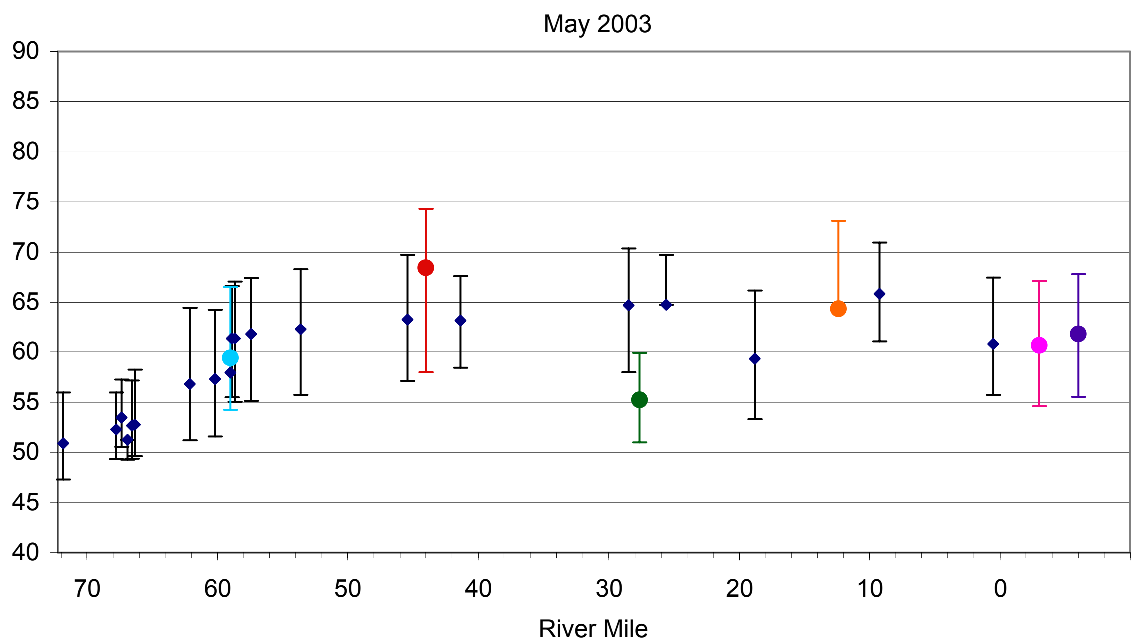

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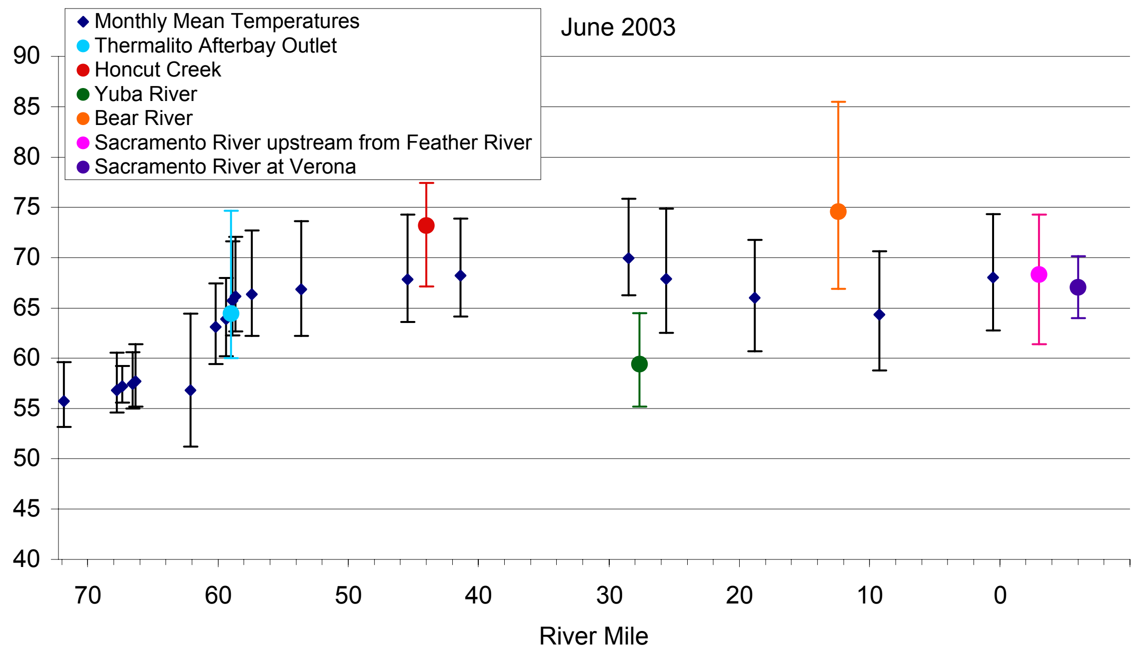

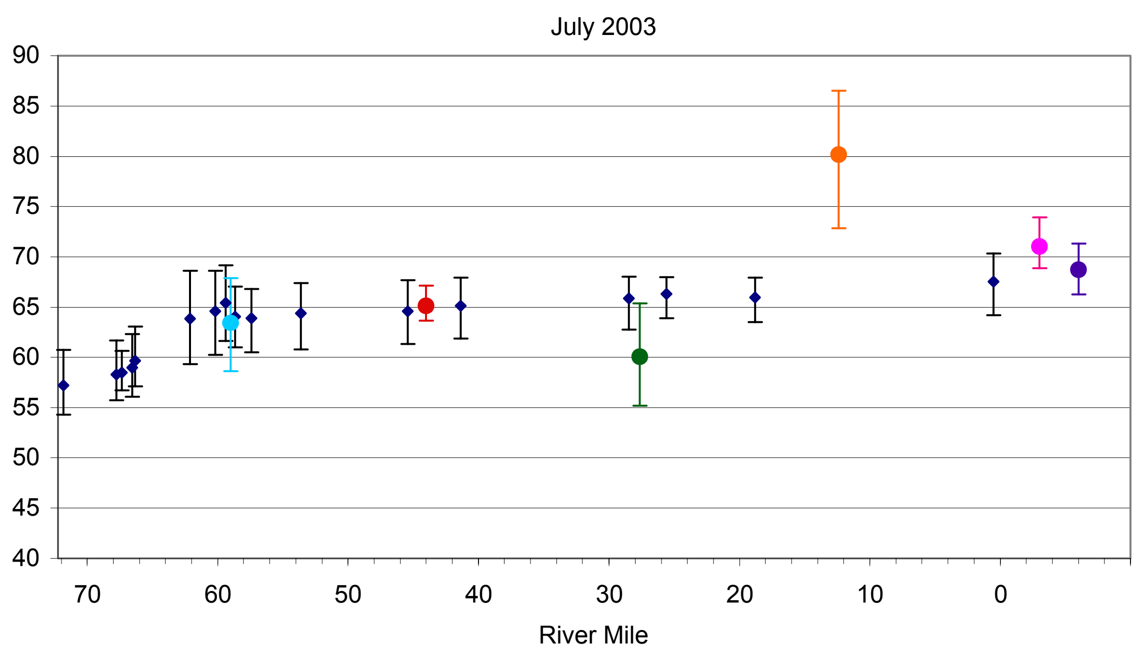

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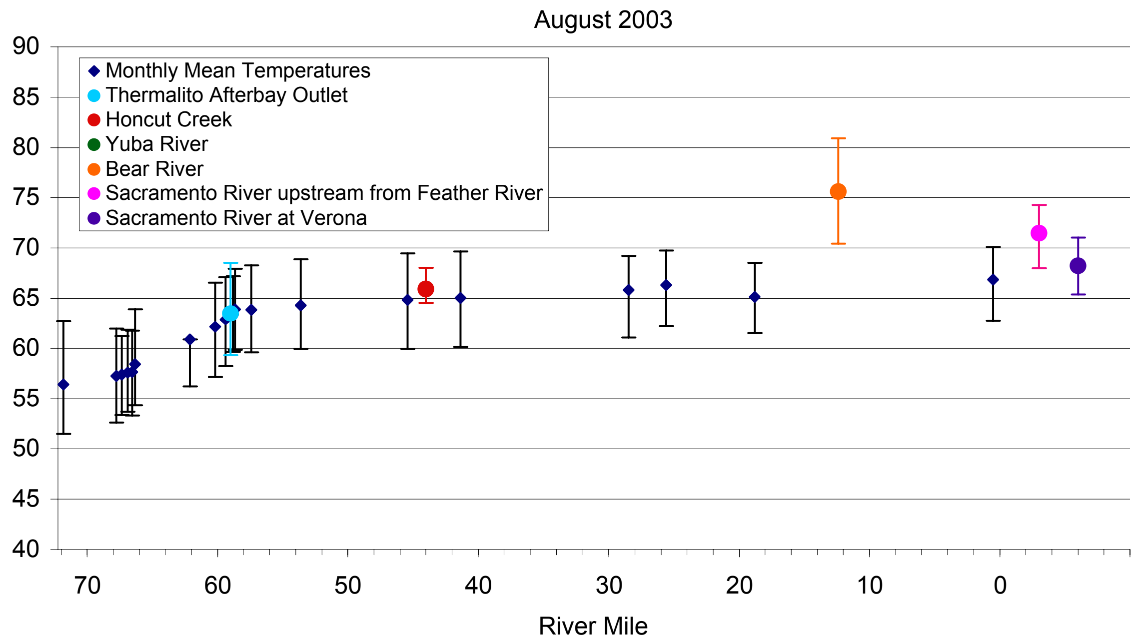

