State of California
The Resources Agency
Department of Water Resources

FINAL REPORT
INVENTORY OF POTENTIALLY AVAILABLE HABITAT, AND DISTRIBUTION OF JUVENILE AND ADULT FISH UPSTREAM FROM LAKE OROVILLE
SP-F15 TASK 2; SP-F3.1 TASK 1C

Oroville Facilities Relicensing
FERC Project No. 2100

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REPORT SUMMARY

The feasibility of re-introducing migratory anadromous salmonids to the upper Feather River currently is being evaluated, including evaluation of fish passage above Oroville Dam. Prior to determining the feasibility of fish passage alternatives, it is essential to evaluate which areas upstream of the Oroville Facilities may provide suitable habitat to meet the biological, hydrologic, and physical habitat requirements of both juvenile and adult migratory anadromous salmonids, and to inventory fish species present in the upper Feather River upstream from Lake Oroville. The objective of the SP-F15 Task 2 and SP-F3.1 Task 1C joint report is to inventory and assesses the suitability of available habitat upstream from Lake Oroville for adult and juvenile anadromous salmonids, and to describe the distribution of species currently present. The objectives for this task were accomplished by evaluating and assessing mesohabitat data, water temperature data, instream flow data, and resident fish distribution data.

The mesohabitat suitability assessment was based on broad-scale mesohabitat data and habitat criteria presented in available literature. Each life stage was assessed separately. Suitable mesohabitat in the upper Feather River for immigrating and holding adult Chinook salmon included glides, pools, and runs which accounted for 84 percent of surveyed areas in the West Branch of the North Fork Feather River (West Branch), 78 percent of surveyed areas in the North Fork Feather River (North Fork), 47 percent of surveyed areas in the Middle Fork Feather River (Middle Fork), and 51 percent of surveyed areas in the South Fork Feather River (South Fork). Riffles and runs were defined as suitable mesohabitat for the Chinook salmon spawning and embryo incubation life stage and the steelhead spawning and embryo incubation life stage. Riffles and runs accounted for 28 percent of surveyed areas in the West Branch, 97 percent of surveyed areas in the North Fork, 62 percent of surveyed areas in the Middle Fork, and 44 percent of surveyed areas in the South Fork. Glides, pools, riffles, and runs were defined as suitable mesohabitat for the following life stages: Chinook salmon juvenile rearing and downstream movement, steelhead adult immigration and holding, steelhead fry and fingerling rearing and downstream movement, and steelhead smolt emigration. Glides, pools, riffles, and runs accounted for 93 percent of surveyed areas in the West Branch, 100 percent of surveyed areas in the North Fork, 92 percent of surveyed areas in the Middle Fork, and 85 percent of surveyed areas in the South Fork.. Based strictly on the mesohabitat data used in this report and suitable mesohabitat definitions, it appears that he major tributaries in the upper Feather River generally provide suitable mesohabitat for all life stages of Chinook salmon and steelhead (see Table 6.2-1). The spawning and embryo incubation life stage, for both Chinook salmon and steelhead, is the life stage for which the least amount of suitable mesohabitat is available in the upper Feather River. The most amount of suitable meso habitat is available for the following life stages: Chinook salmon juvenile rearing and downstream movement, steelhead adult immigration and holding, steelhead fry and fingerling rearing and downstream movement, and steelhead smolt emigration. Overall,

the North Fork appears to be the most suitable for occupancy of anadromous salmonids, while the South Fork appears to be the least suitable.

The water temperature suitability assessment was based on data from 11 water temperature data loggers located in the upper Feather River (see Figure 4.2-2), thermal criteria presented in available literature, and presence dates for each life stage of Chinook salmon and steelhead. Each life stage was assessed separately, and assessments were made only during the time period that each life stage was present. Thermal stress to immigrating and holding Chinook salmon likely occurs from June through early September when mean daily water temperatures in the upper Feather River exceeded 60°F (15.6°C). Assuming that a potential fish passage program would transport adult Chinook salmon above Oroville Dam from March through June, the entire population of Chinook salmon transported into the upper Feather River by a fish passage program would be exposed to potentially stressful high water temperatures from June through early September. Due to the study design associated with the geographic placement and number of water temperature data loggers, it is uncertain if thermal refugia are present in the upper Feather River. High mortality rates of fertilized eggs and alevin reportedly can be expected when water temperatures exceed 62°F (17.8°C). During the defined presence dates for the Chinook salmon spawning and embryo incubation life stage, mean daily water temperatures in the upper Feather River exceeded 62°F generally from August 15 through early September to mid-October. Juvenile Chinook salmon rear in freshwater year round. Available literature and regulatory documents suggest that water temperatures ≤60°F are optimal for growth, and growth is positively correlated with survival. Mean daily water temperatures in the upper Feather River exceeded 60°F generally from mid-May through early August to late September, and during this time period increased mortality of rearing juvenile Chinook salmon may occur. Studies have concluded that acceleration and inhibition of Chinook salmon smolt development may occur at water temperatures above approximately 63°F (17.2°C). Mean daily water temperatures in the upper Feather River exceeded 63°F from early May to early June through early September to early October. However, the effects to smolts from high water temperatures during this time period may be minimal because, in the lower Feather River, juveniles migrate out of the lower Feather River shortly after emergence. Very few smolts reportedly are present in the lower Feather River from early May through early October, and it is assumed that the same downstream movement timing would exist in the upper Feather River. Holding migratory fish at constant water temperatures above 55.4°F to 60.1°F (13.0°C to 15.6°C) reportedly may impede spawning success. Mean daily water temperatures in the upper Feather River exceeded 56°F (13.3°C) generally from September through October, and negative impacts to immigrating and holding adult steelhead from thermal stress may occur during this period. Optimum water temperatures for spawning steelhead in the Central Valley reportedly ranged from 46°F to 52°F (7.8°C to 11.1°C), and for embryo incubation range from 48.0°F to 52.1°F (8.9°C to 11.2°C). During the time period corresponding with the steelhead spawning and embryo incubation life stage, available mean daily water temperatures at most of the data logger locations

exceeded 52°F rarely. Based on thermal index criteria values, thermal stress to rearing steelhead fry and fingerlings is most likely to occur from June through early August, with extreme stress leading to direct mortality occurring July through early September. Most of the available literature available pertaining to smolting steelhead suggest that water temperatures less than 52°F or less than 55°F (12.8°C) are required for successful smoltification to occur. Mean daily water temperatures in the upper Feather River generally exceeded 52°F and 55°F from May through June. Impacts to emigrating steelhead in May and June from elevated water temperatures likely would not be substantial.

Water temperatures, at the locations for which water temperature data were available, approached or exceeded potentially stressful levels for one or many life stages of Chinook salmon and steelhead generally from May through October. However, water temperature data loggers were generally located at low elevations near the tributary/reservoir boundary, which is the location within tributaries that is typically believed to experience the highest water temperatures. Water temperatures in the upper Feather River are a function of natural processes, and in certain instances, are influenced by operations of privately owned facilities. DWR does not have the ability to manipulate water temperatures in the tributaries upstream from Lake Oroville because facilities above the Oroville Dam are owned and operated by entities other than DWR. In the North Fork, the Pacific Gas and Electric Company (PG&E) currently is investigating the feasibility of enhancing coldwater withdrawal from the Prattville Intake at Lake Almanor, which could potentially decrease water temperatures in the Oroville Facilities project boundaries. However, the conclusions from this investigation have yet to be released for public review. Therefore, potential decreases in water temperatures in the North Fork attributed to modifications to PG&E facilities were not included in the water temperature suitability assessment in this report. In-river conditions and water temperatures at low elevations in the upper Feather River were roughly similar to those in Mill Creek and Deer Creek. Assuming the water temperatures in the upper Feather River at higher elevations remain similar to those in the higher elevations in Mill and Deer creeks, water temperatures in the upper Feather River may be suitable for Chinook salmon and steelhead because populations currently persist in Mill and Deer creeks.

Assessing the temporal suitability of instream flows in the upper Feather River, for each life stage of Chinook salmon and steelhead, is difficult because information elucidating appropriate flows for each life stage is site specific and such information is unavailable for the upper Feather River. Therefore, a discussion detailing the temporal and spatial suitability of flows in the upper Feather River was not provided in this report.

The general distribution of resident fish in the upper Feather River was determined primarily through the use of backpack electrofishing gear. The presence/absence of rainbow trout was used as an indicator of potential suitability for Chinook salmon and steelhead. Rainbow trout were found at all fish distribution sampling sites in the upper

Feather River. The presence of rainbow trout throughout the upper Feather River may indicate suitability for anadromous Chinook salmon and steelhead populations.

At certain times of the year, mean daily water temperatures in the upper Feather River appear to be unsuitable for Chinook salmon and steelhead. The degree of unsuitability differed among life stages. However, the upper Feather River generally appears to be suitable for migratory Chinook salmon and steelhead based on the collective assessment of available mesohabitat data, water temperature profiles, and the current distribution of resident rainbow trout populations. The results from this study should be interpreted and applied carefully due to inherent data limitations.

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1.0 INTRODUCTION

1.1 BACKGROUND INFORMATION

Ongoing operation of the Oroville Facilities prevents passage of anadromous and migratory fish in the Feather River above Lake Oroville. Anadromous salmonids, and other migratory fish species migrating up the Feather River to spawn, currently are stopped at the Fish Barrier Dam. Because they are unable to pass over, around, or through the Oroville Facilities, potential upstream spawning habitat is inaccessible. As a component of study plan (SP)-F15, *Evaluation of the Feasibility to Provide Passage for Targeted Species of Migratory and Anadromous Fish Past Oroville Facility Dams,* Task 2 assesses habitat suitability upstream from Lake Oroville for adult and juvenile anadromous salmonids. As a component of SP-F3.1, *Evaluation of Project Effects on Fish and Their Habitat within Lake Oroville, its Upstream Tributaries, the Thermalito Complex, and the Oroville Wildlife Area*, Task 1C characterizes fish habitat and describes fish species assemblages in Lake Oroville's upstream tributaries from Lake Oroville's high water mark to the first identified migration barrier. The objectives of SP-F3.1 Task 1C parallel the objectives of SP-F15 Task 2. Therefore, an inventory and assessment of the suitability of available habitat upstream from Lake Oroville for adult and juvenile anadromous salmonids, and a description of the distribution of species currently present in the upstream tributaries is presented in this report.

Tasks 3 and 4 of SP-F15 assess the devices and methods associated with passage of anadromous salmonids above Oroville Dam, and provide a feasibility assessment model to aid decision makers in assessing the feasibility of a fish passage program, respectively. Prior to assessing the devices and methods associated with a potential fish passage program, and prior to determining the feasibility of fish passage, it was essential to evaluate which areas upstream of the Oroville facilities may provide suitable habitat to meet the biological, hydrologic, and physical habitat requirements of both juvenile and adult anadromous fishes. Task 2 of SP-F15, combined with Task 1C of SP-F3.1, evaluates fish habitat in the upstream tributaries to Lake Oroville as well as provides information to assess the feasibility of potential future Resource Actions associated with the Federal Energy Regulatory Commission (FERC) relicensing process.

1.1.1 Statutory/Regulatory Requirements

The habitat assessment provided by this study will complement the evaluations of project-related effects on the passage of anadromous fish above Lake Oroville, and within the lower Feather River. The evaluations and present habitat assessment will be important components in the evaluation of effects of the Oroville Facilities required to comply with the federal Endangered Species Act (ESA) consultation process, and with Section 18 of the Federal Power Act (FERC 2001).

Anadromous salmonids present in the lower Feather River include spring-run Chinook salmon (*Oncorhynchus tshawytscha*), fall-run Chinook salmon (*O. tshawytscha*), and steelhead (*O. mykiss*). On September 16, 1999, naturally-spawned Central Valley spring-run Chinook salmon were listed as threatened under the federal ESA by NOAA Fisheries (NOAA Fisheries 1999). The Central Valley spring-run Chinook salmon Evolutionarily Significant Unit (ESU) includes all naturally-spawned populations of spring-run Chinook salmon in the Sacramento River and its tributaries, which includes naturally-spawned spring-run Chinook salmon in the lower Feather River (NOAA Fisheries 1999). On March 19, 1998, naturally-spawned Central Valley steelhead were listed as threatened under the federal ESA by NOAA Fisheries (NOAA Fisheries 1998). The Central Valley steelhead ESU includes all naturally-spawned populations of steelhead in the Sacramento and San Joaquin rivers and their tributaries, which includes naturally-spawned steelhead in the lower Feather River (NOAA Fisheries 1998).

The results and recommendations from this study fulfill, in part, statutory and regulatory requirements mandated by the ESA as it pertains to Central Valley spring-run Chinook salmon and steelhead. In addition to the ESA, Section 4.51(f)(3) of 18 CFR requires reporting of certain types of information in the Federal Energy Regulatory Commission application for license of major hydropower projects, including a discussion of the fish, wildlife, and botanical resources in the vicinity of the project (FERC 2001). The discussion is required to identify the potential impacts of the project on these resources, including a description of any anticipated continuing impact for on-going and future operations. In addition to fulfilling these requirements, information collected during this task may be used in developing or evaluating potential Resource Actions associated with the relicensing process.

1.1.2 Study Area

1.1.2.1 Description

The study area encompasses portions of the major tributaries of the Feather River upstream from Lake Oroville, including the West Branch, North Fork, Middle Fork, and South Fork. The upstream boundary of the study area extends to the first stream channel obstruction that completely blocks upstream migration of anadromous salmonids as defined in SP-F3.1 Task 1A, and shown in Figure 1.1-1. For purposes of this report, the first migration barrier considered to be impassable year round is defined as Poe Dam in the North Fork, Curtain Falls in the Middle Fork, and Ponderosa Dam in the South Fork. In the West Branch, a barrier considered impassable year round has yet to be identified. For purposes of this report, the falls below Big Kimshew Creek is defined as a provisionally impassable fish barrier, and represents the upstream boundary of the study area in the West Branch. A more extensive and complete review of upstream migration barriers in the tributaries of the upper Feather River can be

located in SP-F3.1 Task 1A Final Report *Assessment of Potential Fish Passage Impediments Above Lake Oroville's High Water Mark.*

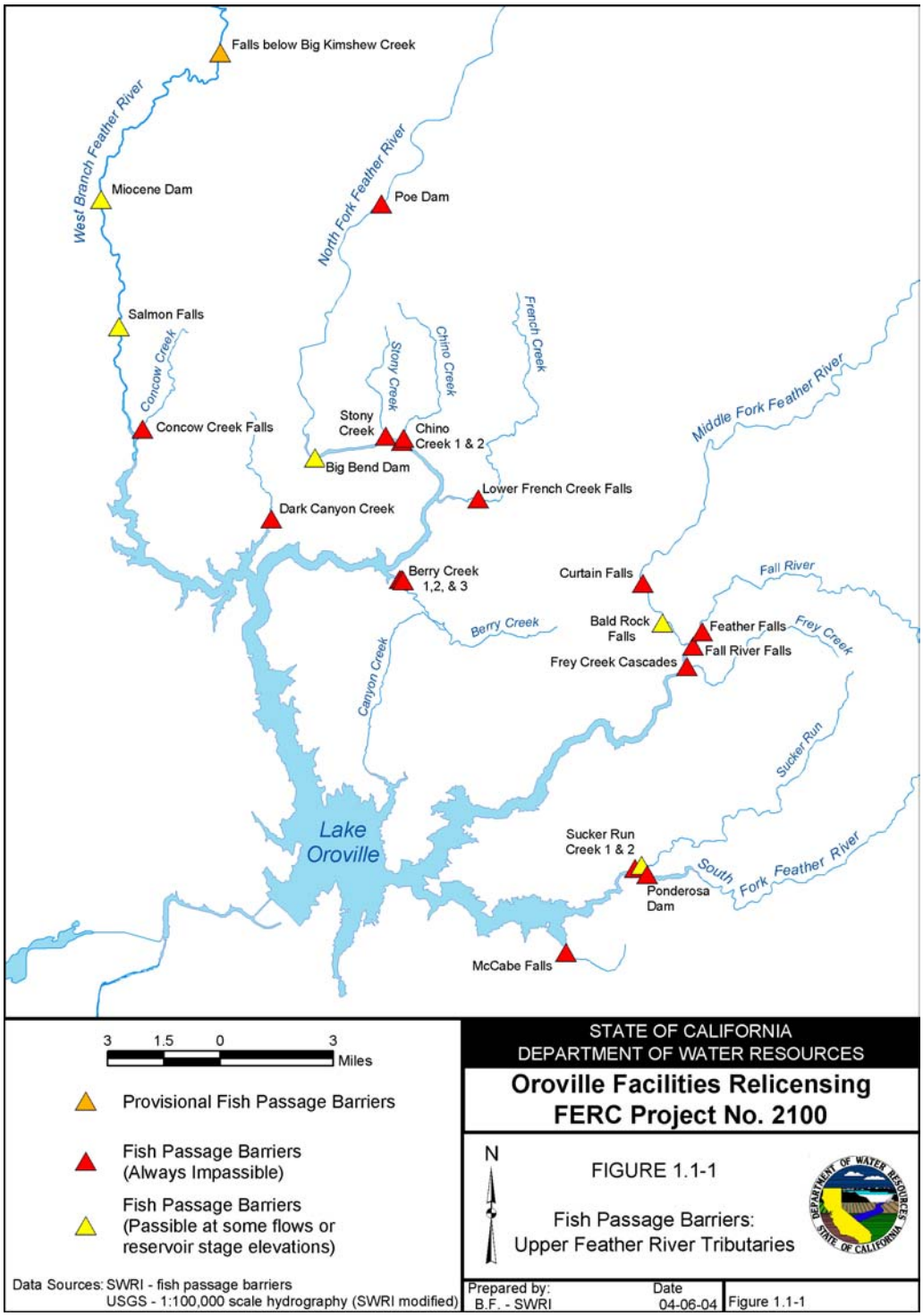


Figure 1.1-1. Fish passage barriers: upper Feather River tributaries.