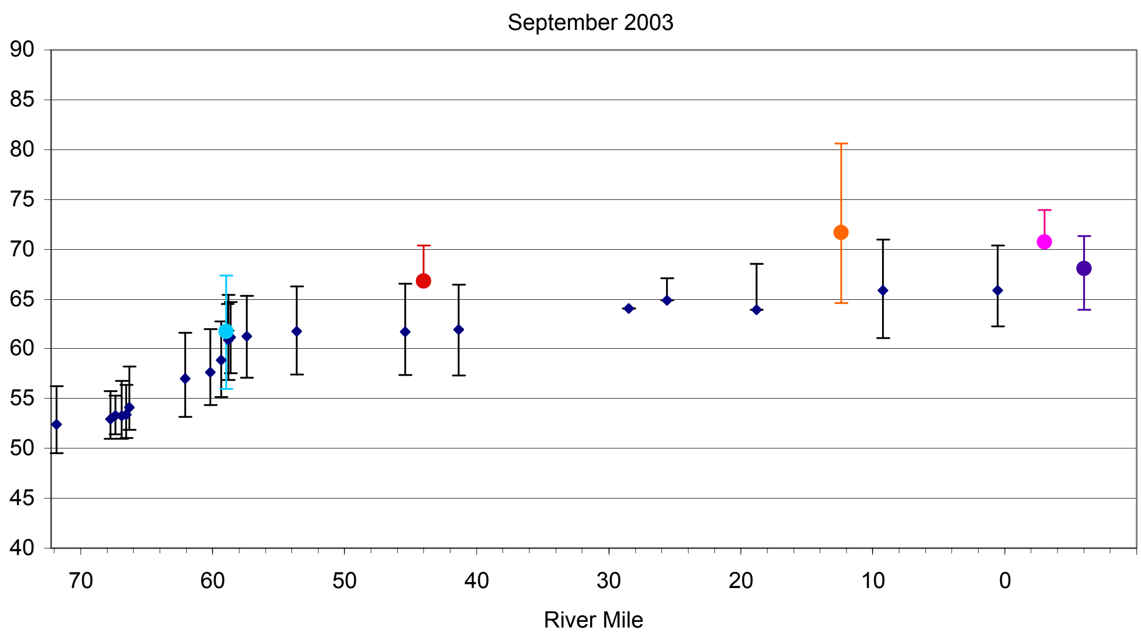

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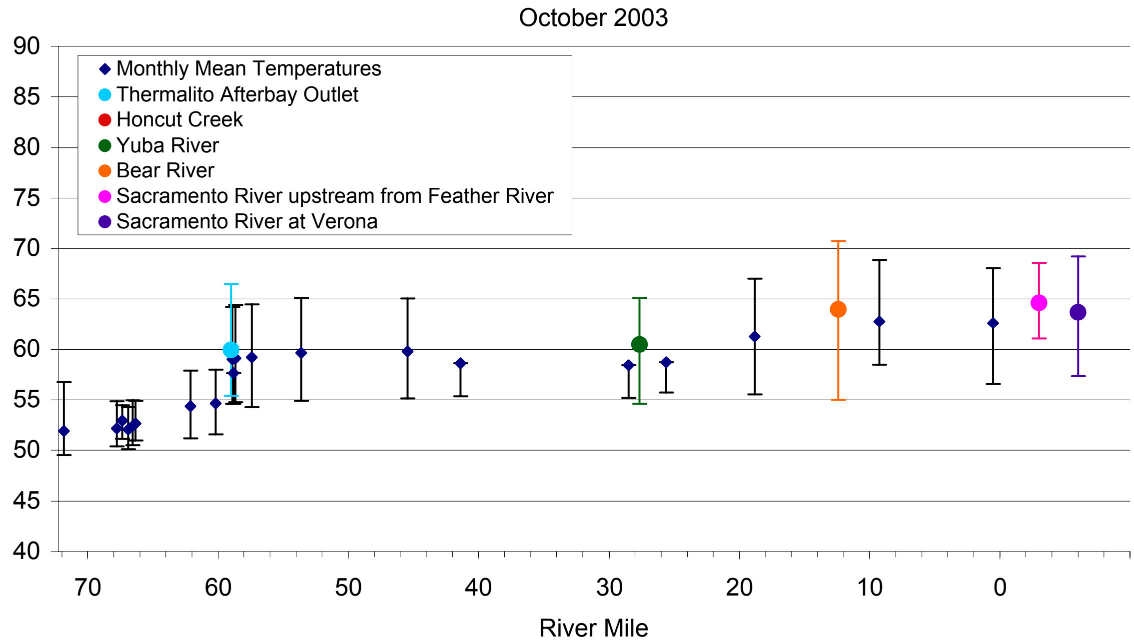

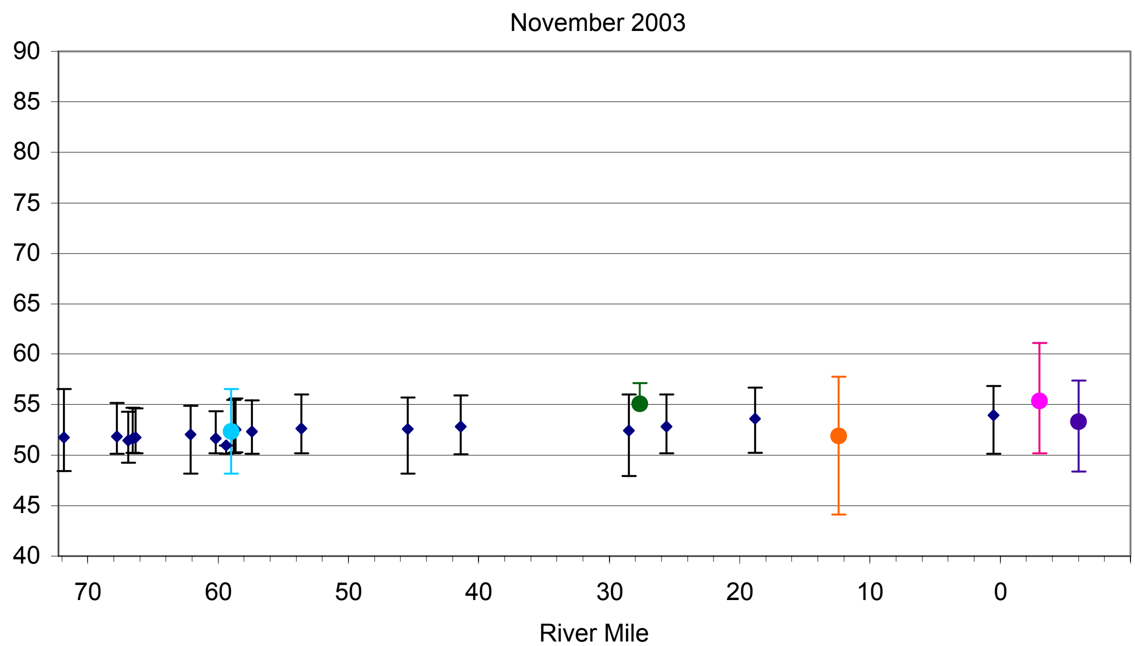

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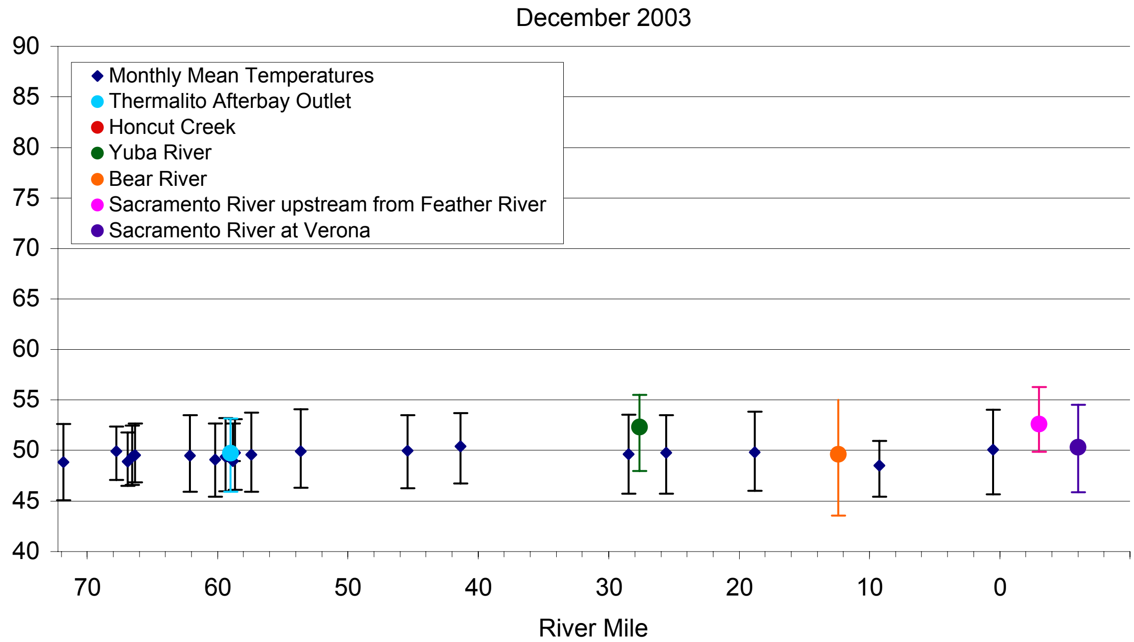

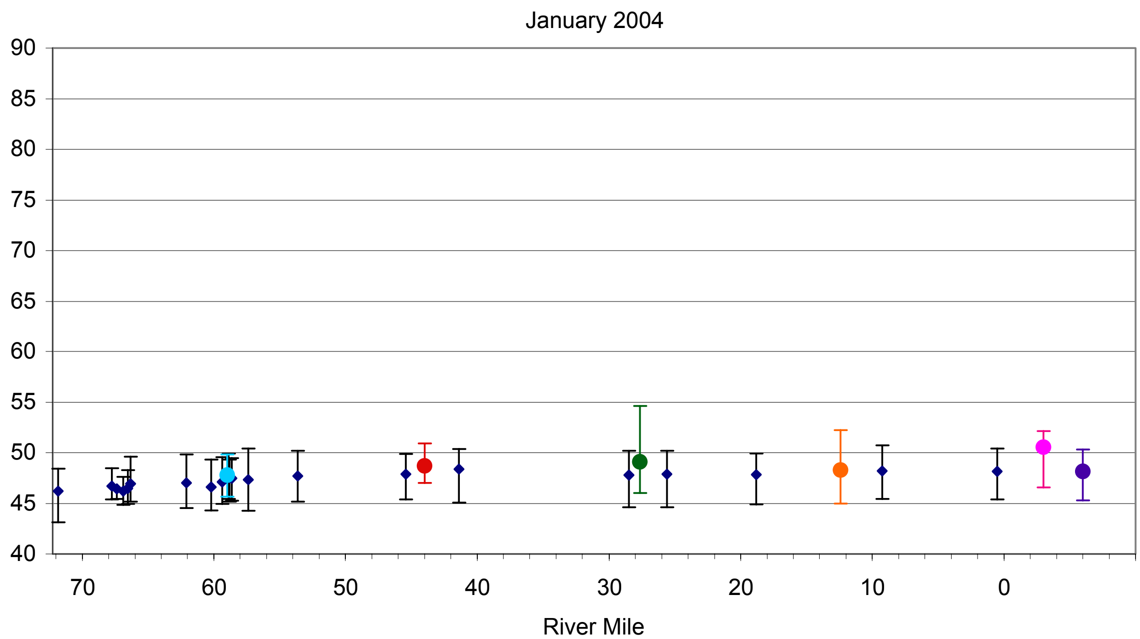

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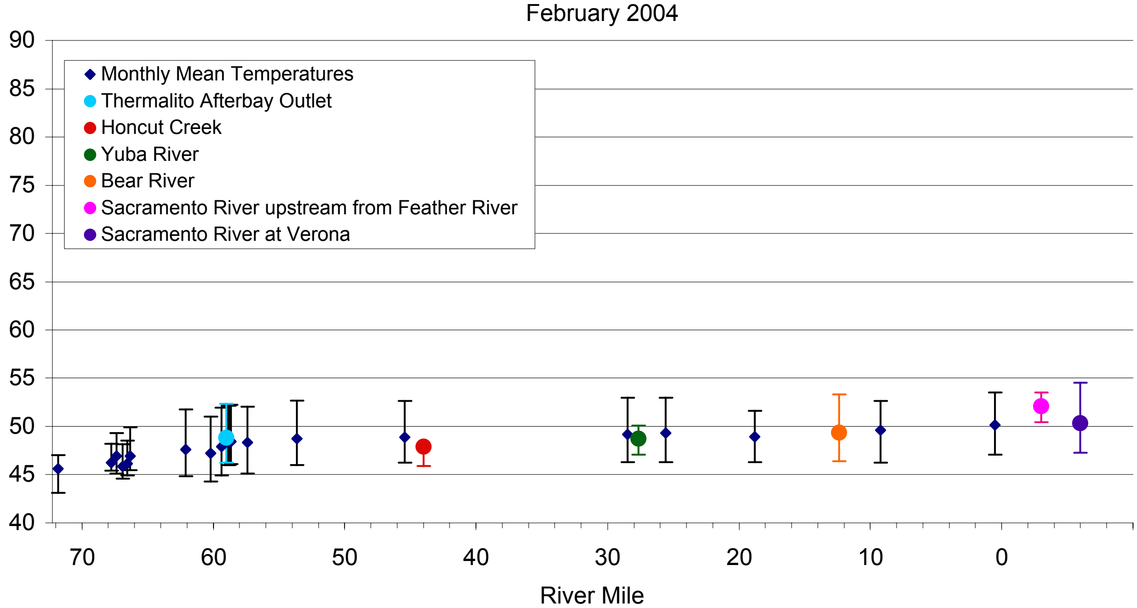
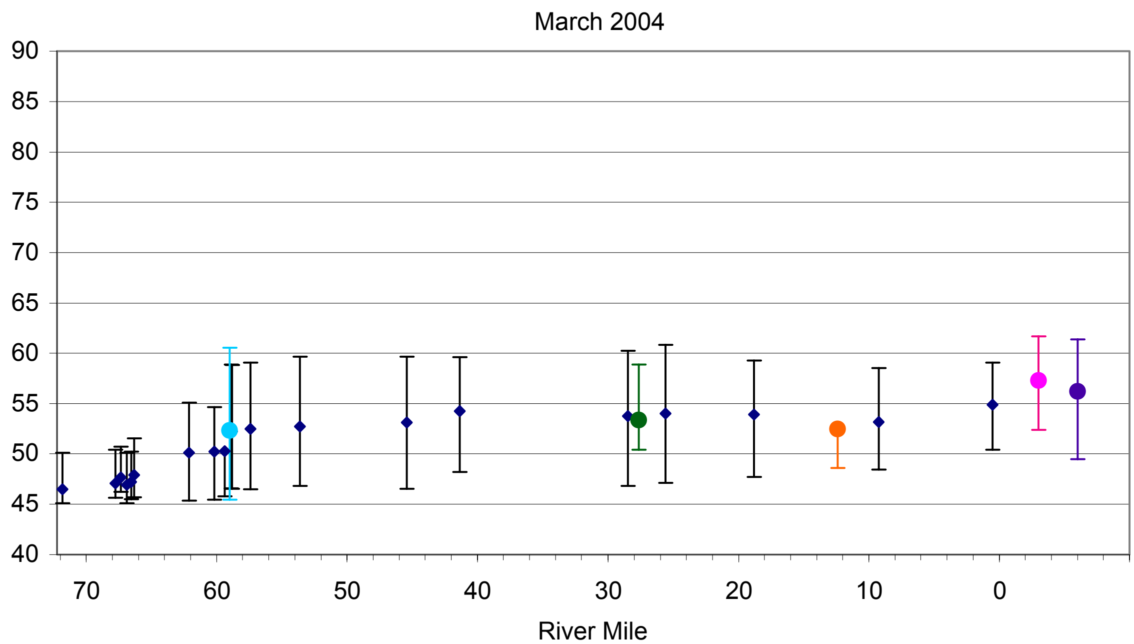
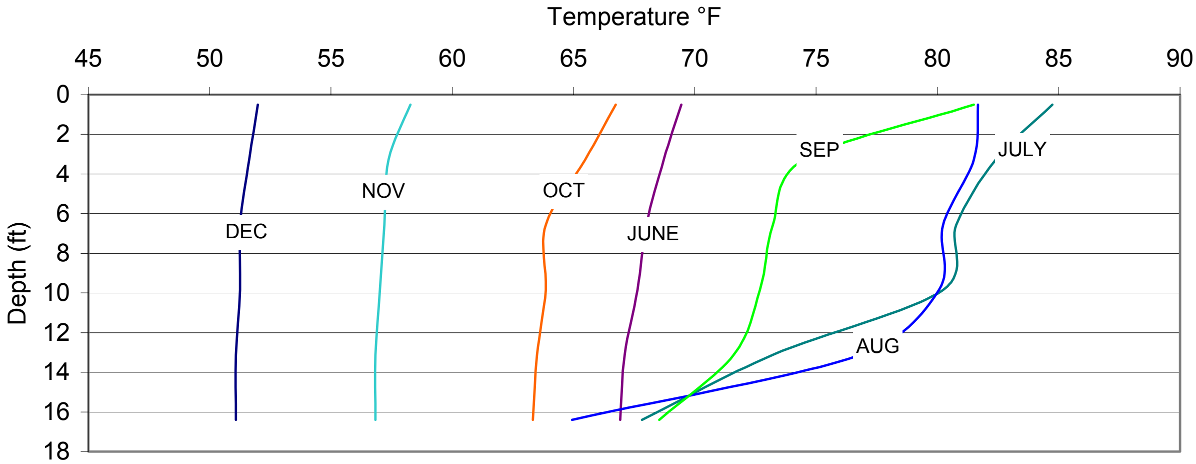


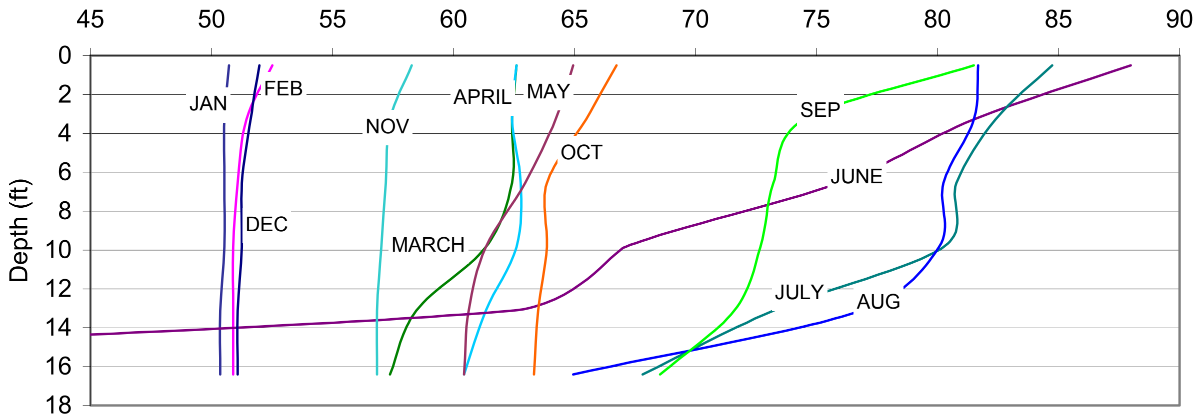


Appendix 6. Water temperatures in the Oroville Wildlife Area ponds.