1.1.2.2 History

The Fish Barrier Dam, as part of the Oroville Facilities, was constructed between 1962 and 1964. Located upstream from the FRFH and approximately five miles below Oroville Dam, it is identified as the first impassible salmonid migration barrier on the Feather River (DWR and USBR 2000; Yoshiyama et al. 1998).

Historically, the upper Feather River watershed provided habitat for anadromous and resident salmonids. Spring-run Chinook salmon and steelhead were reported to ascend the very highest streams and headwaters of the Feather River watershed (Figure 1.1-2), while fall-run Chinook salmon occupied the lower foothill reaches of the river (DWR and USBR 2000; Yoshiyama et al. 1998). Prior to the construction of Oroville Dam, the upstream extent of fish passage was limited by natural fish barriers and previously constructed hydroelectric projects.

Figure 1.1-2 depicts the historical spawning distribution as defined in Yoshiyama et al. (1998), and the current definition of the expected geographic scope of the cumulative analysis for fish passage.

1.1.3 Land Ownership Adjacent to Study Area

The re-introduction of migratory anadromous salmonids to the upper Feather River could potentially impact landowners adjacent to selected watercourses. Spring-run Chinook salmon and steelhead are listed as threatened under the ESA, and management activities associated with alteration of riparian or riverine habitat could be subject to compliance with the ESA, thereby affecting landowners. Figure 1.1-3 displays land ownership adjacent to Lake Oroville and the upper Feather River tributaries. The boundaries of the area that may be affected by a potential fish passage program are restricted to the downstream extent of each tributary extending upstream to the first impassable barrier. The downstream boundary of each tributary is defined as the zone at which the high pool of the reservoir reaches an elevation of 900 feet msl. Landowners adjacent to the South Fork would not be affected by the re-introduction of migratory anadromous salmonids because the first impassable barrier, Ponderosa Dam, is located in an area considered to be within the reservoir. The federal government and private entities (particularly PG&E) own the greatest proportion of land adjacent to those stretches of watercourse in the upper Feather River that would be accessible to anadromous salmonids passed above Oroville Dam. In the West Branch, there are 13.55 river miles between the tributary/reservoir interface and the upstream study area boundary (falls below Big Kimshew Creek). Private entities own 49 percent of the adjacent land, and the federal government owns 51 percent of the adjacent land. In the North Fork, there are 7.76 river miles between the tributary/reservoir interface and the first impassable upstream barrier (Poe Dam). Private entities own 32 percent of the adjacent land, and the federal government owns 68 percent of the adjacent land. In the Middle Fork, there are 2.04 river miles between the tributary/reservoir interface and the

first impassable upstream barrier (Curtain Falls). The federal government and the State government own 97 percent and 3 percent of the adjacent land, respectively.

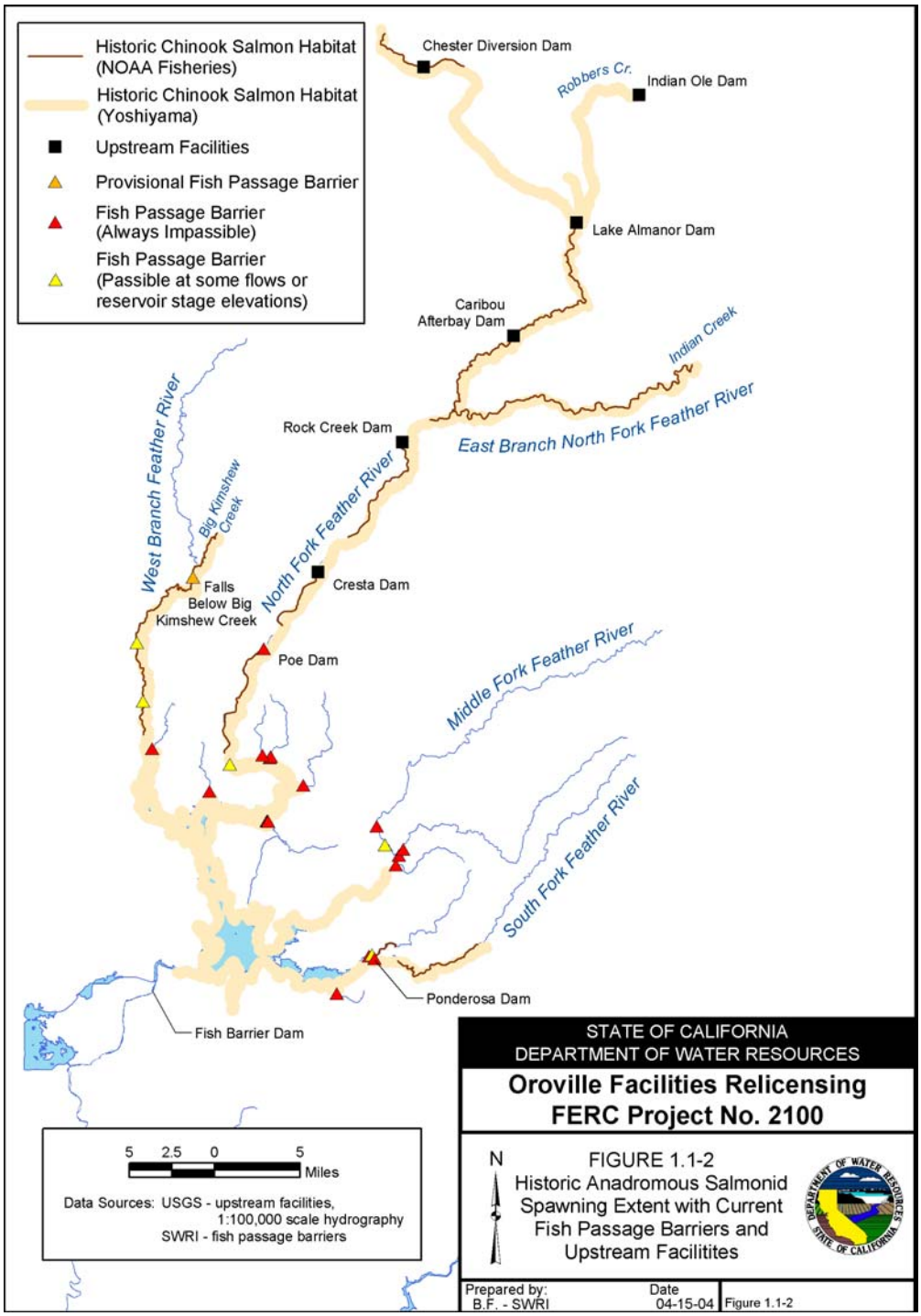


Figure 1.1-2. Historic anadromous salmonid spawning extent with current fish passage barriers and upstream facilities in the upper Feather River.

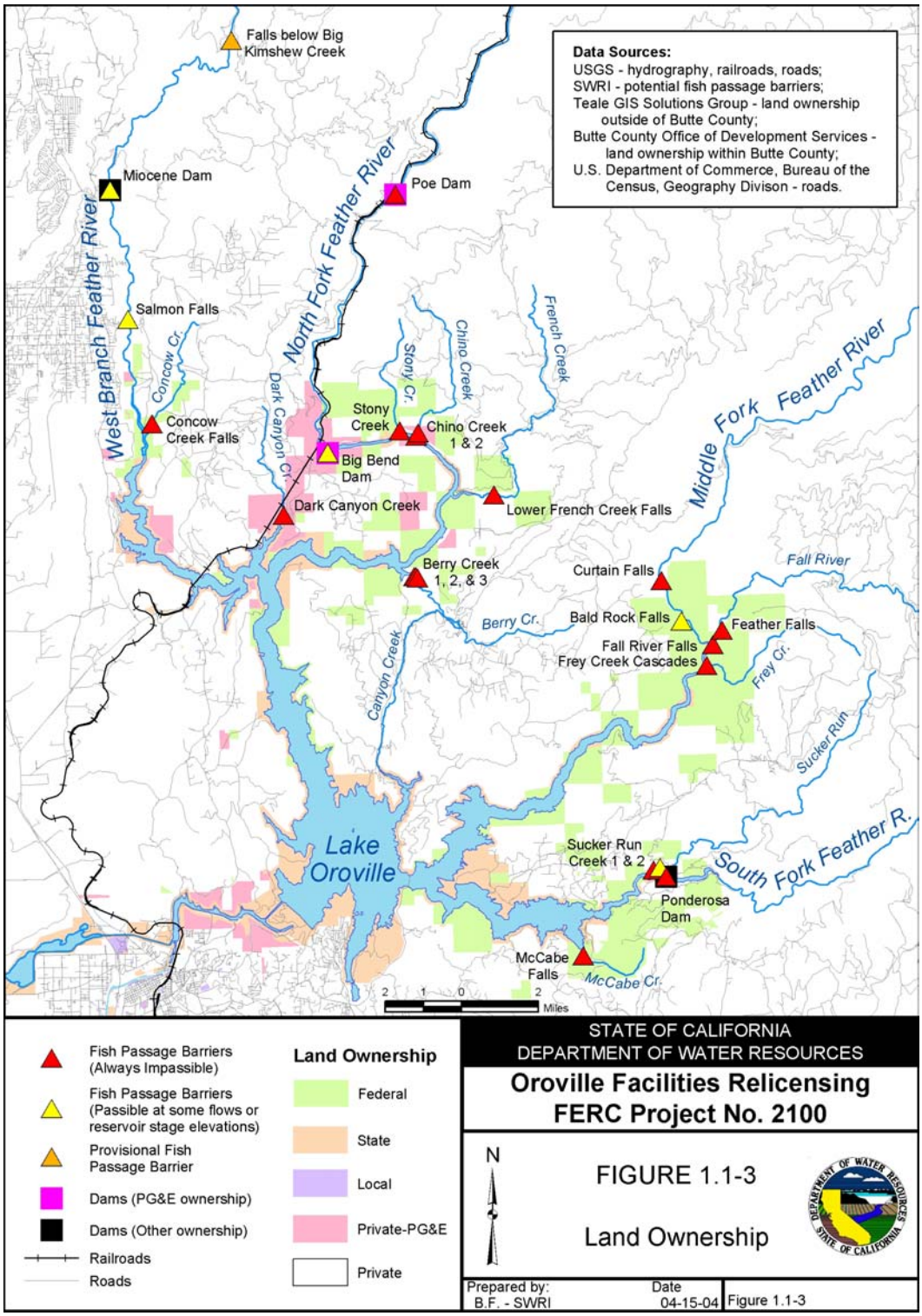


Figure 1.1-3. Land ownership adjacent to tributaries in the upper Feather River.

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 cfs and 5,610 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 cubic feet per second (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 cfs 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.

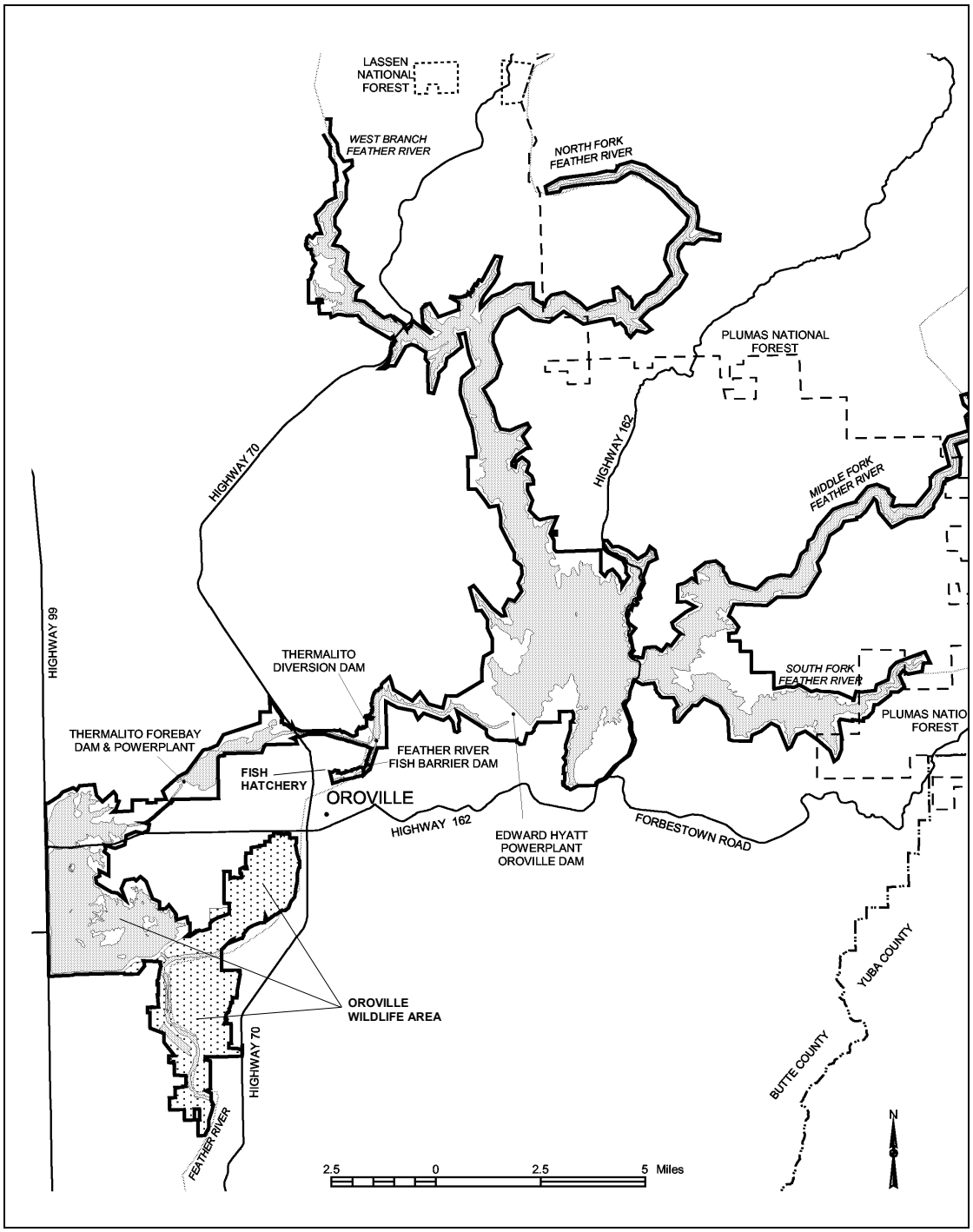


Figure 1.2-1. Oroville Facilities FERC Project Boundary.

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 15,000 to 20,000 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. Major recreational facilities are available 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. California Department of Fish and Game's (DFG) 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.

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 (msl) 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 titled *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. The 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 Water Temperature Requirements

The Diversion Pool provides the water supply for the Feather River Fish Hatchery. The hatchery objectives are 52°F for September, 51°F for October and November, 55°F for December through March, 51°F for April through May 15, 55°F for last half of May, 56°F for June 1-15, 60°F for June 16 through August 15, and 58°F for August 16-31. A temperature range of plus or minus 4°F is allowed for the objectives extending from 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 salmon. From May through August, they must be suitable for shad, striped bass, and other warmwater fish.

NOAA Fisheries has also established an explicit criterion for steelhead 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 salmon and steelhead as a reasonable and prudent measure, DWR is required to maintain daily average water temperature of <65°F at Feather River Mile 61.6 (Robinson Riffle in the low flow channel) from June 1 through September 30. 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°F from approximately April through mid May, and 59°F 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. The 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

Task 2 is a subtask of SP-F15, *Evaluation of the Feasibility to Provide Passage for Targeted Species of Migratory and Anadromous Fish Past Oroville Facility Dams*, which inventories and assesses the suitability of available habitat upstream from Lake Oroville for adult and juvenile anadromous salmonids. Task 1C is a subtask of SP-F3.1, *Evaluation of Project Effects on Fish and Their Habitat within Lake Oroville, its Upstream Tributaries, the Thermalito Complex, and the Oroville Wildlife Area*, which characterizes fish habitat in Lake Oroville's upstream tributaries from Lake Oroville's high water mark to the first identified migration barrier. The objectives of SP-3.1 Task 1C closely parallel the objectives of SP-F15 Task 2. Therefore, the study plan reports for each of the tasks were combined to evaluate fish habitat upstream from Lake Oroville in support of the environmental documentation associated with the relicensing efforts, to facilitate the evaluation of alternatives in support of relicensing negotiations, and to support the development and definition of potential Resource Actions.

This study is necessary, in part, because operation of the Oroville Facilities block upstream passage of migrating anadromous fish to the upstream reaches of the Feather River. Assessment of the potential suitability of the upstream fish habitat to support a potential fish passage program is necessary in order to complete an evaluation of the feasibility of a fish passage program.

3.0 STUDY OBJECTIVES

The objective of SP-F15 Task 2 and SP-F3.1 task 1C is to inventory and assesses the suitability of available habitat upstream from Lake Oroville for adult and juvenile anadromous salmonids, and to describe the distribution of species currently present. Information obtained in this study is associated with, and will be applied to the following purposes and activities.

3.1 APPLICATION OF STUDY INFORMATION

The results of this analysis and description of species present in the upstream tributaries to Lake Oroville is to assist, through habitat assessment, the evaluation of the feasibility of re-introducing anadromous salmonids to tributaries of the upper Feather River.

3.1.1 Department of Water Resources/Stakeholders

The information from Task 2 of SP-F15 and Task 1C of SP-F3.1 will be used by DWR and the Environmental Work Group (EWG) to evaluate the feasibility of providing passage past Oroville Facility Dams by anadromous salmonids. Additionally, data collected in this task will serve as a foundation for future evaluations and development of potential Resource Actions.

3.1.2 Other Studies

In order to aid in the characterization of the habitat availability and fish distribution in the upstream tributaries to Lake Oroville, information was provided by SP-F3.1, SP-F15 Task 1, SP-F21, SP-G1, SP-W1, and SP-W6.

SP-F3.1 Task 1A, *Assessment of Potential Fish Passage Impediments Above Lake Oroville's High Water Mark,* provided the basis for the geographic definition of the study area for SP-F15 Task 2 and SPF3.1 Task 1C.

SP-F15 Task 1, *Describe the Life History and Habitat Requirements of Feather River Anadromous Salmonids and Other Migratory Species*, provided information regarding the life history traits and habitat requirements of anadromous salmonids including:

- Adult upstream migration requirements (timing, and water temperature and flow conditions associated with migration);
- Adult holding requirements (timing, water temperature, and holding pool or stream physical characteristics);
- Adult spawning and embryo incubation requirements (timing, water temperature, substrate, and flow);

- Juvenile rearing (timing, water temperature, substrate, and cover);
- Juvenile outmigration requirements (timing, water temperature, and flow).

SP-F21, *Project Effects on Predation of Feather River Juvenile Anadromous Salmonids,* provided information regarding predation rates and factors associated with predation of juvenile salmonids.

SP-G1, *Effects of Project Operations on Geomorphic Processes Upstream of Oroville Dam*, provided the physical habitat information required to complete the habitat analysis including:

- Mesohabitat maps of the upstream tributaries to the first impassable migration barrier. Due to physical access limitations, the survey was completed by interpolating mapped mesohabitat unit proportions to unsurveyed river reaches.
- Substrate characterization, transect data, channel morphology, assessment of woody debris, and cover cross-sectional monitoring data including water depth, velocity, and turbidity. However, as reported in SP-G1 updates to the Environmental Work Group, these data were not available for all of the areas in the upstream tributaries.
- Inundation flow boundaries at various flow levels. However, as reported in previously in SP-G1 updates to the Environmental Work Group, these data were not available for all of the areas in the upstream tributaries.

SP-W6, *Project Effects on Temperature Regime,* provided water temperature data collected in the upstream tributaries.

3.1.3 Engineering Exhibits

Modeling results from DWR's Engineering and Operations Group were not necessary to complete this study plan report. The focus of SP-F15 Task 2 and SP-F3.1 Task 1C, are not variables being modeled by DWR's Engineering and Operations Group.

3.1.4 Environmental Documentation

In addition to Section 4.51(f)(3) of 18 CFR, which requires reporting of certain types of information in the FERC application for license of major hydropower projects, it may be necessary to satisfy the requirements of the National Environmental Policy Act (NEPA) and the ESA. Because FERC has the authority to grant an operating license to DWR for continued operation of the Oroville Facilities, discussion is required to identify the potential impacts of the project on many types of resources, including fish, wildlife, and botanical resources. In addition, NEPA requires discussion of any anticipated continuing impact from on-going and future operations. To satisfy NEPA and ESA,

DWR is preparing a Preliminary Draft Environmental Assessment (PDEA) to attach to the FERC license application, which will include information provided by this study plan report.

3.1.5 Settlement Agreement

In addition to statutory and regulatory requirements, SP-F15 Task 2 and SP-F3.1 Task 1C could provide information to aid in the development of potential Resource Actions and alternative operating procedures to be negotiated during the settlement agreement.

4.0 METHODOLOGY

4.1 STUDY DESIGN

The objective of SP-F15 Task 2 and SP-F3.1 Task 1C is to inventory and assess the suitability of available habitat upstream from Lake Oroville for adult and juvenile anadromous salmonids, and to describe the distribution of species currently present in the tributaries to Lake Oroville. Prior to determining the feasibility of fish passage alternatives, it is essential to evaluate which areas upstream from the Oroville facilities may provide suitable habitat to meet the biological, hydrologic, and physical habitat requirements of both juvenile and adult anadromous salmonids. The objectives of this task were accomplished by evaluating and assessing mesohabitat data, water temperature data, instream flow data, and resident fish distribution data.

4.1.1 Differentiating Spring-Run Chinook Salmon from Fall-Run Chinook Salmon

Other than genetic analysis, several methods are commonly used to determine the specific race, or run, of juvenile Chinook salmon. The spawning period for each race reportedly typically is unique, with only slight overlap between races (Yoshiyama et al. 1998). Assuming universal time periods between incubation and initiation of emigration, the time period during which each race emigrates can be predicted. Another method involves using standardized daily fork-length tables (Greene 1992). Lengths of individual juvenile Chinook salmon are compared, by sample date, to standardized charts in order to determine the race of the measured individual. Both methodologies are useful but should be used with caution due to inherent uncertainties. Environmental and physical variables can vary seasonally and annually, which can influence the timing and duration of each life stage cycle causing more extensive overlap in emigration time frames between races. DWR (2002) attempted to differentiate between spring-run and fall-run juvenile Chinook salmon using daily fork-length tables developed by Greene (1992). DWR biologists concluded "*most spring-run sized fish were nearly identical in size to the fall-run emigrating at the same time, clearly illustrating the uncertainties of using the Daily Length Table alone as an indicator of race* (DWR 2002)." The Fisher Key (1994) and the Modified Fisher Key (1997; also known as the Delta Model Key) are commonly used by natural resource agencies in the Sacramento-San Joaquin river system (pers. com. K. Souza, 2003). The methodology used to develop these keys, however, was unavailable. Like the daily length tables developed by Greene (1992), lengths of samples are compared, by sample date, to the Fisher Key (1994) and Modified Fisher Key (1997) standardized tables in order to determine race. For example, on October 17 the Modified Fisher Key defines fall-run Chinook salmon as ranging from 4.8 in to 10.6 in (123 mm to 269 mm) FL and defines spring-run Chinook salmon as ranging from 10.6 in to 11.8 in (270 mm to 300 mm) FL. Keys are a useful tool for making general classifications but, when making resource management decisions, should be used with caution due to inherent uncertainties associated with

interannual variation in environmental variables influencing Chinook salmon life history characteristics.

Separating spawning spring-run Chinook salmon from spawning fall-run Chinook salmon historically has been based on time of spawning and differences in spawning site locations (Fry 1961). Under natural conditions, run separation is accomplished by reproductive isolation, whereby the runs maintain temporal and spatial separation (Fisher 1994). Such differences largely have been responsible for maintaining genetic integrity between the spring-run and fall-run Chinook salmon in the Sacramento-San Joaquin river system. Construction of the dams on the Feather River tributaries including the construction of Oroville Dam on the mainstem Feather River eliminated access to high elevation headwater reaches of the Feather River that reportedly were the historic spawning grounds for spring-run Chinook salmon (Sommer et al. 2001). Restricted access caused spring-run Chinook salmon and fall-run Chinook salmon to spawn in the same lowland reaches of the Feather River. The overlap in spawning sites, combined with some overlap in spawn timing (Moyle 2002), reportedly may be responsible for in-breeding between spring-run and fall-run Chinook salmon in the lower Feather River (Hedgecock et al. 2001). Based on the timing of Chinook salmon brood stock collection from the Feather River, FRFH operations also may contribute to genetic introgression between spring-run and fall-run Chinook salmon in the lower Feather River. For example, repeatedly selecting early arriving fall-run Chinook salmon for brood fish could alter run timing, and inadvertently contribute to overlap in spawn timing and genetic flow between races. A disproportionate number of early arriving salmon in the broodstock may occur because hatcheries typically collect eggs until a certain quota is met. When large numbers of fish arrive at hatcheries early, quotas are met quickly and late arrivals typically are not used as broodstock. The temporal and spatial boundaries historically present between spring-run and fall-run Chinook salmon in the lower Feather River reportedly may be eroding, and some authors question whether the spring-run are genetically distinct (Hedgecock et al. 2001; Sommer et al. 2001). Therefore, separating spawning spring-run Chinook salmon from fall-run Chinook salmon based on calendar day may be unreliable.

Based on a review of available methodologies and literature, the analyses in this report does not differentiate between spring-run Chinook salmon and fall-run Chinook salmon. Thus, the temporal distributions provided for each life stage include both spring-run and fall-run Chinook salmon.

4.1.2 Mesohabitat

Mesohabitat was inventoried in portions of each of the four major tributaries upstream from Lake Oroville. Each portion of stream sampled was referred to as a survey reach. For each survey reach sampled, the percentage of each mesohabitat type delineated was extrapolated for the entire tributary up to the first identified migration barrier. For example, seven percent of the reach sampled in the West Branch was comprised of

"cascade" habitat types. By assuming the survey reach was representative of the entire tributary, and extrapolating the percentage of mesohabitat available within each survey reach to the entire tributary, it was estimated that seven percent of the West Branch up to the first impassible migration barrier was comprised of cascade-type habitat. ArcView 8.0, a geographic information system (GIS), was used to estimate the linear extent of each survey reach, and the percentage of each mesohabitat type that occurred within that reach. A literature review was conducted to characterize appropriate habitat types for each defined life stage of Chinook salmon and steelhead.

Information from available literature was compared to the available mesohabitat data to yield general information on habitat availability in each of the four main tributaries for each life stage of Chinook salmon and steelhead. The large scale of the mesohabitat data precluded all analyses other than basic generalizations regarding habitat availability.

4.1.2.1 Availability of Holding Habitat in the Upper Feather River

The mesohabitat data were used to estimate the availability of holding pools in the upper Feather River. Availability of holding pools was estimated by first establishing a criterion by which to designate pools as holding habitat. For purposes of this report, a pool was designated as holding habitat if the average depth was >6.6 ft. A rationalization for selection of this criterion is provided in the interim report for SP-F10 Task 1E, *Identification and Characterization of Early Up-Migrant Adult Chinook Salmon Holding Habitat and Habitat Use Patterns*. For each mesohabitat transect sampled, the total surface area of available holding habitat was estimated by selecting pools meeting the depth criterion, multiplying the average length of the pool by the average width of the pool, and then summing the surface areas of the pools. The length of each mesohabitat transect and the length of each tributary up to the first impassable barrier was estimated using ArcView 8.0. The total surface area of available holding habitat was then extrapolated to the tributary scale by using the following equation:

$$\left(\frac{T_l}{t_l}\right) \times H_t = H_T \text{, where}$$

T_l = Tributary length,

t_l = Mesohabitat transect length,

H_t = Surface area of available holding habitat within the mesohabitat transect,

H_T = Extrapolated surface area of available holding habitat at the tributary scale.

Total holding habitat surface area was calculated in ft^2 and converted to hectares. Estimates of availability of holding habitat may be underestimated because holding

habitat estimates only represent the habitat present in each major tributary, and do not take into account the multitude of smaller drainages and minor tributaries.

4.1.2.2 Availability of Spawning Habitat in the Upper Feather River

Availability of spawning habitat was estimated by first establishing which mesohabitat types represented spawning habitat. To remain consistent with methodologies associated with the draft report for SP-F8, *Transfer of Energy and Nutrients by Anadromous Fish Migrations*, riffles were the only mesohabitat type designated as spawning habitat. For each mesohabitat transect sampled, the total surface area of available spawning habitat was estimated by summing the surface area of each riffle within the transect. Riffle surface areas were estimated by multiplying the length of the riffle by the width of the riffle. The length of each mesohabitat transect and the length of each tributary up to the first impassable barrier was estimated using ArcView 8.0. The total surface area of available spawning habitat was then extrapolated to the tributary scale by using the following equation:

$$\left(\frac{T_l}{t_l}\right) \times H_t = H_T \text{, where}$$

T_l = Tributary length,

t_l = Mesohabitat transect length,

H_t = Surface area of available spawning habitat within the mesohabitat transect,

H_T = Extrapolated surface area of available spawning habitat at the tributary scale.

Total surface area was calculated in ft^2 and converted to hectares. Estimates of availability of spawning habitat may be underestimated because spawning habitat estimates only represent the habitat present in each major tributary, and do not account for potential habitat in each of the smaller drainages and minor tributaries.

4.1.2.3 Potential Escapement Estimates of Anadromous Salmonids Upstream of Lake Oroville

Potential escapement estimates were developed for each major tributary in the upper Feather River based on the surface area of available spawning habitat and a range of spawning densities determined from available literature. Chinook salmon spawning habitat was not differentiated from steelhead spawning habitat, however. Estimates of potential spawning densities were therefore assumed to account for both Chinook salmon and steelhead. The potential escapement estimates represent the best efforts to assess potential escapement in the absence of the Oroville Facilities, and assume unhindered passage of anadromous salmonids into the upper Feather River.

Reliable information on pre-project salmon and steelhead escapement in the upper Feather River and tributaries was quite limited because the terrain of Feather River canyons and tributaries was considered too rugged for standardized sampling of salmon escapement or carcass surveys (DWR 2003f). At the time, resources devoted to monitoring salmon escapement in the Sacramento River Basin were focused on Sacramento River mainstem locations or on other tributaries to the Sacramento River where permanent fish passage facilities aided monitoring efforts. Fish counting weirs used on the Feather River prior to completion of the Oroville Dam did not function properly, allowing fish to pass without being counted (Fry 1961). Additionally, low visibility in the Feather River caused some spawning survey estimates to be low (Fry 1961). Alternative estimates of abundance are unavailable because DFG did not keep harvest data for the Feather River prior to construction of Oroville Dam, and because there is little information on tribal harvest and fishing practices in the upper Feather River tributaries (DWR 2003f).

Most of the pre-project escapement data were collected during the decade and a half prior to the completion of the Oroville Facilities in 1968. Reports providing escapement estimates from this period include DFG 1960, Fry 1961, Menchen 1966, and Painter et al. 1977.

The spawning density estimates, presented in this report as the potential number of spawners able to fully utilize available habitat in the upstream tributaries, were derived from a limited number of redd count surveys with spawning habitat surface area estimates from the Columbia River, Tuolumne and Stanislaus Rivers (Carl Mesick Consultants 2002; DWR 2003f; Visser et al. 2002), and escapement and spawning habitat surface area estimates for the Low Flow Channel in the lower Feather River (DWR 2003f; Sommer et al. 2001). Most existing information regarding spawning densities in streams is reported in terms of the average density of spawners in a surveyed section of stream, which is not appropriate for purposes of this report because the surveyed sections include non-spawning habitat and, therefore, are biased. Useful spawning density estimates could have been computed if the percentage of the surveyed stream sections with spawning habitat had been reported, but available reports did not provide such information. The spawning density estimate provided by DWR (2003f) for the lower Feather River included fall-run and spring-run Chinook salmon combined, while the other estimates were for fall-run Chinook salmon only. Spawning density estimates for spring-run Chinook salmon were assumed to be within the range of estimates provided for fall-run Chinook salmon. The redd count surveys were from the Hanford Reach of the Columbia River in Oregon (Visser et al. 2002), a 7-mile reach of the Stanislaus River downstream from Goodwin Dam (Carl Mesick Consultants 2002), and a 4-mile reach Tuolumne River downstream from La Grange Dam (DWR 2003f).

To convert estimates of redd density to spawning density, each redd is generally assumed to represent one spawning pair. However, redd counts may be biased because redds are easily obscured by gravel movement, which commonly results from high flows and redd superimposition. Turbid conditions and deep water spawning locations also make redds difficult to see. Comparisons with escapement estimates based on carcass surveys or other methods indicated that the number of redds were substantially underestimated in the redd count surveys on the Tuolumne and Columbia Rivers (DWR 2003f; Visser et al. 2002). Visser et al. (2002) concluded that their redd counts, which were made from aerial photographs, underestimated the actual number of redds by at least fifty percent. In contrast, the total number of redds counted in the Stanislaus redd surveys were similar or moderately higher than expected based on comparisons to escapement estimates (Carl Mesick Consultants 2002). Females may construct more than one redd, which may partially explain higher than expected redd counts (Carl Mesick Consultants 2002). Based on review of available literature, spawning densities for the Tuolumne and Columbia Rivers were used in this report by multiplying the observed redd densities by four (two fish per redd and two redds present for each redd observed), and the spawning densities for the Stanislaus River were estimated by doubling the observed redd densities.

Spawning density in the LFC of the lower Feather River was estimated from the total surface area of available spawning habitat (773, 732 ft^2) and the number of spawners present in the channel (DWR 2003f). The surface area of spawning habitat was based on aerial photographic interpretation of where salmon actually constructed redds, and salmon escapement was estimated from carcass mark-recapture surveys. In addition, spawning density in Battle Creek was derived from estimates of spawning habitat area in the creek and an estimate for the surface area around each redd defended by spawning fish (DWR 2003f).

The potential escapement of Chinook salmon into the upper tributaries was approximated as the product of the surface area of spawning habitat available in the upstream tributaries and the range of spawning densities (spawner utilization per unit of available habitat) estimated for the Columbia, Tuolumne, Stanislaus, and Feather rivers. Escapement estimates calculated using this method assume full utilization of the available habitat in the upstream tributaries over a range of spawning densities.

The tributary reaches that were included in the mesohabitat survey represent a small portion of the total anadromous salmonid spawning habitat rendered inaccessible by the Oroville Facilities. The smaller upstream tributaries were not surveyed, but likely contain some potential spawning habitat. Therefore, estimates of total potential escapement may be underestimated. A range of spawning densities was calculated for each of the four major tributaries in the upper Feather River by taking the minimum and maximum estimated spawning density values from reviewed literature, and then multiplying these values by the total surface area of available spawning habitat within each tributary.

4.1.3 Water Temperature

A review of available literature was conducted to determine appropriate water temperatures to use as index values to determine potential effects of water temperature on all life stages of Chinook salmon and steelhead. Development and appropriate application of technical evaluation guidelines is necessary when assessing potential project impacts with respect to the suitability of various water temperatures for fish. Salmon have many different life stages, and the thermal requirements and tolerance ranges generally differ between life stages. Many of the water temperature values in the available literature are supported by anecdotal evidence, and values derived from experimental testing are limited. In general, three types of literature provide information on thermal criteria used for resource management decisions: (1) research results that are typically published in peer reviewed journals; (2) literature reviews citing various types of documents; (3) and agency publications that often contain legal mandates. Selection of water temperature index values for use as criteria for impact assessment for the various life stages of Chinook salmon and steelhead is difficult because of the wide range of values, often contradictory, recommended in available literature. The water temperature index values selected as criteria in this report were chosen from values reported and recommended in regulatory agency documents and from source data, usually peer reviewed journal articles. In a few instances, literature reviews were cited because source data and references could not be determined or located. Values found in the documents of regulatory agencies are important because they have legal ramifications, and water use projects are typically mandated to operate within the thermal criteria set forth in these documents. A literature review concerning the thermal requirements, preferences, and tolerance ranges of Chinook salmon and steelhead found many different water temperature values. Index values were chosen from this literature set. In certain instances, index values were rounded up or down from those reported in the literature, but were still very similar to, and representative of, reported water temperature values. The water temperature index values selected in this report as criteria for impact assessment were chosen because they represent the values most commonly cited by researchers and regulatory agencies as suitable, preferred, optimal, or detrimental to each life stage of Chinook salmon and steelhead, and because the range of selected values encompass the range of values most often referenced in available literature.