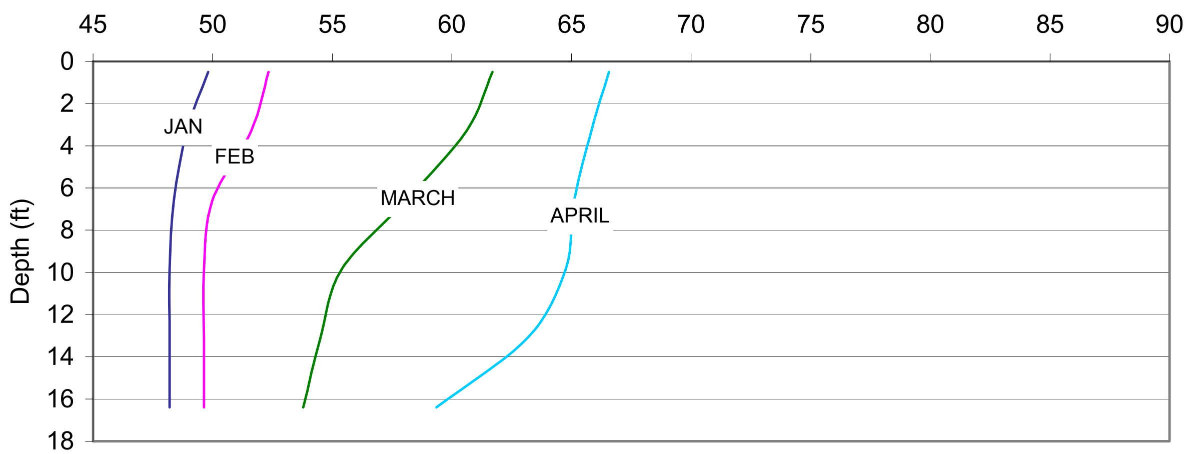
Oroville Fishing Pond - 2002



2003



2004



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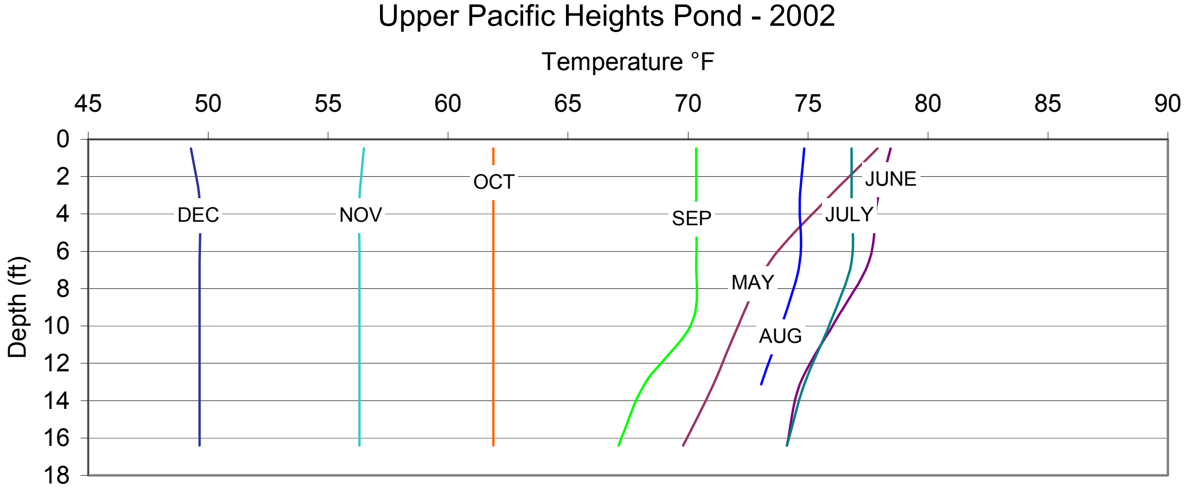