Water temperature data were collected from 11 data loggers in the upper Feather River representing all four of the major tributaries. Water temperature index values chosen for each life stage, to use as criteria for suitability evaluation, were compared to water temperatures from each data logger during reported presence dates for each life stage to determine if water temperatures are suitable for occupancy in the upper Feather River. Presence dates for each life stage were determined from data collected in the lower Feather River when such data were available. When data from the lower Feather River were unavailable, presence dates were determined from available literature.

4.1.4 Instream Flow

Instream flow data representing the major tributaries in the upper Feather River were extracted from the California Data Exchange Center (CDEC) website (http://cdec.water.ca.gov/). Flow data gathered from CDEC was converted to average monthly flow and presented in cfs. For all data loggers, multiple years of data were available. Data were pooled by month and by data logger to determine temporal trends and the magnitude of flow fluctuations. Presence dates for each life stage of Chinook salmon and steelhead were superimposed on the monthly average flow for each data logger enabling general observations of expected flows during dates of concern. A literature review was conducted to determine if specific flows were appropriate for specific life stages.

4.1.5 Resident Fish Distribution

The numbers of fish sampled, by species and length group, were reported for each tributary sampled in the upper Feather River. Comparisons between tributaries (relative numbers, composition) could not be made because sampling effort and design differed between tributaries. Also, reference to the mesohabitat types that each species was observed in, and the number of observations in each mesohabitat type, could not be reported because the information was not available.

4.2 DATA COLLECTION

4.2.1 Mesohabitat Data Collection

DWR recorded mesohabitat data for portions of the West Branch, North Fork, Middle Fork, and South Fork. The mesohabitat survey reaches are shown in Figure 4.2-1. Mesohabitat type was determined through field surveys, by delineating mesohabitat units from the 1995 Brush Creek digital orthophoto quarter-quadrangle (DOQQ), and from aerial photographs taken in 1990, 1996, and 2001.

Field Surveys were conducted during October and November of 2002, and June and October 2003. The Brush Creek DOQQ was created from source images taken on August 1, 1993, and has a 1-meter ground resolution. DOQQs must meet horizontal National Map Accuracy Standards (NMAS) at 1:12,000 scale, which specify that 90 percent of the well-defined points tested must fall within 33.3 feet (1/30 inch).

The mesohabitat classifications were based on definitions found in DFG (1998b). The following sixteen mesohabitat types were recorded for portions of the four main tributaries in the upper Feather River:

- Reservoir
- Degraded habitat
- Pool
- Junction pool
- Plunge pool
- Step
- Step pool
- Glide
- Riffle
- High gradient riffle
- Run
- Complex pool
- Boulder run
- Step run
- Chute
- Cascade

The mesohabitat units were digitized as polylines, and units that were delineated by field survey, along with some of the photo-delineated units, were attributed with average width and average length. The mesohabitat types were generalized into the following six classes for analyses:

- Degraded habitat: included degraded habitat.
- Cascade: included cascade, chute, and step.
- Glide: included glide.
- Pool: included pool, complex pool, step pool, reservoir, junction pool, and plunge pool.
- Riffle: included riffle, and high gradient riffle.
- Run: included run, boulder run, and step run.

The percentage of each mesohabitat type delineated in the surveyed transects was extrapolated to the entire tributary up to the first identified permanent anadromous salmonid migration barrier. The percentage of each mesohabitat type found in each major tributary is presented in Figure 4.2-1.

4.2.1.1 Tributary Details

For purposes of this report, the downstream geographic boundary of each tributary is defined as the fluctuation zone between high and low pools of the reservoir in areas adjacent to what is traditionally considered the border between reservoir and tributary. The upstream geographic border of each tributary is defined as the first barrier considered impassable year-round by migratory anadromous salmonids. In the West Branch, the falls below Big Kimshew Creek is defined as a provisional impassable fish barrier and represents the upstream boundary of the study area in that tributary. Thus, 17.5 miles of river are available to anadromous salmonids in the West Branch. In the North Fork, the first impassable barrier is defined as Poe Dam, which allows anadromous salmonids access to 16.3 miles of potential habitat. In the Middle Fork, the first impassable barrier is defined as Curtain Falls, which allows anadromous salmonids access to 16.9 miles of potential habitat. In the South Fork, the first impassable barrier is defined as Ponderosa Dam, which allows anadromous salmonids access to 4.0 miles of potential habitat. The amount of potential habitat available to migratory salmonids, as described above, does not take into account for potential availability in the multitude of smaller drainages and minor tributaries to each of the four major tributaries. A more detailed description of fish passage barriers in the upper Feather River can be located

in SP-F3.1 Task 1A *Assessment of Potential Fish Passage Impediments Above Lake Oroville's High Water Mark*.

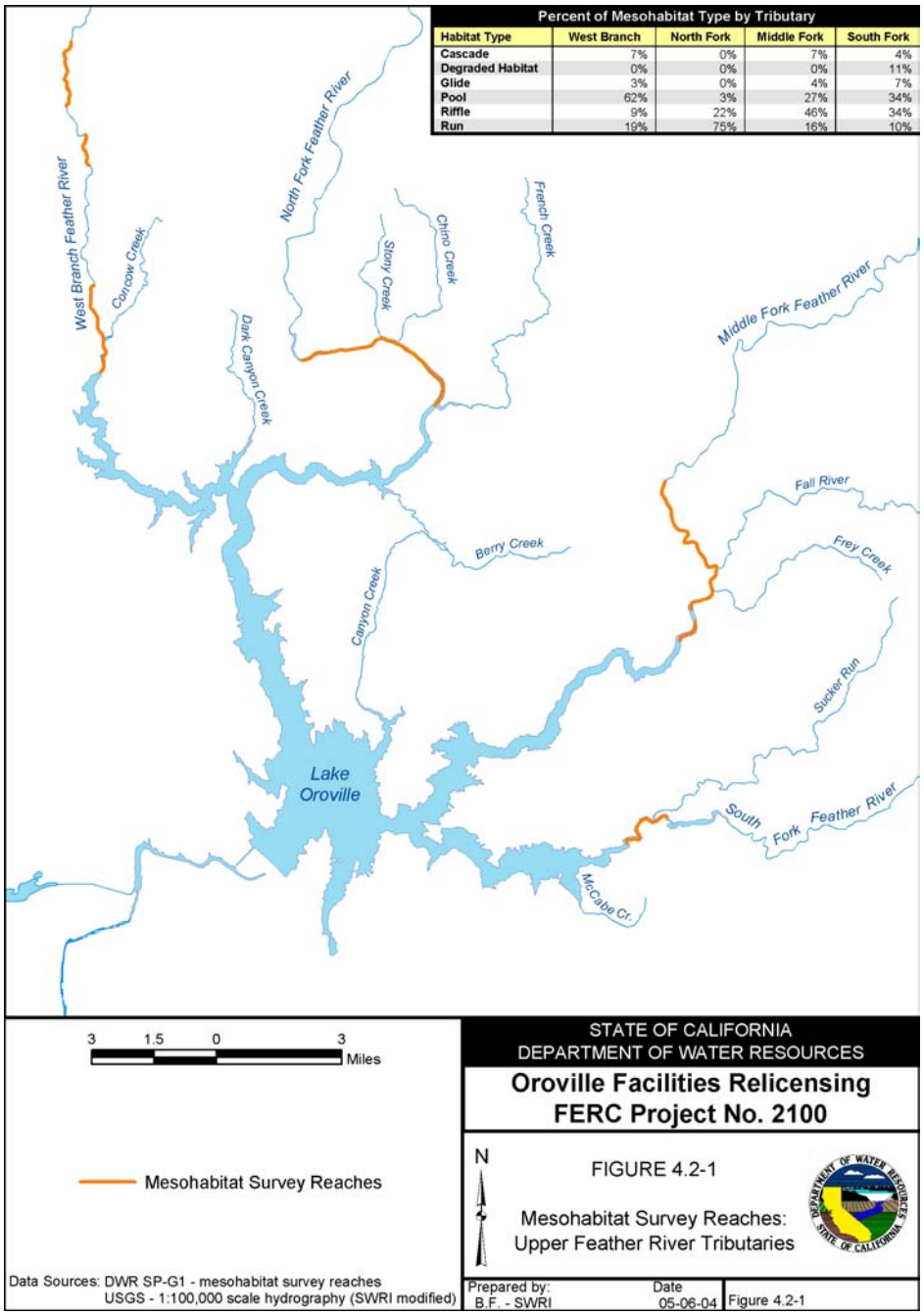


Figure 4.2-1. Mesohabitat survey reaches: upper Feather River tributaries.

Mesohabitat was characterized for approximately 5.9 river miles in the West Branch. A portion of the mesohabitat data was gathered in the fluctuation zone when the reservoir was at low pool. In October 2002, approximately 2.8 river miles were surveyed above

and below Miocene Dam. In November 2002, field crews surveyed a noncontiguous portion of river downstream, between Salmon Falls and Miocene Dam, spanning approximately 0.8 river miles. In October of 2002 and 2003, and June 2003, approximately 1.7 miles were surveyed below Salmon Falls. An additional 0.6 river miles of mesohabitat were characterized below Salmon Falls by delineating units from 2001 aerial photographs. In the North Fork, mesohabitat was characterized for approximately 4.5 river miles by delineating habitat units from aerial photographs taken in 1990. In the Middle Fork, mesohabitat was characterized for approximately 5.1 river miles based on field surveys conducted in October 2002, and by delineating habitat units from 1996 aerial photographs and the 1995 Brush Creek DOQQ. In the South Fork, mesohabitat was characterized for approximately 1.6 river miles based on field surveys conducted in October 2002. All of the habitat data in the South Fork was collected in the fluctuation zone at low pool.

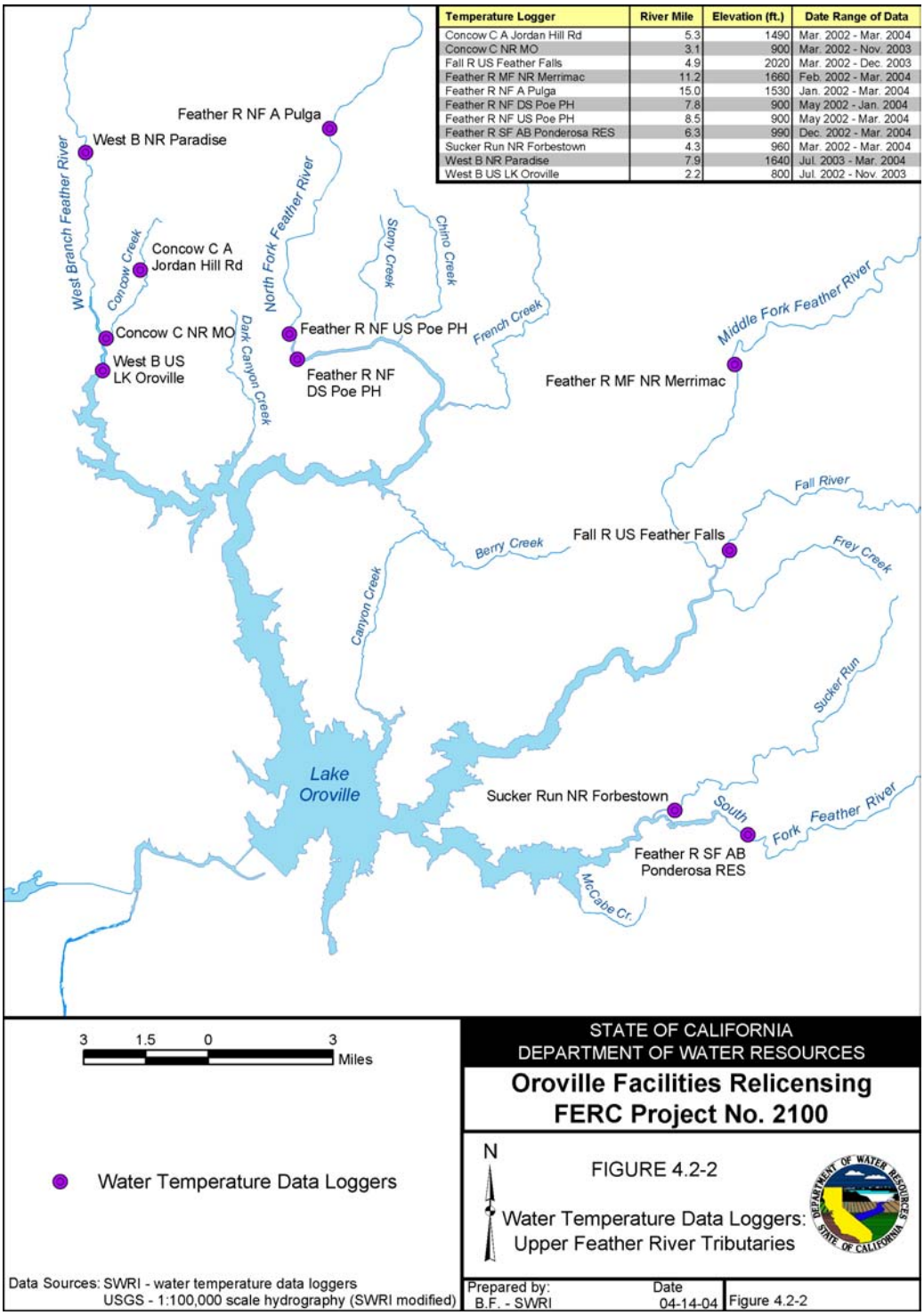
4.2.2 Water Temperature Data Collection

Water temperature data loggers were used to measure mean daily water temperatures at 11 sites in the upper Feather River. Four data loggers were located in the West Branch, 3 data loggers were located in the North Fork, and 2 data loggers were located in each of the Middle and South forks (Figure 4.2-2). Water temperatures were recorded from February 6, 2002 through March 15, 2004, however, the dates and extent of data collection differed between data loggers. In general, between 48 and 96 data points were collected, at even intervals, during each 24-hour period from each water temperature data logging station. In certain instances, water temperature data were unavailable and/or sample dates were inconsistent because of dewatered logging stations, vandalism, and/or malfunction. Mean daily water temperatures were determined for each data logger by pooling and averaging water temperature recordings for each 24-hour period.

4.2.3 Instream Flow Data Collection

Instream flow data representing the major tributaries in the upper Feather River were extracted from the California Data Exchange Center (CDEC) website (http://cdec.water.ca.gov/). Locations for each instream flow data logger are shown in Figure 4.2-3. All flow data were converted to average monthly flow and presented in cfs. Data were gathered from 1986 through 2002, however, the dates and extent of data collection differed between data loggers. In the West Branch, data from October 1985 through September 2003 were obtained from the data collection station named *Miocene Canal* (MIC). The MIC data collection station is operated by PG&E and is located at an elevation of 1,000 feet. In the North Fork, data from September 1995 through August 2002 were obtained from the data collection station named *Feather NF at Pulga* (FPL). The FPL data collection station is operated by PG&E and is located at an elevation of 1,305 feet. In the Middle Fork, data from October 1986 through October 2003 were obtained from the data collection station named *Feather River At Merrimac*

(MER). The MER data collection station is operated by DWR and is located at an elevation of 1,560 feet. Instream flow data were unavailable for the South Fork.



Temperature Logger	River Mile	Elevation (ft.)	Date Range of Data
Concow C A Jordan Hill Rd	5.3	1490	Mar. 2002 - Mar. 2004
Concow C NR MO	3.1	900	Mar. 2002 - Nov. 2003
Fall R US Feather Falls	4.9	2020	Mar. 2002 - Dec. 2003
Feather R MF NR Merrimac	11.2	1660	Feb. 2002 - Mar. 2004
Feather R NF A Pulga	15.0	1530	Jan. 2002 - Mar. 2004
Feather R NF DS Poe PH	7.8	900	May 2002 - Jan. 2004
Feather R NF US Poe PH	8.5	900	May 2002 - Mar. 2004
Feather R SF AB Ponderosa RES	6.3	990	Dec. 2002 - Mar. 2004
Sucker Run NR Forbestown	4.3	960	Mar. 2002 - Mar. 2004
West B NR Paradise	7.9	1640	Jul. 2003 - Mar. 2004
West B US LK Oroville	2.2	800	Jul. 2002 - Nov. 2003

Figure 4.2-2. Water temperature data logger locations in the tributaries of the upper Feather River.

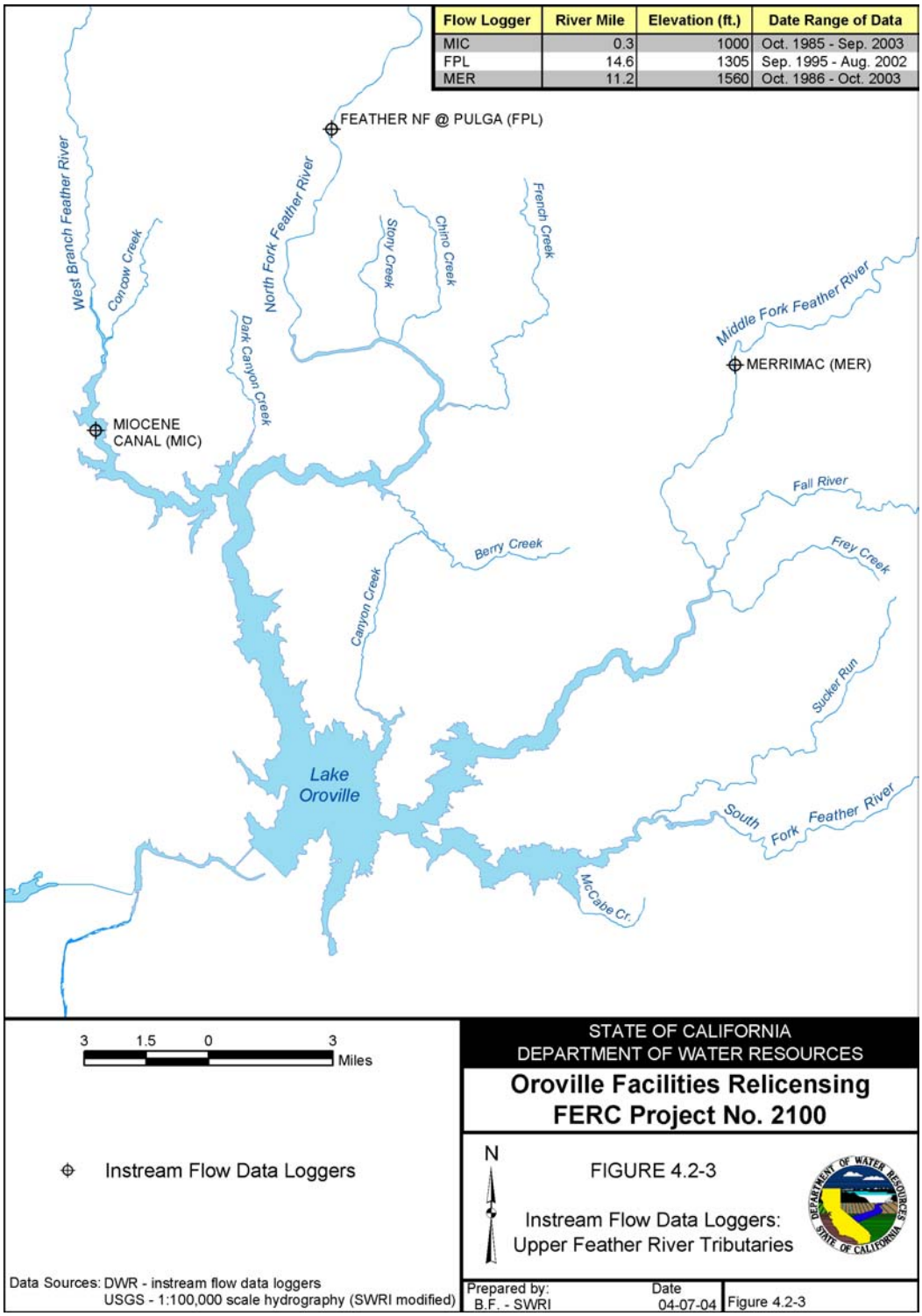


Figure 4.2-3. Instream flow data logger locations in the tributaries of the upper Feather River.

4.2.4 Resident Fish Distribution Data Collection

Resident fish distribution in the upper Feather River was determined through snorkel surveys, backpack electrofishing, and hook-and-line sampling. The resident fish distribution survey reaches are shown in Figure 4.2-4. Surveys were conducted in each of the four major tributaries of the upper Feather River. In Sucker Run, a tributary of the South Fork, sampling occurred on five separate occasions in 2002 and 2003 (November 18, 2002; May 12, 2003; May 28, 2003; August 28, 2003; September 2, 2003). Backpack electrofishing was the primary sampling technique used. Approximately 24,278 linear feet (7,400 linear meters) were sampled by electrofishing. Hook-and-line sampling occurred during the May 28, 2003 sampling effort. In the Middle Fork, snorkel surveys were conducted on two survey reaches on three separate occasions in 2002 and 2003 (December 5, 2002; July 29, 2003; August 19, 2003). The same reach was sampled on December 5, 2002 and August 19, 2003, while a second reach was sampled on July 29, 2003, so the total linear extent of river sampled was approximately 1,969 ft (600 m). In Berry Creek, a tributary of the North Fork, an approximately 1,312 ft (400 m) reach was sampled on November 12, 2002 using backpack electrofishing gear. In the West Branch, backpack electrofishing and snorkel surveys were conducted on three separate occasions in 2002 and 2003 (November 22, 2002; November 25, 2002; September 4, 2003). On November 22, 2002 and November 25, 2002, backpack electrofishing gear was used to sample two separate reaches measuring approximately 4,921 ft (1,500 m) and approximately 6,562 ft (2,000 m) in length, respectively. On September 4, 2003, two separate snorkel surveys were conducted along reaches measuring approximately 1,312 ft (400 m) and approximately 2,625 ft (800 m). However, the snorkel survey reaches completely overlapped the electrofishing reaches, and did not add to the linear extent of river sampled.

4.3 DATA LIMITATIONS

Data containing mesohabitat type, water temperature, instream flow, and fish species distribution were collected in the four main tributaries of the upper Feather River. Mesohabitat type and fish distribution data were gathered at broad scales, limiting analyses to generalities. Comparisons between tributaries were not possible because survey effort and design differed between tributaries. Surveyed areas represent a small proportion of the linear extent of the upper Feather River, and it is uncertain if results are applicable to the system as a whole. The fish distribution data were not collected year-round. Additionally, due to access limitations and safety concerns, mesohabitat data were collected only where access was available and were extrapolated to represent unsurveyed reaches. Thus, it is uncertain if all available mesohabitat types were sampled. Due to sampling constraints beyond the control of DWR staff, the fish distribution data, and species assemblages, may not be reflective of the entire upper Feather River because: (1) fish have seasonal migrations; (2) fish have seasonal habitat preferences; and (3) chosen sampling techniques have inherent bias. Water temperature and flow data were gathered at few locations and generally at low

elevations near Lake Oroville. Due to the seasonal influence of tributary inflow on flow and water temperature, it is likely that water temperature and flow profiles for the four main tributaries of the upper Feather River do not accurately reflect spatial and temporal variation. In general, flow and water temperature data represent conditions in downstream sections of each tributary, and application of these data to the entire upper Feather River watershed assumes that water temperature and flow gradients do not exist. However, the water temperature data likely represent the highest water temperatures in the upper Feather River because, in general, there is a positive correlation between distance traveled downstream and water temperature (DWR 2003c).

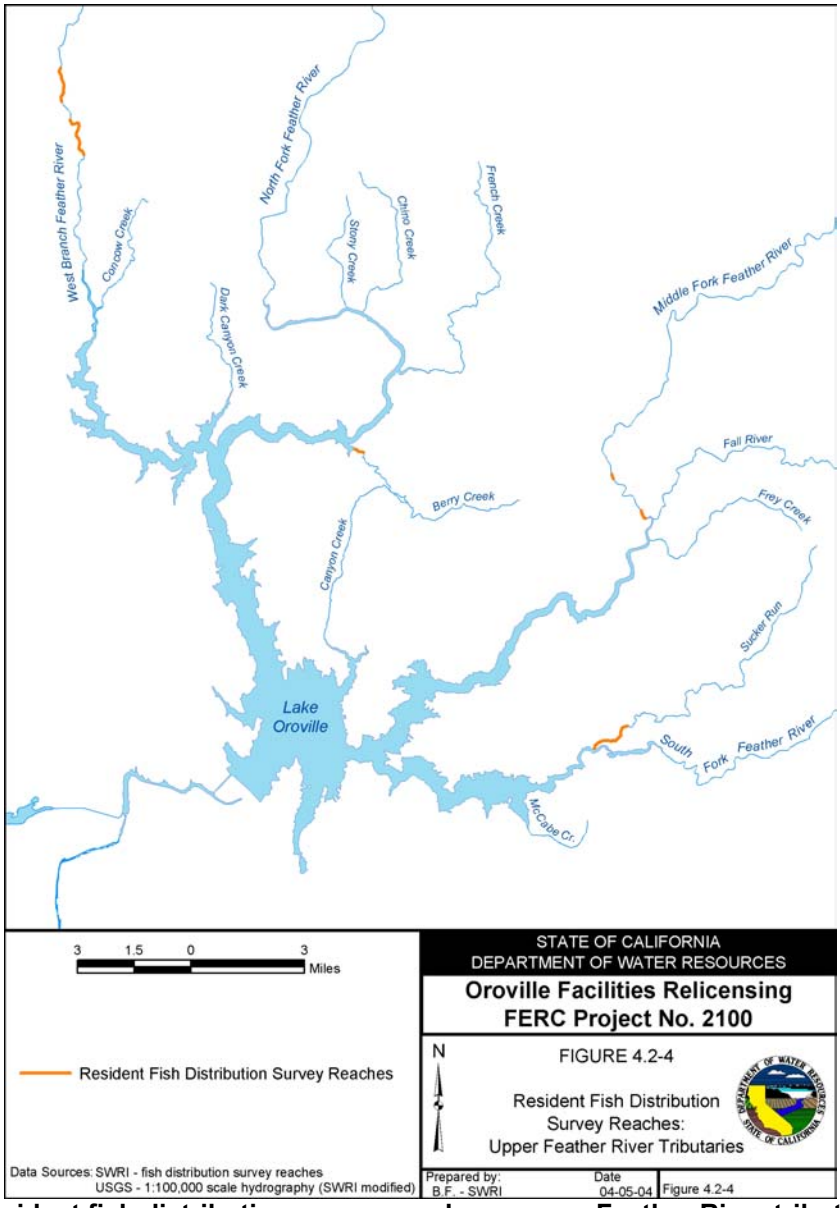


Figure 4.2-4. Resident fish distribution survey reaches: upper Feather River tributaries.

5.0 STUDY RESULTS

5.1 MESOHABITAT IN THE UPPER FEATHER RIVER

The extrapolated percentage of each mesohabitat type found in each of the 4 tributaries in the upper Feather River is summarized in Table 5.1-1 and in Figure 4.2-1.

Table 5.1-1. Percentage of mesohabitat found in the major tributaries of the upper Feather River.

Habitat Type	West Branch	North Fork	Middle Fork	South Fork
Cascade	7%	0%	7%	4%
Degraded Habitat	0%	0%	0%	11%
Glide	3%	0%	4%	7%
Pool	62%	3%	27%	34%
Riffle	9%	22%	46%	34%
Run	19%	75%	16%	10%

In the West Branch, the most abundant mesohabitat type present was pool habitat (62 percent) with run habitat being the second most abundant habitat type (19 percent). In the North Fork, the most abundant mesohabitat type present was run habitat (75 percent), with smaller percentages of riffle (22 percent) and pool (3 percent) habitats present. Mesohabitat types in the Middle and South forks were more evenly distributed when compared to the other tributaries. In the Middle Fork, riffle and pool habitat types were dominant (46 percent and 27 percent, respectively), with lesser amounts of run (16 percent), cascade (7 percent), and glide (4 percent) habitat types present. The South Fork had equal amounts of riffle and pool habitat (34 percent), and approximately 10 percent or less of each of the remaining mesohabitat types. The South Fork was the only tributary in which degraded habitat (11 percent) was identified.

5.1.1 Availability of Holding Habitat in the Upper Feather River

For each of the four major tributaries in the upper Feather River, the mesohabitat survey reach length, the tributary length, the estimated total surface area of holding habitat for each survey reach, and the extrapolated estimated total surface area of holding habitat for each tributary are shown in Table 5.1-2. In the West Branch, a total of 52 pools were identified during the mesohabitat sampling effort. A total of 12 of the 52 pools identified had an average depth that was greater than 6.6 ft (2 m), and were designated as holding habitat. The summed surface area of the pools considered as holding habitat within the survey reach was 2.31 hectares, which was extrapolated to 7.22 hectares within the entire tributary. In the North Fork, a total of 1 pool was identified during the mesohabitat sampling effort. Depth and width data for this pool were not available, and therefore the amount of available holding habitat in the North Fork could not be estimated. In the Middle Fork, a total of 26 pools were identified during the mesohabitat sampling effort. A total of 2 of the 26 pools identified had an average depth that was greater than 6.6 ft, and were designated as holding habitat. The summed surface area of the pools considered as holding habitat in the Middle Fork

survey reach was 1.29 hectares, which was extrapolated to 4.27 hectares within the tributary. In the South Fork, a total of 13 pools were identified during the mesohabitat sampling effort. None of the 13 pools identified had an average depth greater than 6.6 ft. Therefore, holding habitat was not considered present in the South Fork based on holding habitat definitions and sampling protocols.

Table 5.1-2. Mesohabitat survey reach length, tributary length, and total surface area of holding habitat within survey reaches and within each tributary for each major tributary in the upper Feather River.

Tributary	Mesohabitat Survey Reach Length (miles)	Tributary Length (miles)	Estimated Total Surface Area of Holding Habitat Within Each Survey Reach (hectares)	Estimated Total Surface Area of Holding Habitat Within Each Tributary (hectares)
West Branch	5.90	17.50	2.31	7.22
North Fork	4.50	16.30	Not Available	Not Available
Middle Fork	5.10	16.90	1.29	4.27
South Fork	1.60	4.00	Not Available	Not Available

5.1.2 Availability of Spawning Habitat in the Upper Feather River

For each of the four major tributaries in the upper Feather River, the mesohabitat survey reach length, the tributary length, the estimated total surface area of spawning habitat for each transect, and the extrapolated estimated total surface area of spawning habitat for each tributary are shown in Table 5.1-3.

Table 5.1-3. Mesohabitat survey reach length, tributary length, and total surface area of spawning habitat within survey reaches and within each tributary for each major tributary in the upper Feather River.

Tributary	Mesohabitat Survey Reach Length (miles)	Tributary Length (miles)	Estimated Total Surface Area of Spawning Habitat Within Each Survey Reach (hectares)	Estimated Total Surface Area of Spawning Habitat Within Each Tributary (hectares)
West Branch	5.90	17.50	0.66	1.96
North Fork	4.50	16.30	Not Available	Not Available
Middle Fork	5.10	16.90	0.66	2.19
South Fork	1.60	4.00	1.05	2.63

In the West Branch, a total of 23 riffles were identified during the mesohabitat sampling effort. The summed surface area of the 23 riffles was 0.66 hectares within the survey reach, which was extrapolated to 1.96 hectares within the tributary. In the North Fork, a total of 19 riffles were identified during the mesohabitat sampling effort. Width data for the 19 riffles were not available, and therefore the amount of available spawning habitat in the North Fork could not be estimated. In the Middle Fork, a total of 18 riffles were identified during the mesohabitat sampling effort. Width data for 6 of the 18 riffles were available. The summed surface area of the 6 riffles for which width data were available was 0.66 hectares within the survey reach, which extrapolated to 2.19 hectares within

the tributary. In the South Fork, a total of 13 riffles were identified during the mesohabitat sampling effort. The summed surface area of the 13 riffles was 1.05 hectares within the survey reach, which extrapolated to 2.63 within the tributary.

5.1.3 Potential Escapement Estimates of Anadromous Salmonids Upstream of Lake Oroville

Historical records indicate that Chinook salmon were present in all four major tributaries of the Feather River upstream from the present location of Oroville Dam, but their specific distribution and abundance among the smaller tributaries is unreported. Spring-run Chinook salmon usually spawned in higher streams and headwaters than fall-run Chinook salmon, which generally prefer lower regions of tributaries and mainstem river areas for spawning (Moyle 2002). Early documentation of historical salmon abundance rarely mentions steelhead distribution or abundance in the Feather River Basin. Because steelhead have similar spawning habitat preferences to spring-run Chinook salmon, the two species are believed to have occupied the same areas.

Among the earliest scientific accounts of Chinook salmon in the Feather River are those by Clark (1929). Clark (1929) noted that spring-run and fall-run Chinook salmon were present in the Feather River and reported that both runs were “very heavy in the Feather River previous to the building of obstructions.” He further suggested that fall-run Chinook salmon had an ocean cycle of three to four years based on statements made by local residents and the run also was described as “large, although not extremely abundant.” Earlier reports stated that Native Americans could capture as many as 200 salmon with spears in a single night in the Feather River (Yoshiyama et al. 2001). Moyle (2002) reports historical run-size estimates of 8,000 to 20,000 spring-run Chinook salmon in the Feather River upstream from the current Oroville Dam location.

Within the North Fork, spring-run Chinook salmon probably used Indian Creek, Yellow Creek, and Spanish Creek for spawning (Yoshiyama et al. 2001). In the Middle Fork, Chinook salmon probably ascended the Fall River up to Feather Falls (Yoshiyama et al. 2001). McCabe Creek and Powell Creek in the South Fork drainage reportedly were key locations of the historical fishery (DWR 2003f).

An early report by DFG (1952) indicated that the Middle Fork of the Feather River had the “largest portion” of spring-run Chinook salmon summer residency. The report also noted that the North Fork was a “good salmon river”, the West Branch was a “fair salmon stream”, and that the South Fork had limited spawning areas as a result of water diversions. Reports of salmon escapement by Fry (1961) corroborated DFG’s (1952) assessments. Fry (1961) noted that most spring-run Chinook salmon used the Middle Fork for spawning, although a few adults also used the North Fork, South Fork, and West Branch. Fry (1961) also reported that 10,000 to 86,000 fall-run Chinook salmon spawned in the Feather River from 1953 to 1959. Fry’s (1961) estimates included reaches upstream and downstream from the current location of Oroville Dam.

Approximately 1,000 to 4,000 spring-run Chinook salmon spawned in the Feather River during the same time period. Menchen (1966) reported that an average of 1,700 spring-run Chinook salmon spawned in the Feather River from 1953 to 1962, with annual spawning estimates ranging from 0 to 4,000 fish. The entire spring-run population was believed to spawn upstream of the present location of Oroville Dam. All of these estimates were considered to be minimal estimates of escapement (Fry 1961).

Another report written by DFG during the pre-project time period estimated that of the anadromous salmonids spawning upstream of the present dam site, spring-run Chinook salmon had the largest run size (DFG 1960). Estimates of 5,200 spring-run Chinook salmon, 2,300 fall-run Chinook salmon, and 2,000 steelhead were reported upstream from the dam site (DFG 1960). The report does not provide estimates of the distribution or abundance of these fish among the four branches of the Feather River.