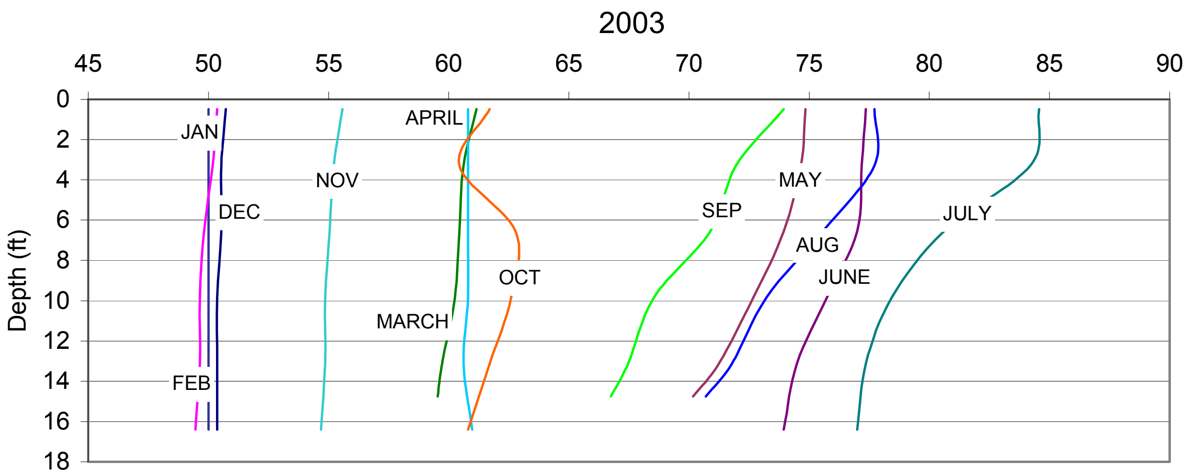

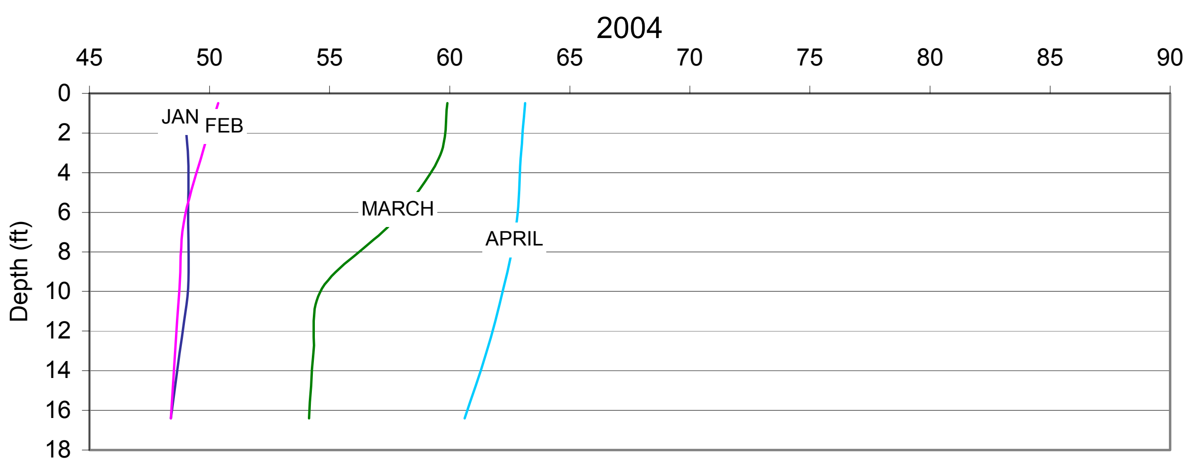

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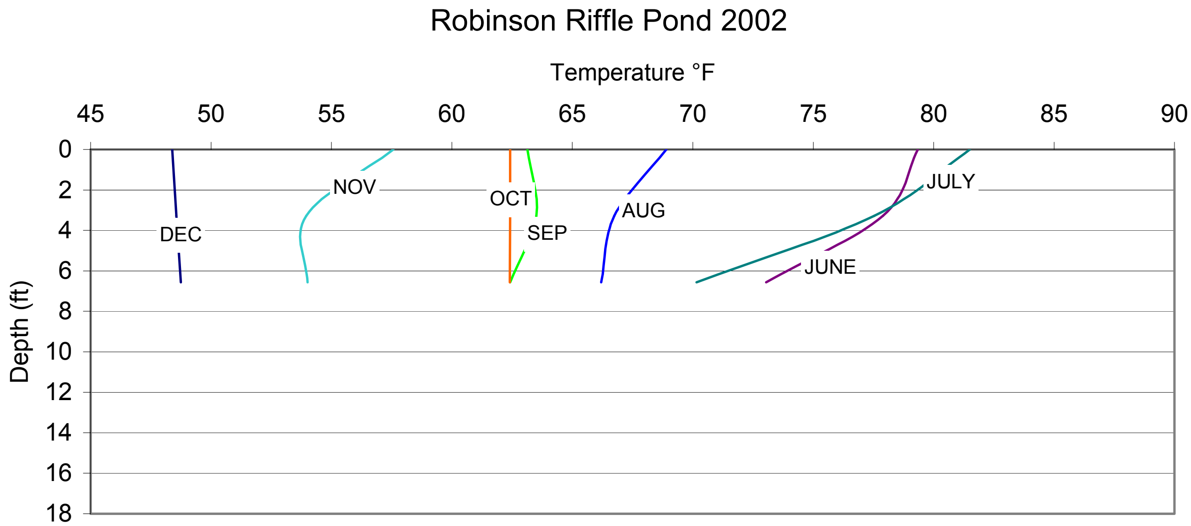
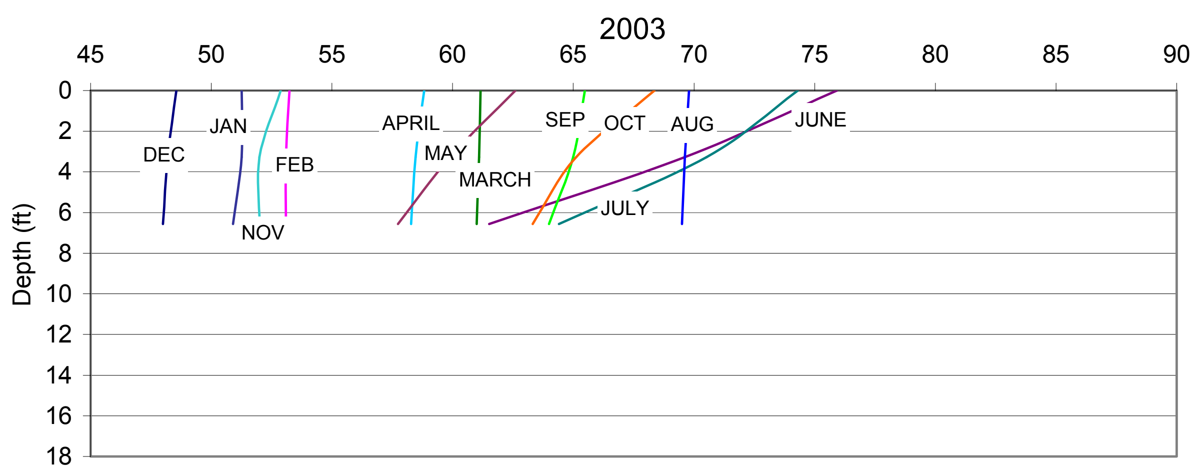
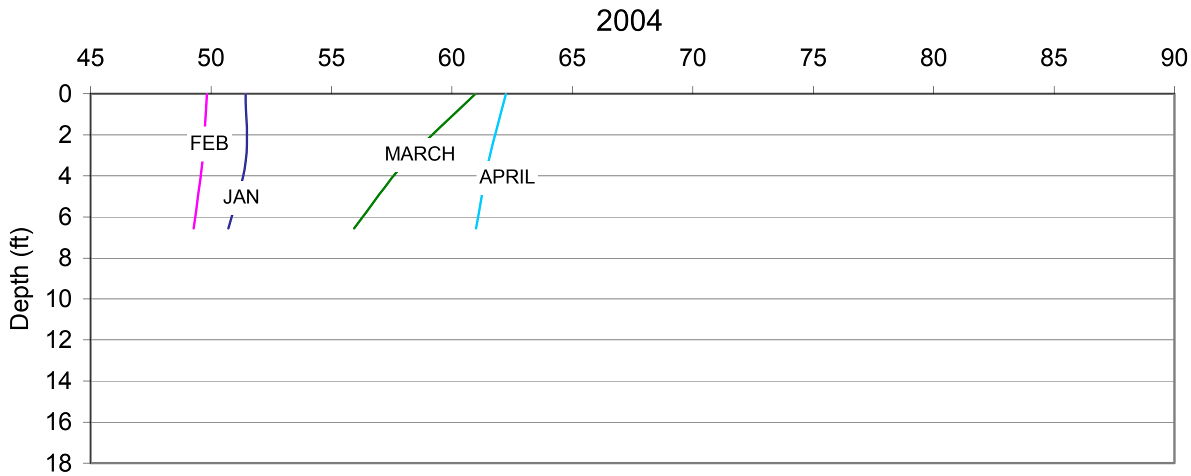
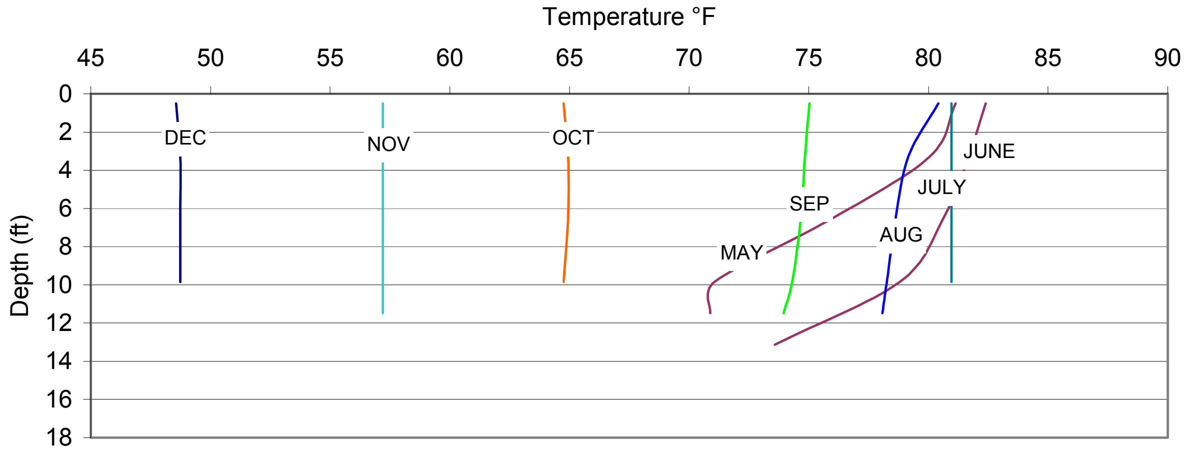




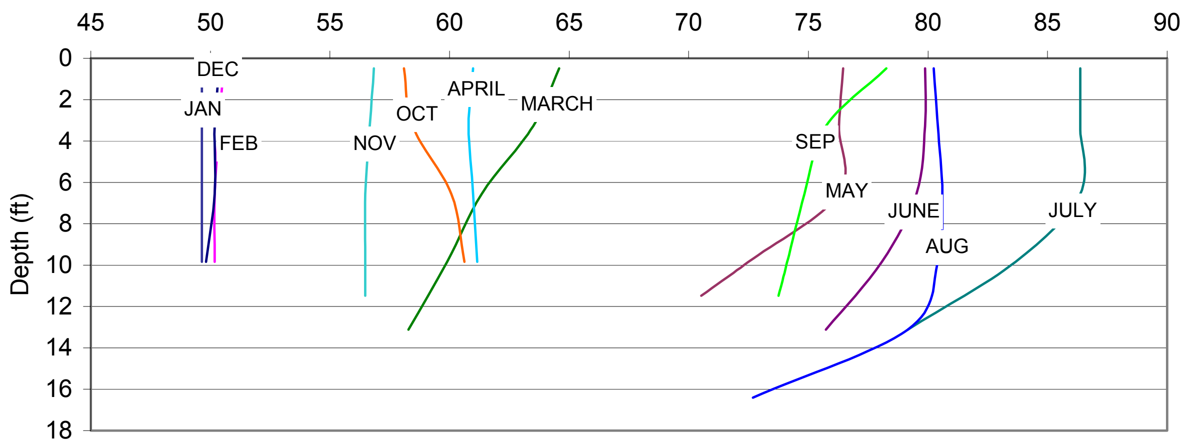


Appendix 6 continued.