Spring-run Chinook salmon and steelhead were present in the Feather River immediately prior to the completion of Oroville Dam in 1967, but construction of the Oroville Project prevented access to historical spawning habitat (DFG 1993; Yoshiyama et al. 2001). Spring-run Chinook salmon and steelhead populations were counted by DFG from 1963 to 1966 at a counting facility near the city of Oroville. During four years of counting preceding dam construction, an average of 1,362 spring-run Chinook salmon and 582 steelhead returned per year (ranges: 296 to 3,362 spring-run Chinook salmon, and 416 to 914 steelhead) (Painter et al. 1977). Sommer et al. (2001) cite pre-project escapement estimates in the Feather River of 1,718 spring-run Chinook salmon and 41,100 fall-run Chinook salmon spawning in the Feather River, and (DWR and USBR 2000) cite pre-project escapement estimates of 500 to 4,000 spring-run Chinook salmon averaging 2,200 per year.

Table 5.1-4 lists the different estimates for fall-run Chinook salmon redd density and spawning density obtained from studies in the lower Feather, Stanislaus, Tuolumne and Columbia rivers, and Battle Creek. The table footnotes provide information on the methods and assumptions used to compute the estimates. The estimated spawning densities are highly variable due to differences in spawning habitat quality and hydrological characteristics of the river, and the number of hatchery produced fish in the river. Differences are likely a function of different survey protocols and sampling conditions (i.e., redd counts biased by turbidity or by degree of superimposition of redds), and therefore estimates should not be compared between each other. Estimates range from a low of 216 spawning salmon per hectare in the Columbia River, to a high of 8,440 spawning salmon per hectare in the Feather River.

The potential escapement estimates for Chinook salmon in the upper Feather River are shown in Table 5.1-5. Estimates were calculated by multiplying the estimated total surface area of available habitat (Table 5.1-3) by the minimum and maximum escapement densities as determined from available literature (Table 5.1-4). Escapement estimates range from a low of 423 salmon per hectare in the West Branch,

to a high of 22,197 salmon per hectare in the South Fork. Estimates were lowest in the West Branch and highest in the South Fork. Escapement estimates were positively correlated with estimated spawning habitat availability, and negatively correlated with tributary length. Width data for spawning riffles in the North Fork were not available, therefore escapement estimates for the North Fork could not be calculated.

Table 5.1-4. Summary of Spawning Density Estimates for Fall-Run Chinook Salmon.

Water Body	Year	Range of Observed Redd Densities (redds/ha)	Mean Observed Redd Density (redds/ha)	Estimated Spawning Density (salmon/ha)	Reference
Feather River	2001	---	---	8,440[1]	Cavallo (2003)
Feather River	1995	---	---	6,137[1]	Sommer et al. (2001)
Stanislaus River	1999	709 – 5,606[2]	2,462	4,924[3]	Carl Mesick Consultants (2002a)
Stanislaus River	2000	1,063 - 6,126[2]	3,347	6,694[3]	Carl Mesick Consultants (2002b)
Tuolumne River	1988	78 - 374[4]	214	856[5]	Mierau (2003)
Battle Creek	1989	---	554[6]	1,108[3]	Ward and Kier (1999)
Columbia River (Oregon)	1994	56 – 84	73	292[5]	Visser et al. (2002)
Columbia River (Oregon)	1995	32 – 84	54	216[5]	Visser et al. (2002)

[1] *Estimates based on escapement estimates and aerial photo estimates of spawning habitat area in Low Flow Channel.*
[2] *Estimates based on redd counts and surface area measurements in selected spawning riffles in 7 miles below Goodwin Dam.*
[3] *Estimate computed from mean redd density and assumption of two salmon per observed redd.*
[4] *Estimates based on redd counts and surface area measurements in selected spawning riffles in 3 to 4 miles downstream of La Grange Dam.*
[5] *Estimate computed from mean redd density and assumption of four salmon per observed redd.*
[6] *Estimate computed from measured spawning habitat area and assumption of 194 square feet per redd (includes redd plus defended territory).*

Table 5.1-5. Estimated escapement densities for each tributary in the upper Feather River.

Tributary of the Upper Feather River	Estimated Total Surface Area of Available Spawning Habitat (hectare)	Estimated Escapement Density (salmon/hectare)	Tributary Length (mile)
West Branch	1.96	423 – 16,542	17.50
North Fork	Not Available	Not Available	16.30
Middle Fork	2.19	473 – 18,4836	16.90
South Fork	2.63	568 – 22,197	4.00

5.2 DEFINED LIFE STAGES, PRESENCE DATES, AND WATER TEMPERATURE INDEX VALUES

The life history characteristics of Chinook salmon and steelhead include multiple life stages. Response to, and the effects from, water temperature differs between life stages and species. Therefore, each life stage must be explicitly defined prior to selecting appropriate water temperature index values to be used as guidelines for

resource management decisions, impact assessment, and habitat suitability evaluations. Definitions for each life stage of Chinook salmon and steelhead, presence dates, associated water temperature index values, and literature supporting selection of each index value are summarized below. Presence dates represent estimates based on data gathered in the lower Feather River, and from information found in available literature.

5.2.1 Chinook Salmon Adult Immigration and Holding

The adult immigration and holding life stage is defined as the time period from freshwater entry until spawning site selection. Adult Chinook salmon reportedly immigrate and hold in the lower Feather River from March through December (DWR 2003b). For purposes of this report, 60°F (15.6°C), 64°F (17.8°C) and 68°F (20°C) were used as index values to assess the suitability of water temperatures in the upper Feather River for immigrating and holding adult Chinook salmon. Table 5.2-1 summarizes the selected water temperature index values and provides references supporting the selection of each value. A detailed discussion describing the selection process for each index value, and the potential biological effects from exceedance of each index value, is provided in section 6.2.3.1.

Table 5.2-1. Chinook salmon adult immigration and holding water temperature index values and references supporting selection of each value.

Water Temperature Index Value	Supporting Literature
60°F	NOAA Fisheries 1997, 2000; ODEQ 1995; USFWS 1995
64°F	Berman 1990; EPA 2003; NOAA Fisheries 1997
68°F	Berman 1990; Marine 1992; NOAA Fisheries 1997; Ordal and Pacha 1963

5.2.2 Chinook Salmon Spawning and Embryo Incubation

The spawning and embryo incubation life stage is defined as the time period from redd construction and egg deposition through fry emergence. The effects to spawning adults from elevated water temperatures generally are a function of cumulative exposure time. Salmon are first exposed to in-river water temperatures during the immigration and holding life stage, therefore, the effects to adults from elevated water temperatures are addressed in that life stage. The spawning and embryo incubation life stage focuses on thermal effects to incubating eggs and alevins. Incubation of eggs and alevin reportedly occurs in the lower Feather River from August 15 through February 15 (DWR 2004; Moyle 2002). For purposes of this report, 56°F (13.3°C), 58°F (14.4°C), 60°F (15.6°C), and 62°F (16.7°C) were used as index values to assess the suitability of water temperatures in the upper Feather River for the Chinook salmon spawning and embryo incubation life stage. Table 5.2-2 summarizes the selected water temperature index values and provides references supporting the selection of each value. A detailed discussion describing the selection process for each index value, and the potential biological effects from exceedance of each index value, is provided in section 6.2.3.2.

Table 5.2-2. Chinook salmon spawning and embryo incubation water temperature index values and references supporting selection of each value.

Water Temperature Index Value	Supporting Literature
56°F	Groves and Chandler 1999; NOAA Fisheries 1993, 1997, 2002; USBR 2003; USFWS 1995, 1999
58°F	Combs and Burrows 1957; NOAA Fisheries 2002; USBR 2003
60°F	Dauble and Watson 1997; Johnson and Brice 1953; NOAA Fisheries 1993; Seymour 1956; USFWS 1995
62°F	Hinze 1959; USBR 2003; USFWS 1999

5.2.3 Chinook Salmon Juvenile Rearing and Downstream Movement

The juvenile rearing and downstream movement life stage is defined as the time period from emergence through ocean entry. Because no distinction was made in this report between spring-run Chinook salmon and fall-run Chinook salmon, and in order to capture both ocean-type and stream-type life history rearing strategies, the rearing and downstream movement life stage of Chinook salmon in the lower Feather River was determined to occur year-round (i.e. from January through December) (DWR 2003c). For purposes of this report, 60°F (15.6°C), 63°F (17.2°C), 65°F (18.3°C), 68°F (20°C), 70°F (21.1°C), and 75°F (23.9°C) were used as index values to assess the suitability of water temperatures in the upper Feather River for the Chinook salmon juvenile rearing and downstream movement life stage. Table 5.2-3 summarizes the selected water temperature index values and provides references supporting the selection of each value. A detailed discussion describing the selection process for each index value, and the potential biological effects from exceedance of each index value, is provided in section 6.2.3.3.

Table 5.2-3. Chinook salmon juvenile rearing and downstream movement water temperature index values and references supporting selection of each value.

Water Temperature Index Value	Supporting Literature
60°F	Banks et al. 1971; Brett 1982; Marine 1997; NOAA Fisheries 1993,1997, 2000, 2002; Rich 1987; Seymour 1956
63°F	Clarke and Shelbourn 1985; Marine 1992, 1997; Zedonis and Newcomb 1997
65°F	Brett et al. 1982; Cech and Myrick 1999; EPA 2003; Johnson and Brice 1953; NOAA Fisheries 2002; Ordal and Pacha 1963; Rich 1987; USFWS 1995
68°F	Marine 1997; Zedonis and Newcomb 1997
70°F	Brett 1982; Rich 1987
75°F	Rich 1987

5.2.4 Steelhead Adult Immigration and Holding

The adult immigration and holding life stage is defined as the time period from freshwater entry until spawning site selection. Adult steelhead reportedly immigrate and hold in the lower Feather River from September through April 15 (DWR 2003a). For purposes of this report, 52°F (11.1°C), 56°F (13.3°C), and 70°F (21.1°C) were used as

index values to assess the suitability of water temperatures in the upper Feather River for immigrating and holding adult steelhead. Table 5.2-4 summarizes the selected water temperature index values and provides references supporting the selection of each value. A detailed discussion describing the selection process for each index value, and the potential biological effects from exceedance of each index value, is provided in section 6.2.3.4.

Table 5.2-4. Steelhead adult immigration and holding water temperature index values and references supporting selection of each value.

Water Temperature Index Value	Supporting Literature
52°F	NOAA Fisheries 2000,2002; USBR 1997, 2003
56°F	Leitritz and Lewis 1980; McCullough et al. 2001; Smith et al. 1983
70°F	McCullough et al. 2001

5.2.5 Steelhead Spawning and Embryo Incubation

The spawning and embryo incubation life stage is defined as the time period from redd construction and egg deposition through fry emergence. The steelhead spawning and embryo incubation life stage reportedly occurs in the lower Feather River from December through May (DWR 2003a; Moyle 2002). For purposes of this report, 52°F (11.1°C), 54°F (12.2°C), 57°F (13.9°C), and 60°F (15.6°C) were used as index values to assess the suitability of water temperatures in the upper Feather River for the steelhead spawning and embryo incubation life stage. Table 5.2-5 summarizes the selected water temperature index values and provides references supporting the selection of each value. A detailed discussion describing the selection process for each index value, and the potential biological effects from exceedance of each index value, is provided in section 6.2.3.5.

Table 5.2-5. Steelhead spawning and embryo incubation water temperature index values and references supporting selection of each value.

Water Temperature Index Value	Supporting Literature
52°F	Humpesch 1985; NOAA Fisheries 2000, 2001, 2002; USBR 1997; USFWS 1995
54°F	EPA 2001; Kamler and Kato 1983; McCullough et al. 2001; Redding and Schreck 1979; Rombough 1988
57°F	Velsen 1987
60°F	Kwain 1975; Velsen 1987

5.2.6 Steelhead Fry and Fingerling Rearing and Downstream Movement

The fry and fingerling rearing and downstream movement life stage is defined as the time period from emergence through rearing, and does not include juveniles undergoing smoltification during true seaward migrations. The steelhead fry and fingerling rearing and downstream movement life stage occurs during all months of the year in the lower Feather River because juveniles remain in freshwater for 1 to 3 years before smolting and migrating to saltwater (Myrick and Cech 2001). For purposes of this report, 65°F

(18.3°C), 68°F (20°C), 72°F (22.2°C), and 75°F (23.9°C) were used as index values to assess the suitability of water temperatures in the upper Feather River for the steelhead fry and fingerling rearing and downstream movement life stage. Table 5.2-6 summarizes the selected water temperature index values and provides references supporting the selection of each value. A detailed discussion describing the selection process for each index value, and the potential biological effects from exceedance of each index value, is provided in section 6.2.3.6.

Table 5.2-6. Steelhead juvenile rearing and downstream movement water temperature index values and references supporting selection of each value.

Water Temperature Index Value	Supporting Literature
65°F	Cech and Myrick 1999; Cherry et al. 1977; McCauley and Pond 1971; NOAA Fisheries 2002
68°F	Cech and Myrick 1999; Cherry et al. 1977
72°F	Nielsen et al. 1994
75°F	EPA 2002; NOAA Fisheries 2001

5.2.7 Steelhead Smolt Emigration

The steelhead smolt emigration life stage is defined as the time period encompassing the onset of smoltification (primarily physiological changes) through saltwater entry. In the lower Feather River, steelhead smolts reportedly emigrate to the ocean from January through June (Cavallo 2002). For purposes of this report 52°F (11.1°C), and 55°F (12.8°C) were used as index values to assess the suitability of water temperatures in the upper Feather River for the steelhead smolt emigration life stage. Table 5.2-7 summarizes the selected water temperature index values and provides references supporting the selection of each value. A detailed discussion describing the selection process for each index value, and the potential biological effects from exceedance of each index value, is provided in section 6.2.3.7.

Table 5.2-7. Steelhead smolt emigration water temperature index values and references supporting selection of each value.

Water Temperature Index Value	Supporting Literature
52°F	Adams et al. 1975; Myrick and Cech 2001; Rich 1987
55°F	EPA 2003; McCullough et al. 2001; Wedemeyer et al. 1980; Zaugg and Wagner 1973

5.3 WATER TEMPERATURES IN THE UPPER FEATHER RIVER

The water temperature profiles that are provided in this report may represent thermal extremes because water temperature data loggers were generally located in downstream sections at low elevations where, typically, the highest water temperatures would be expected to exist. Mean daily water temperatures in the upper Feather River for each water temperature data logger (by life stage and tributary), the associated water temperature index values, and presence dates are summarized below. Water temperature data logger locations, at times, are referred to according to river mile (RM).

The mileage was measured from the defined beginning of the study area upstream to each loggers location. In the West Branch and South Fork, several water temperature loggers were located in feeder tributaries, and not in the main tributary channel. In lotic systems, water temperature typically is positively correlated with distance moved downstream. However, because some loggers are located out of main tributary channel, this generality may not remain consistent, and RM, by itself, could be a poor indicator of water temperature differences between data loggers.

5.3.1 Chinook Salmon Adult Immigration and Holding

During the Chinook salmon immigration and holding life stage in the upper Feather River (March through December), mean daily water temperatures in the West Branch generally remained below 60°F (15.6°C) from March through May, and again from October through December (Figure 5.3-1). At most of the locations at which water temperature was recorded, mean daily water temperatures exceeded 68°F (20°C) from June through August. In the North Fork, mean daily water temperatures remained below 60°F from March through May, and again from early October through December (Figure 5.3-2). As a general statement, mean daily water temperatures exceeded or were very near 68°F from June through September. In the Middle Fork, mean daily water temperatures remained below 60°F from March through May, and again from early September to early October through December (Figure 5.3-3). At RM 4.9, mean daily water temperatures rarely exceeded 68°F. At RM 11.2, mean daily water temperatures exceeded 68°F from approximately mid-June through late August. In the South Fork, mean daily water temperatures remained below 60°F from March through early May, and again from mid-September through December (Figure 5.3-4). Mean daily water temperatures occasionally exceeded 68°F during each month from June through August.

5.3.2 Chinook Salmon Spawning and Embryo Incubation

During the time period corresponding with the Chinook salmon spawning and embryo incubation life stage in the upper Feather River (August 15 through February 15), mean daily water temperatures in the West Branch remained below 56°F (13.3°C) from November through February 15 (Figure 5.3-5). At most of the locations that water temperature was recorded, mean daily water temperatures exceeded 62°F (16.7°C) from August 15 through September. In the North Fork, mean daily water temperatures remained below 56°F generally from November through February 15 (Figure 5.3-6). Mean daily water temperatures exceeded 62°F generally from August 15 through mid-October. In the Middle Fork, mean daily water temperatures remained below 56°F from October through February 15 (Figure 5.3-7). At RM 4.9, mean daily water temperatures exceeded 62°F rarely in late August and early September. At RM 11.2, mean daily water temperatures exceeded 62°F generally from August 15 through mid-September to early October. In the South Fork, mean daily water temperatures remained below 56°F from mid-October through February 15 (Figure 5.3-8). Mean daily water temperatures

exceeded 62°F from August 15 through early September at RM 4.3, and from August 15 through late September at RM 6.3.

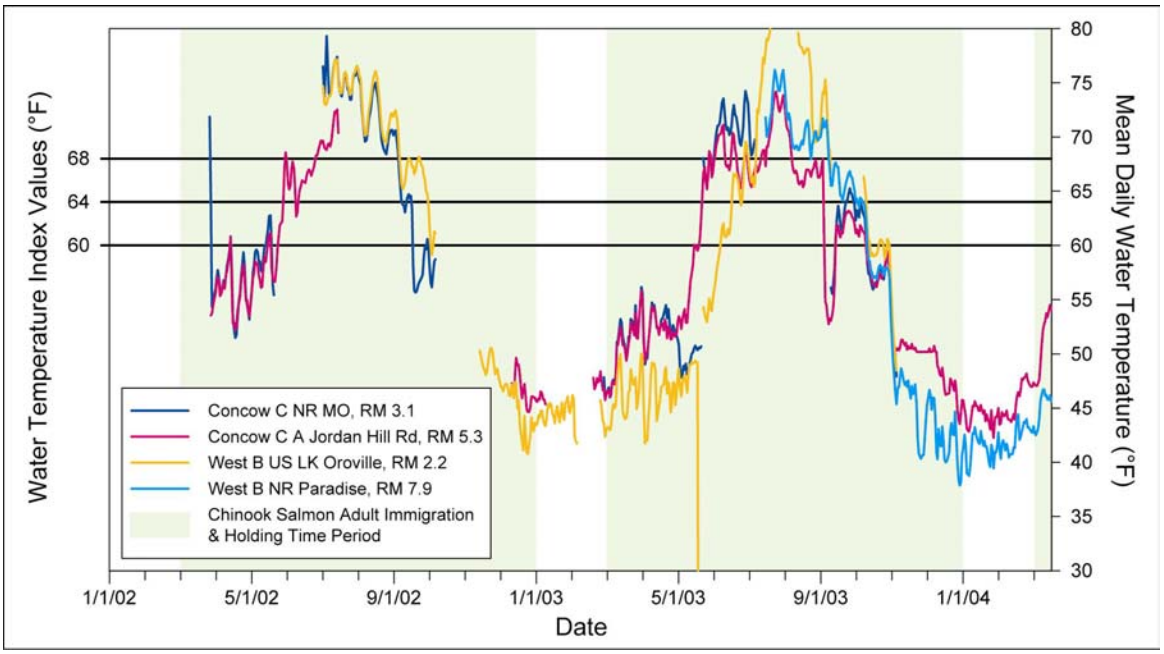


Figure 5.3-1. Water temperature index values, mean daily water temperatures for each data logger in the West Branch of the upper Feather River, and presence dates for the Chinook salmon adult immigration and holding life stage.

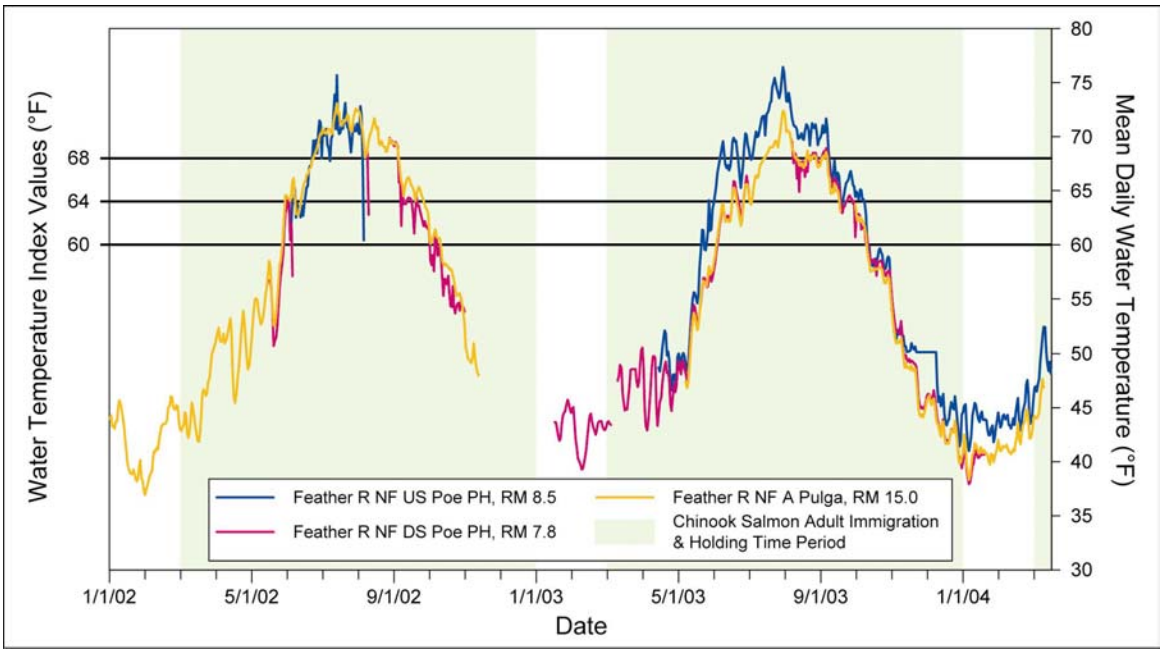


Figure 5.3-2. Water temperature index values, mean daily water temperatures for each data logger in the North Fork of the upper Feather River, and presence dates for the Chinook salmon adult immigration and holding life stage.

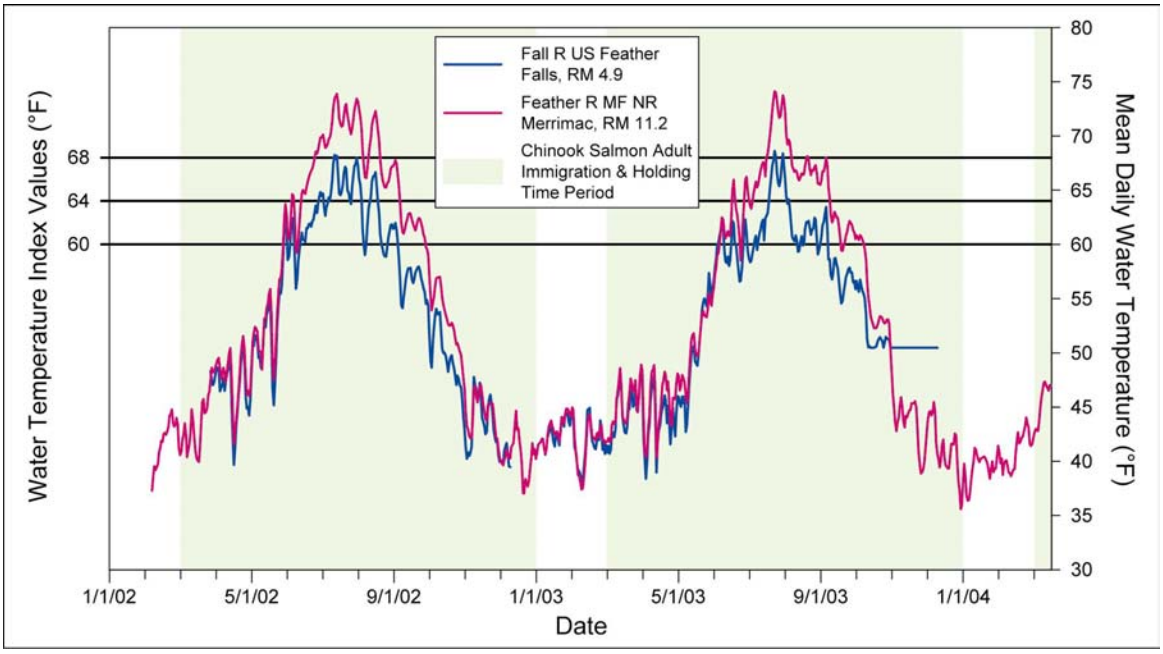


Figure 5.3-3. Water temperature index values, mean daily water temperatures for each data logger in the Middle Fork of the upper Feather River, and presence dates for the Chinook salmon adult immigration and holding life stage.

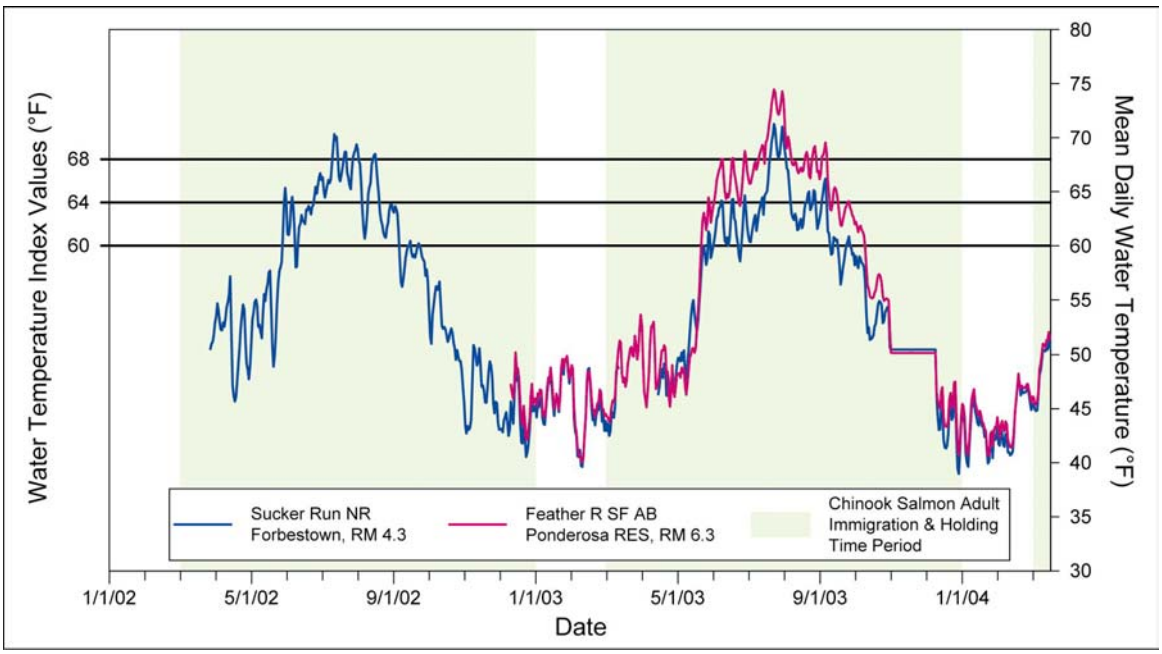


Figure 5.3-4. Water temperature index values, mean daily water temperatures for each data logger in the South Fork of the upper Feather River, and presence dates for the Chinook salmon adult immigration and holding life stage.

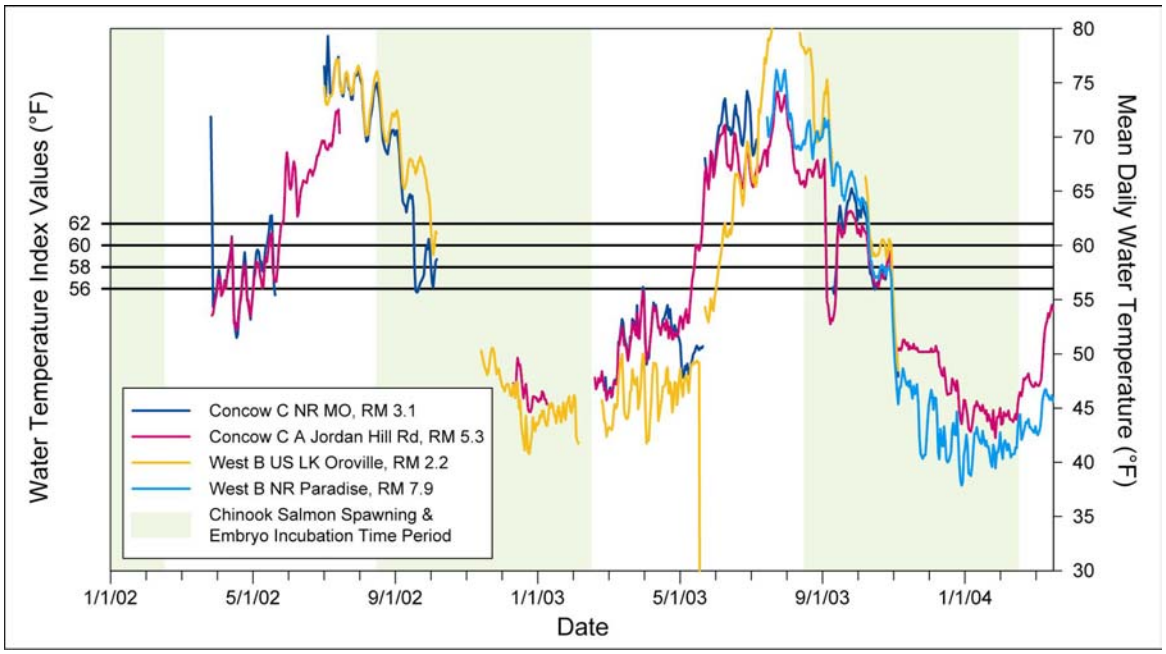


Figure 5.3-5. Water temperature index values, mean daily water temperatures for each data logger in the West Branch of the upper Feather River, and presence dates for the Chinook salmon spawning and embryo incubation life stage.

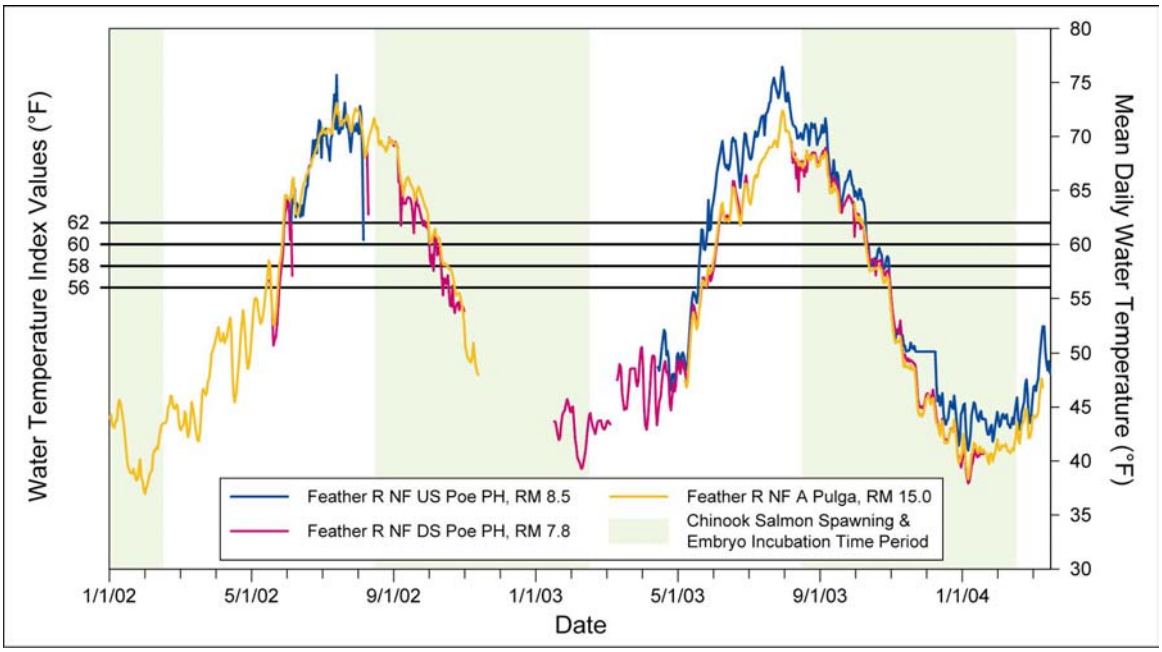


Figure 5.3-6. Water temperature index values, mean daily water temperatures for each data logger in the North Fork of the upper Feather River, and presence dates for the Chinook salmon spawning and embryo incubation life stage.

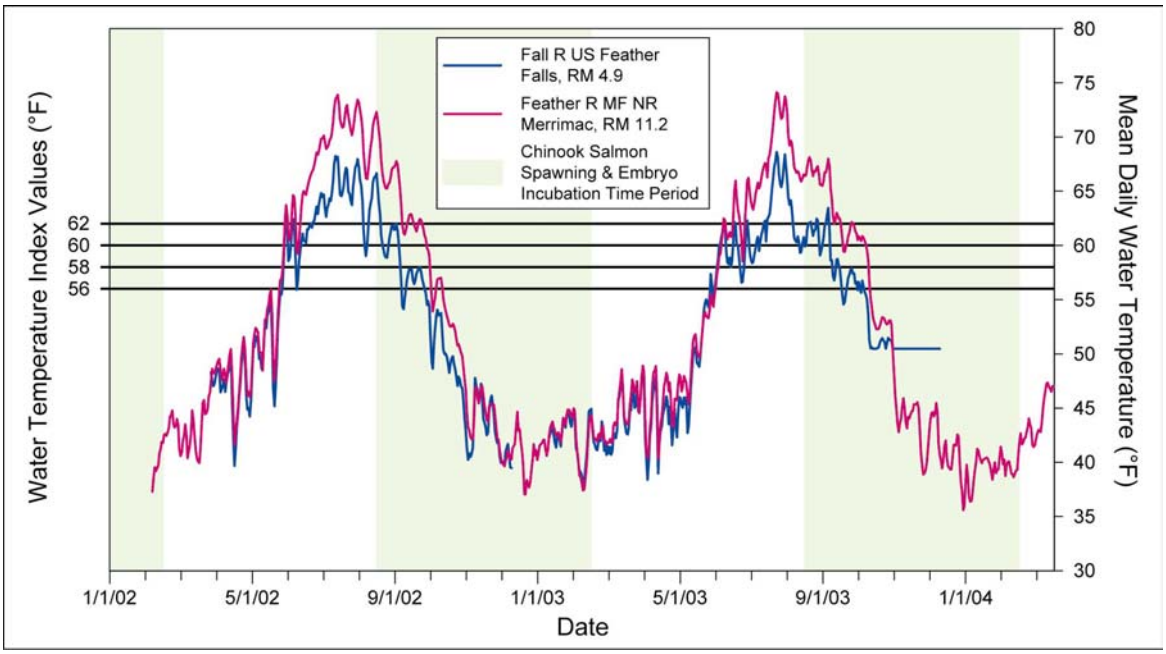


Figure 5.3-7. Water temperature index values, mean daily water temperatures for each data logger in the Middle Fork of the upper Feather River, and presence dates for the Chinook salmon spawning and embryo incubation life stage.