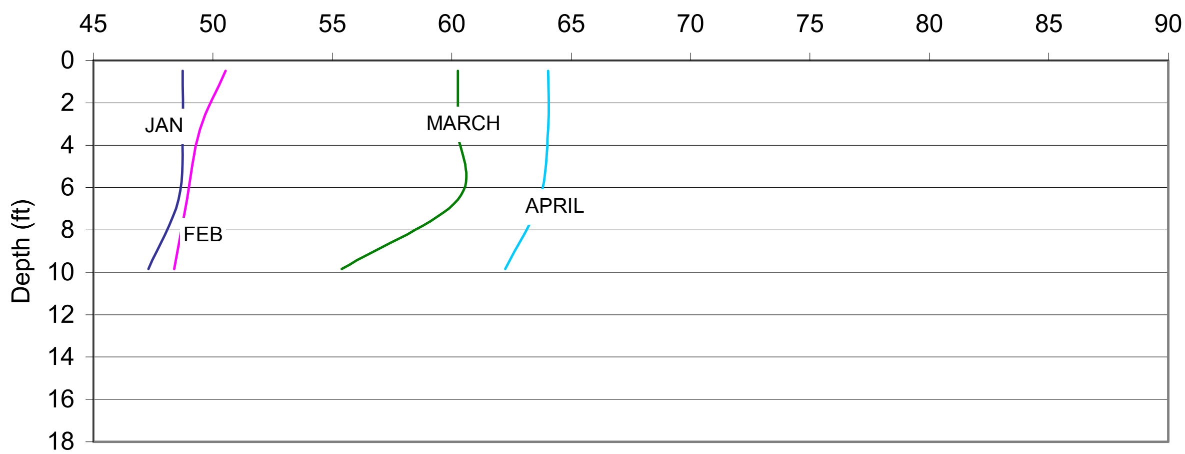
Lower Pacific Heights Pond - 2002



2003



2004



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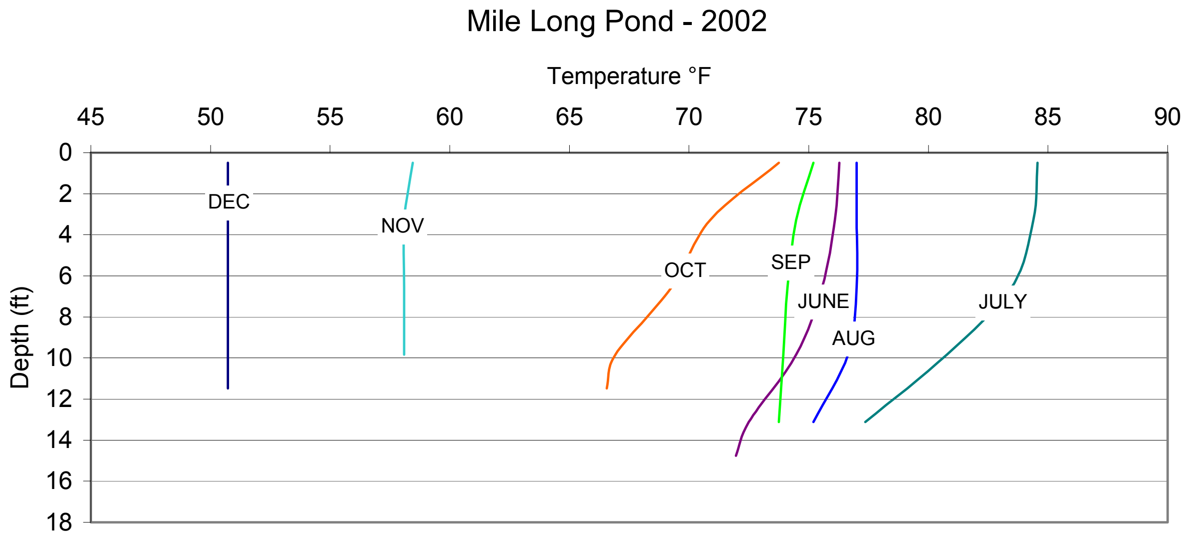
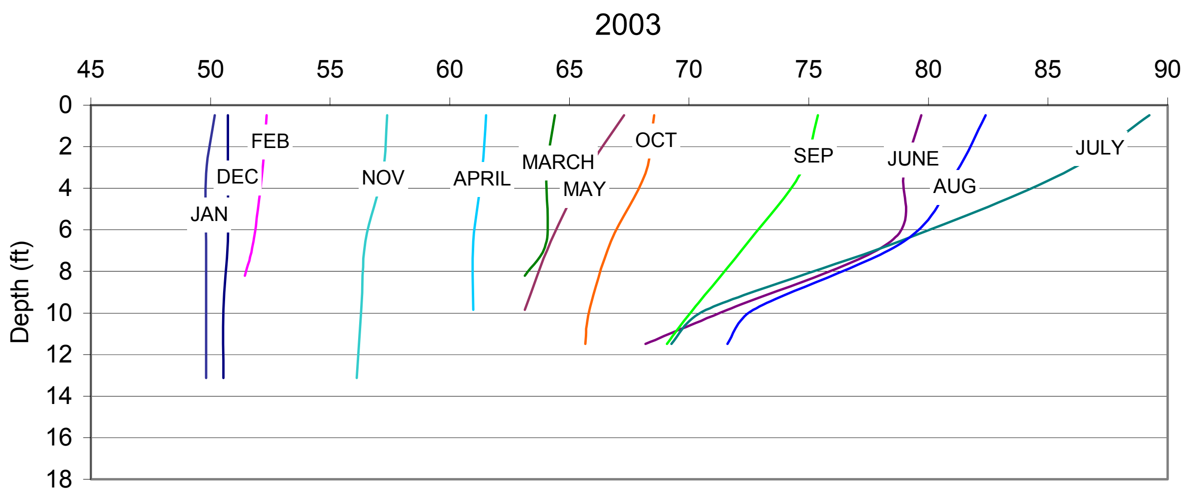
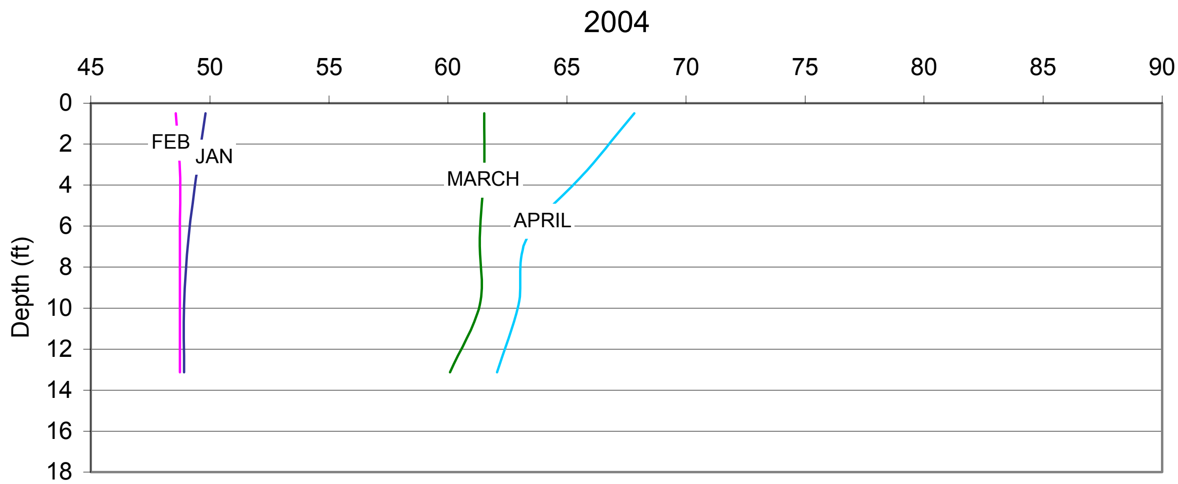
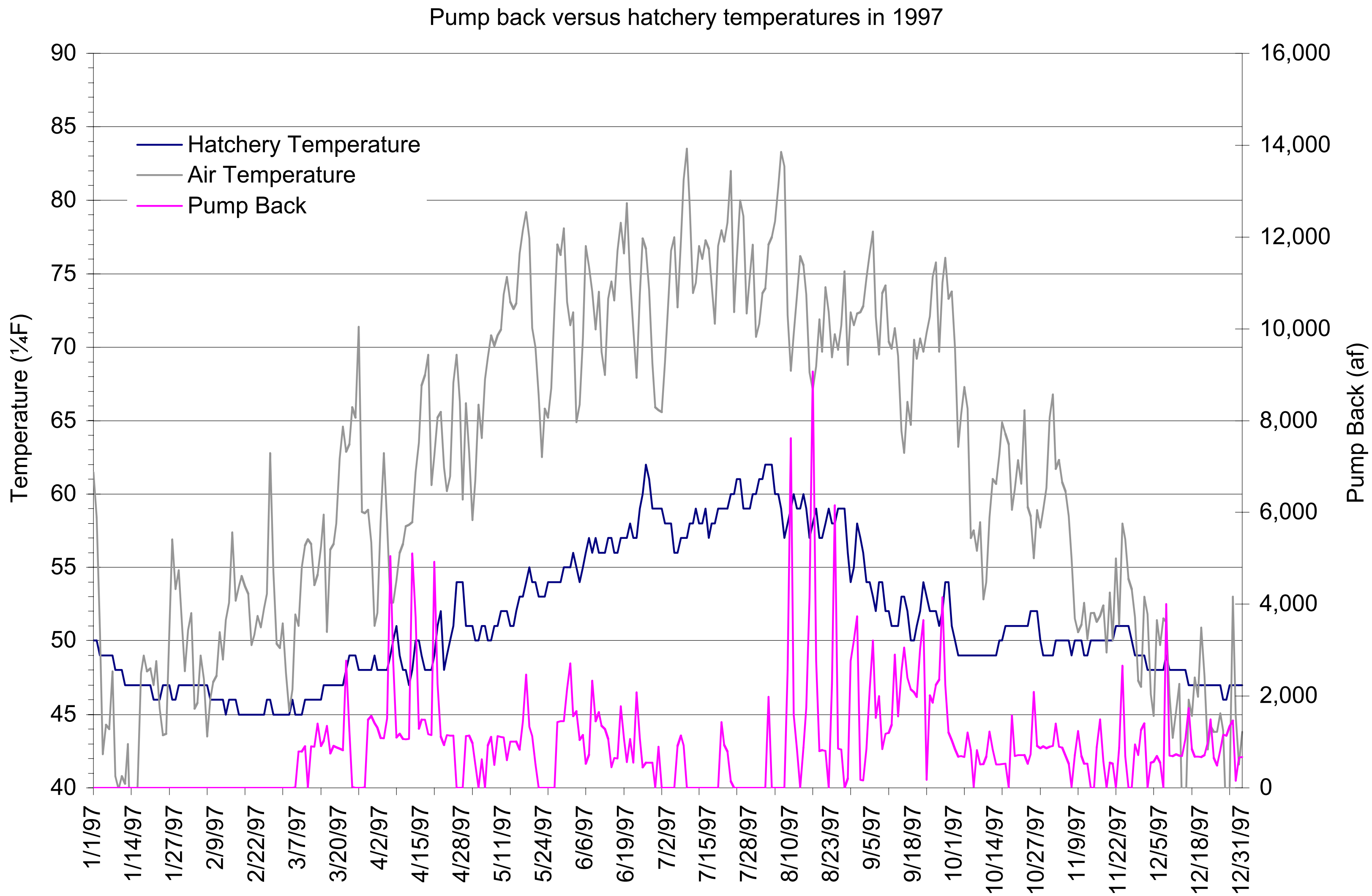


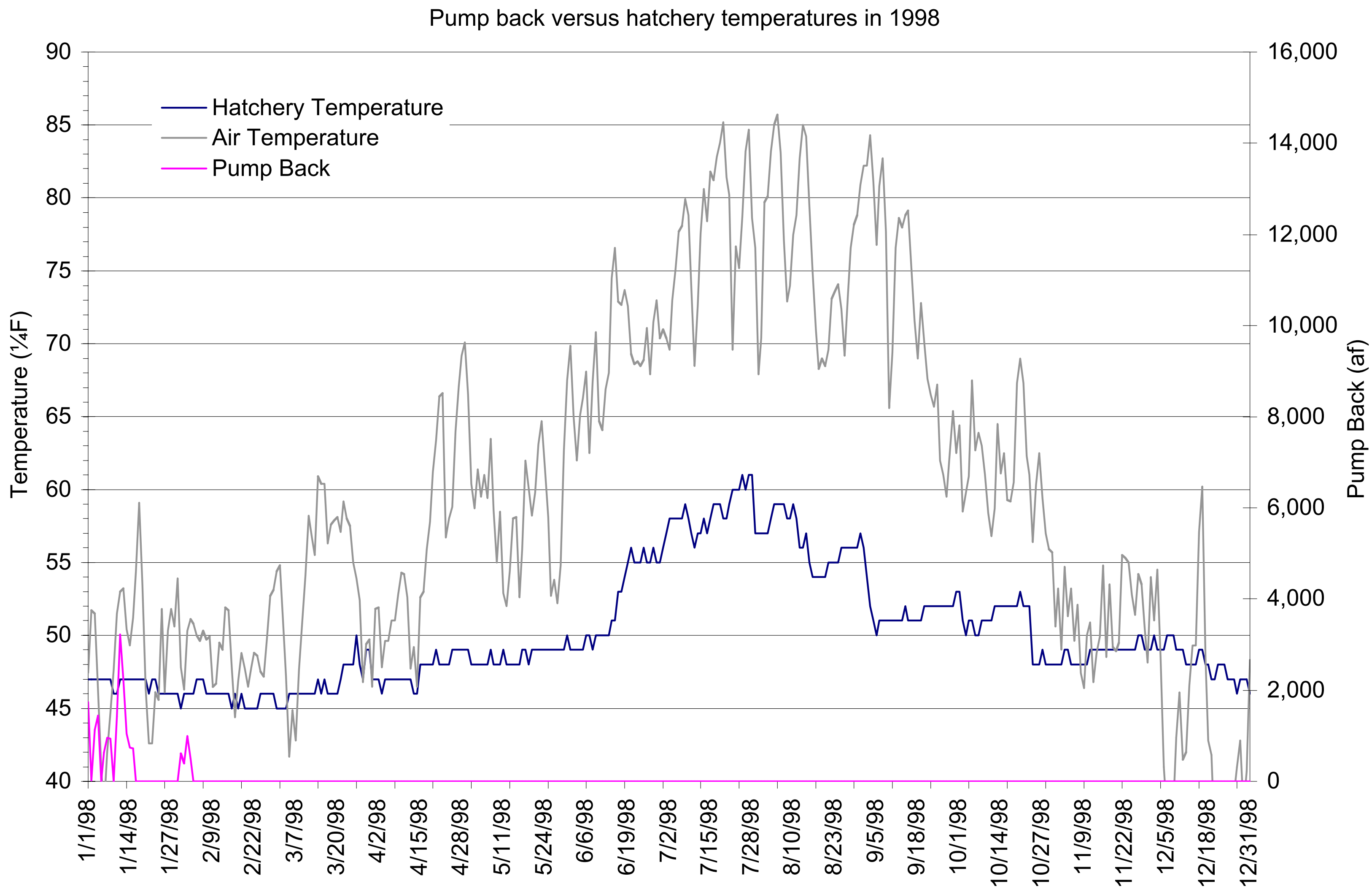




Appendix 7. Pump back effects to water temperatures at the Feather River Fish Hatchery.

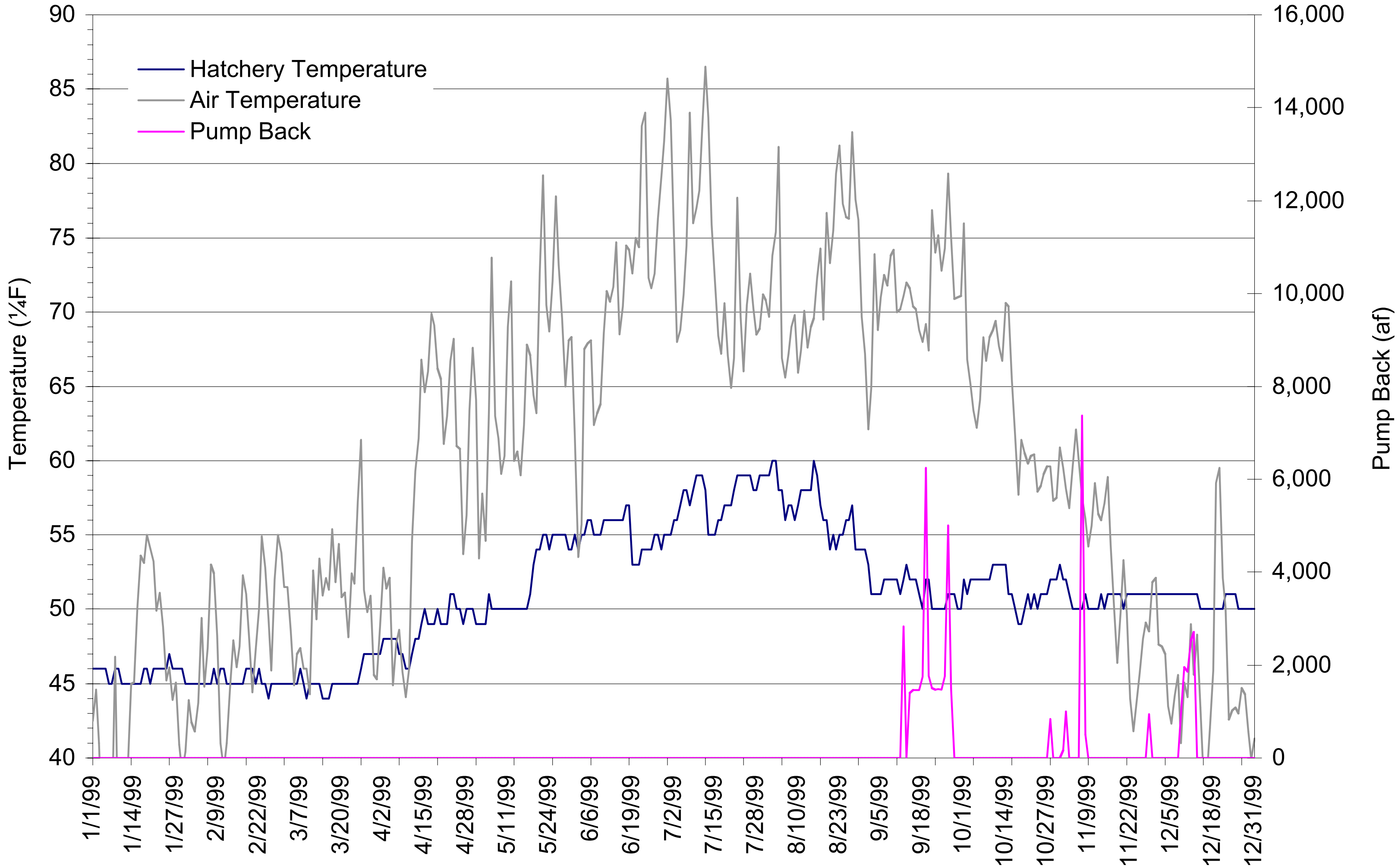


Appendix 7. Continued.



Appendix 7. Continued.

Pump back versus hatchery temperatures in 1999



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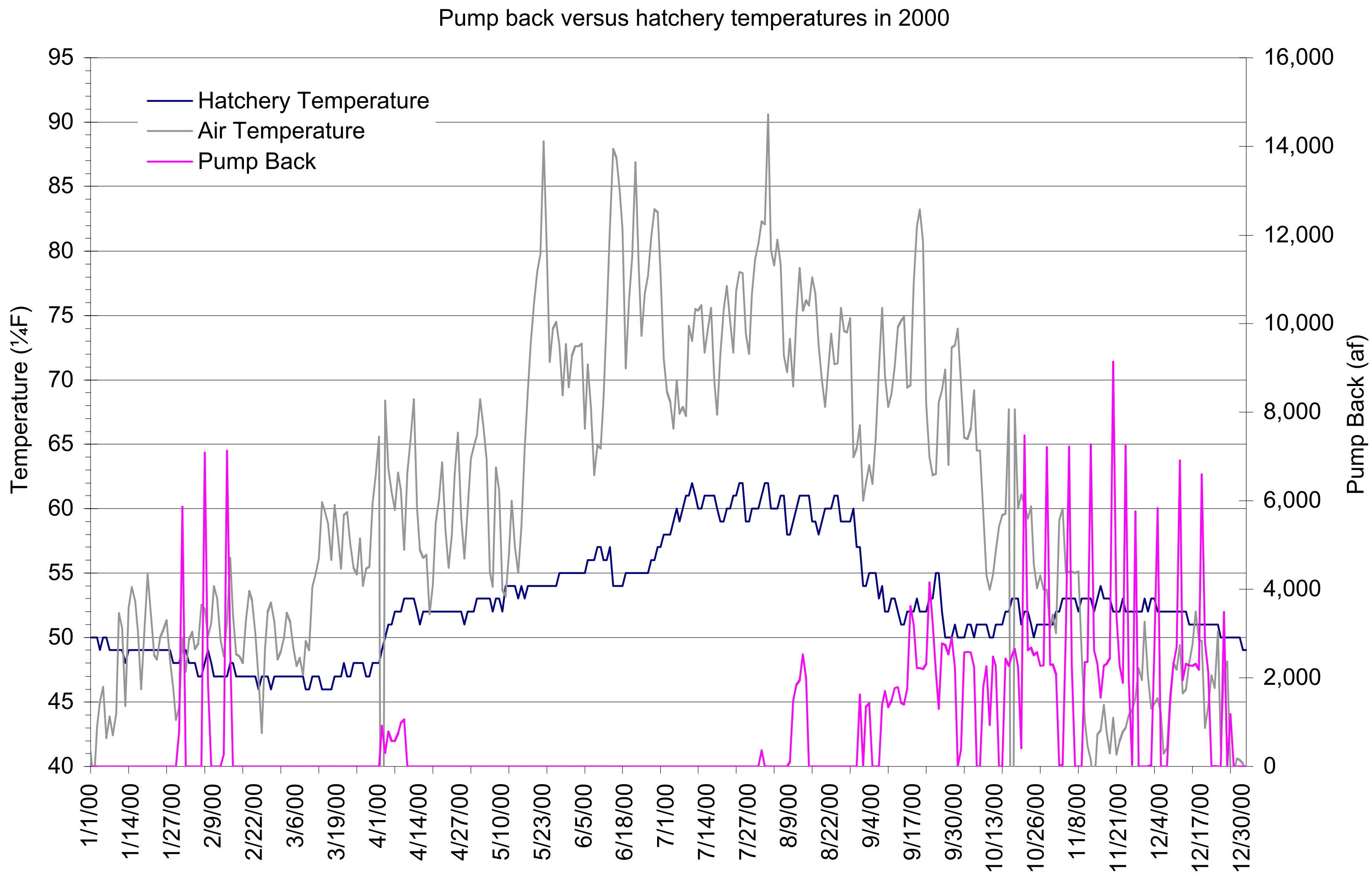

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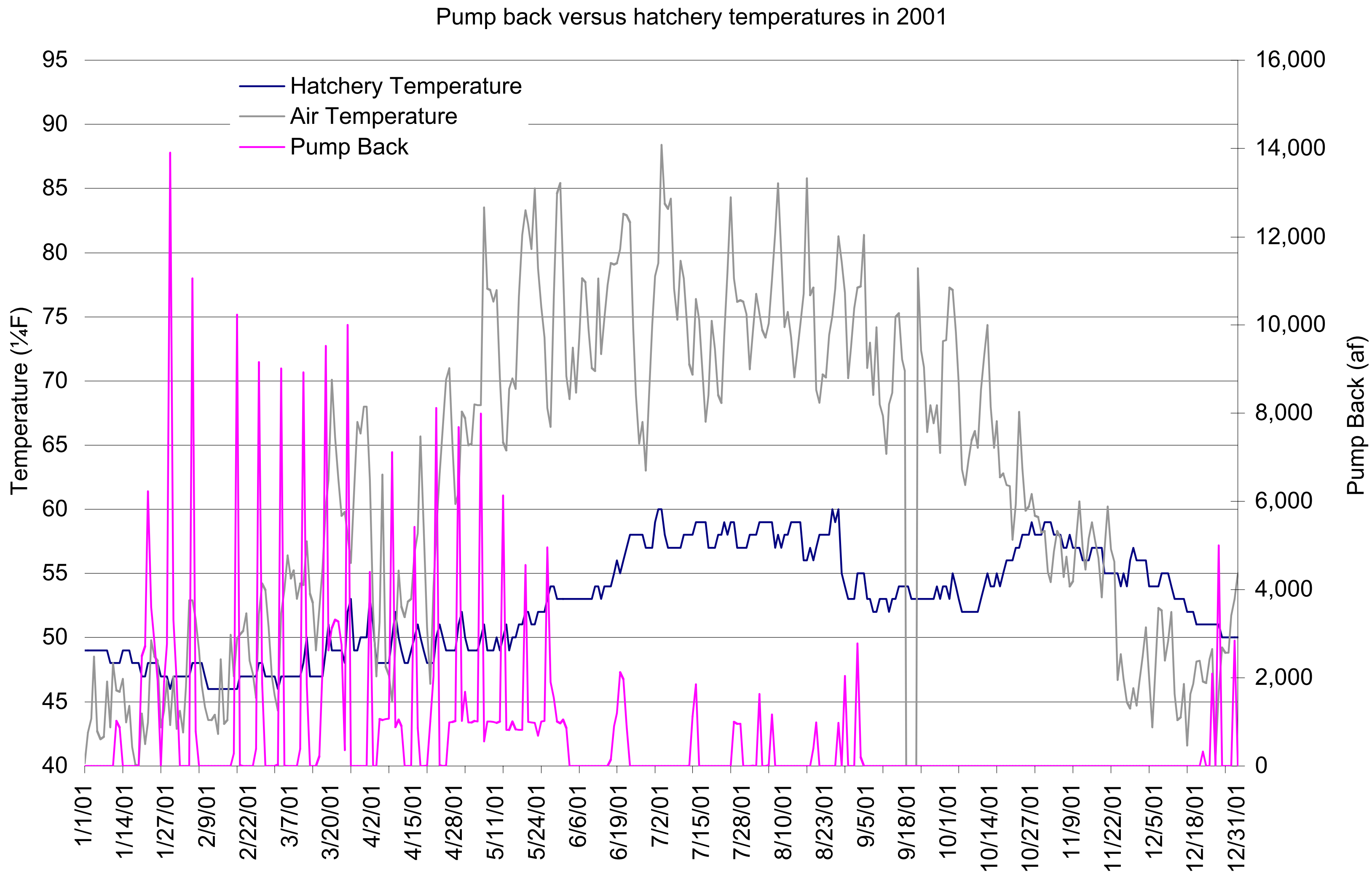

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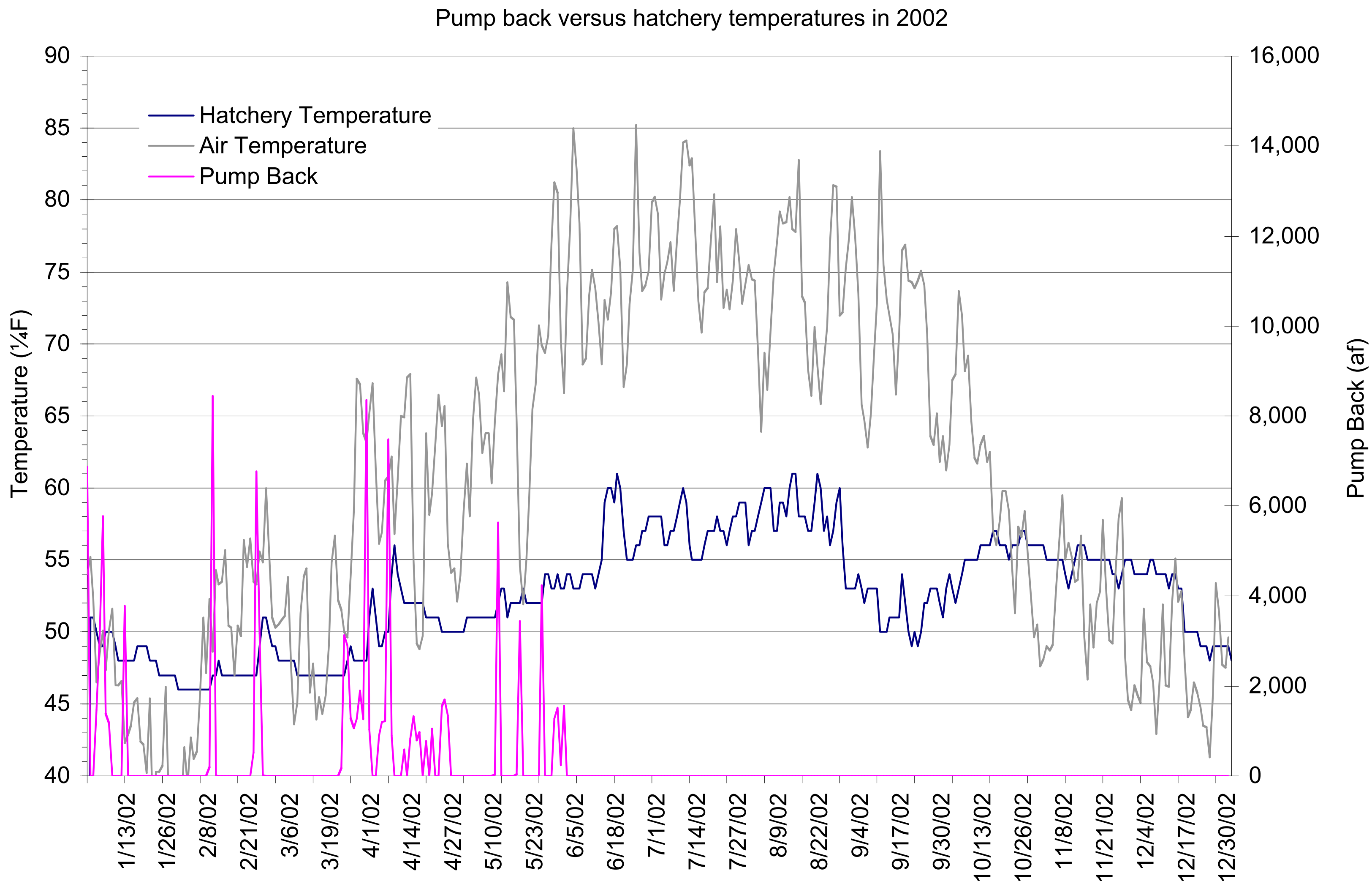

Appendix 7. Continued.