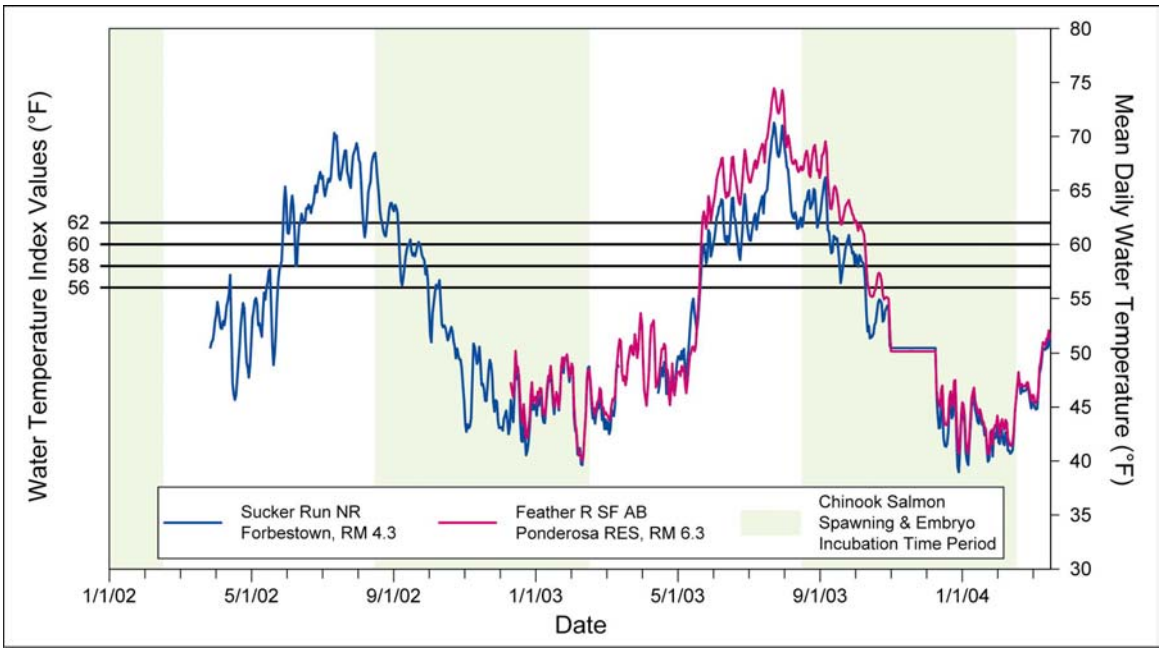


Figure 5.3-8. Water temperature index values, mean daily water temperatures for each data logger in the South Fork of the upper Feather River, and presence dates for the Chinook salmon spawning and embryo incubation life stage.

5.3.3 Chinook Salmon Juvenile Rearing and Downstream Movement

During the rearing and downstream movement life stage (year round), mean daily water temperatures in the West Branch remained below 60°F (15.6°C) generally from October through mid-May (Figure 5.3-9). Mean daily water temperatures occasionally exceeded 75°F (23.9°C) during July and early August, exceeded 68°F (20°C) generally from June through mid-September, and exceeded 63°F (17.2°C) from mid-May through September. In the North Fork, mean daily water temperatures remained below 60°F generally from early October through mid-May (Figure 5.3-10). At RM 8.5, mean daily water temperatures rarely exceeded 75°F. Mean daily water temperatures exceeded 68°F generally from June through early September. Mean daily water temperatures exceeded 63°F generally from late May through early October. In the Middle Fork, mean daily water temperatures first dropped below 60°F in September and remained there through late May to early June (Figure 5.3-11). Mean daily water temperatures did not exceed 75°F. At RM 11.2, mean daily water temperatures exceeded 68°F from early July through August, and exceeded 63°F from early June through mid-September. At RM 4.9, mean daily water temperatures rarely exceeded 68°F, and exceeded 63°F generally from late June through late August. In the South Fork, mean daily water temperatures first fell below 60°F in late August and remained there through early to mid-May. Mean daily water temperatures did not exceed 75°F, and exceeded 68°F occasionally from July through August. Mean daily water temperatures first exceeded 63°F in late May, and first fell below 63°F generally in mid-August.

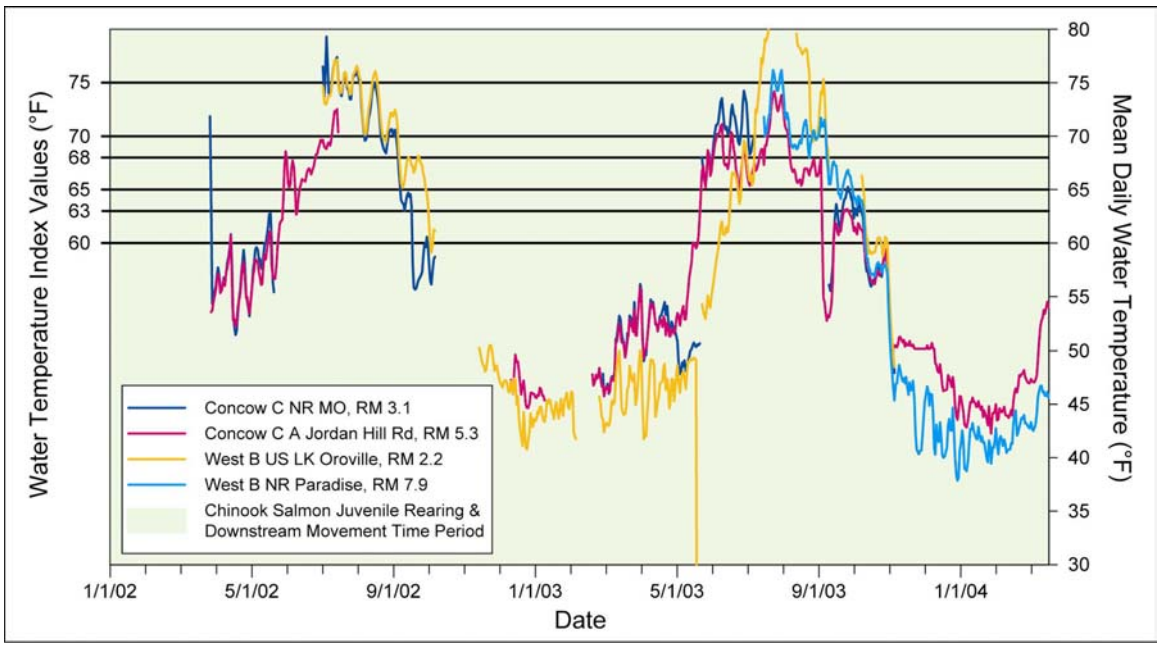


Figure 5.3-9. Water temperature index values, mean daily water temperatures for each data logger in the West Branch of the upper Feather River, and presence dates for the Chinook salmon juvenile rearing and downstream movement life stage.

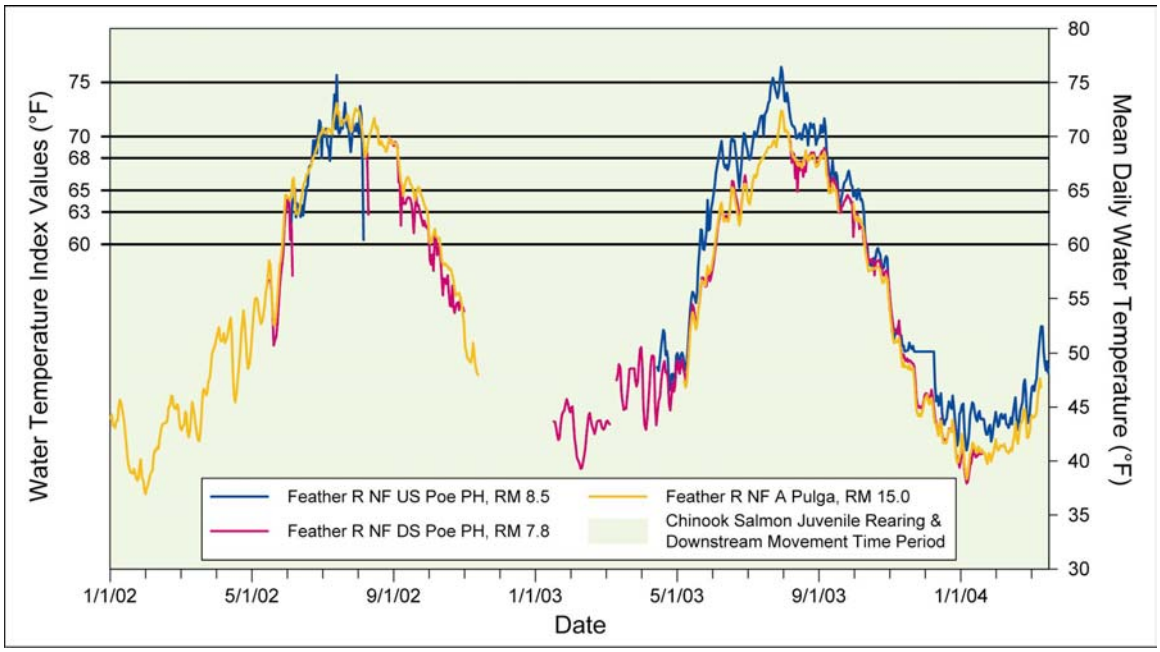


Figure 5.3-10. Water temperature index values, mean daily water temperatures for each data logger in the North Fork of the upper Feather River, and presence dates for the Chinook salmon juvenile rearing and downstream movement life stage.

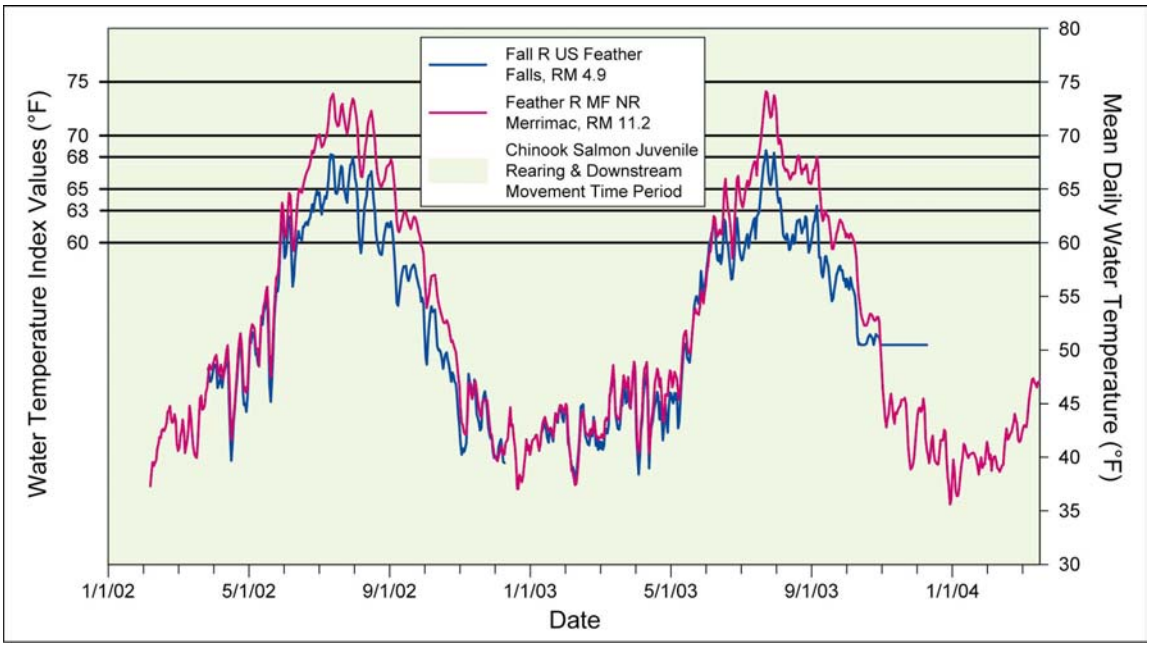


Figure 5.3-11. Water temperature index values, mean daily water temperatures for each data logger in the Middle Fork of the upper Feather River, and presence dates for the Chinook salmon juvenile rearing and downstream movement life stage.

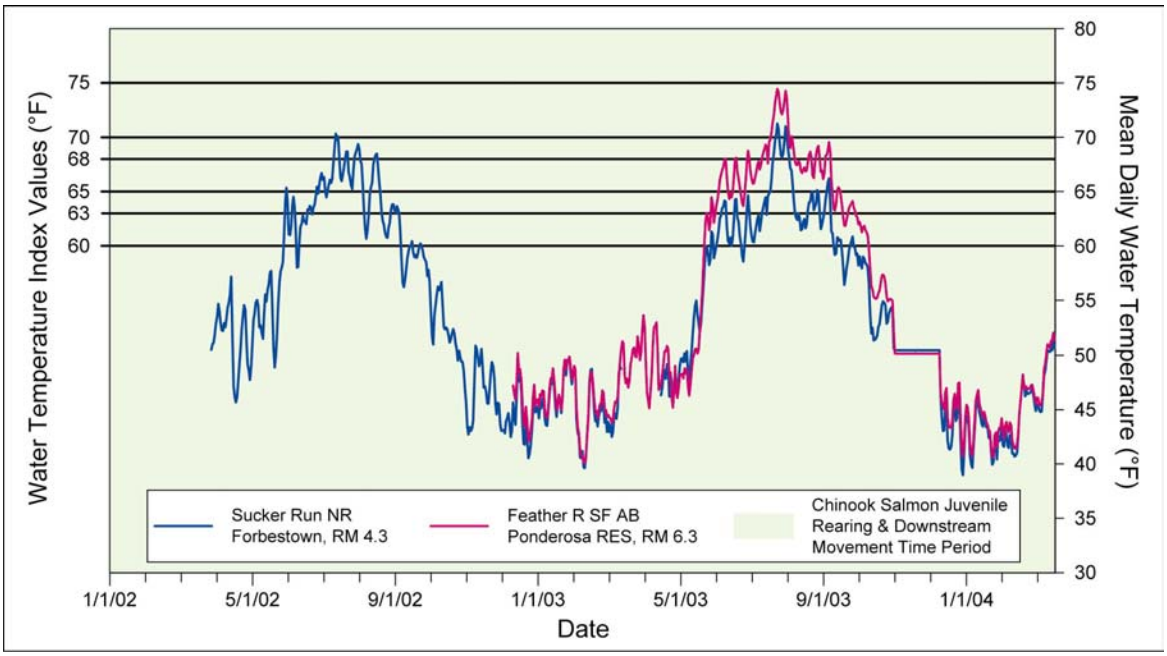


Figure 5.3-12. Water temperature index values, mean daily water temperatures for each data logger in the South Fork of the upper Feather River, and presence dates for the Chinook salmon juvenile rearing and downstream movement life stage.

5.3.4 Steelhead Adult Immigration and Holding

During the time period that steelhead would be expected to be immigrating and holding in the upper Feather River (September through April 15), mean daily water temperatures in the West Branch remained below 52°F (11.1°C) generally from November through April 15 at RM 2.2, and through mid-March at RM 5.3 (Figure 5.3-13). Mean daily water temperatures exceeded 70°F rarely (21.1°C), and remained below 56°F (13.3°C) generally from November through April 15. In the North Fork, mean daily water temperatures remained below 52°F generally from early November through April 15 (Figure 5.3-14). Water temperatures exceeded 70°F rarely, and remained below 56°F generally from late October through April 15. In the Middle Fork, mean daily water temperatures remained below 52°F from late October to early November through April 15 (Figure 5.3-15). Water temperatures did not exceed 70°F, and remained below 56°F generally from early October through April 15. In the South Fork, mean daily water temperatures remained below 52°F from late October and early November through March (Figure 5.3-16). Water temperatures did not exceed 70°F, and remained below 56°F generally from mid-October through April 15.

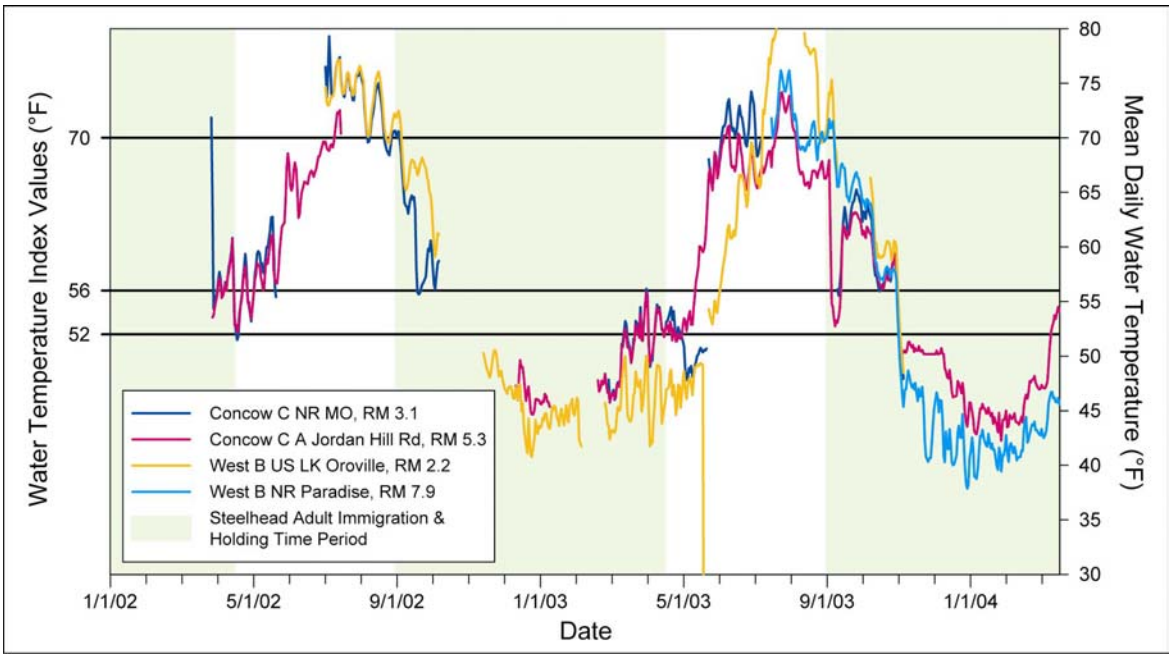


Figure 5.3-13. Water temperature index values, mean daily water temperatures for each data logger in the West Branch of the upper Feather River, and presence dates for the steelhead adult immigration and holding life stage.

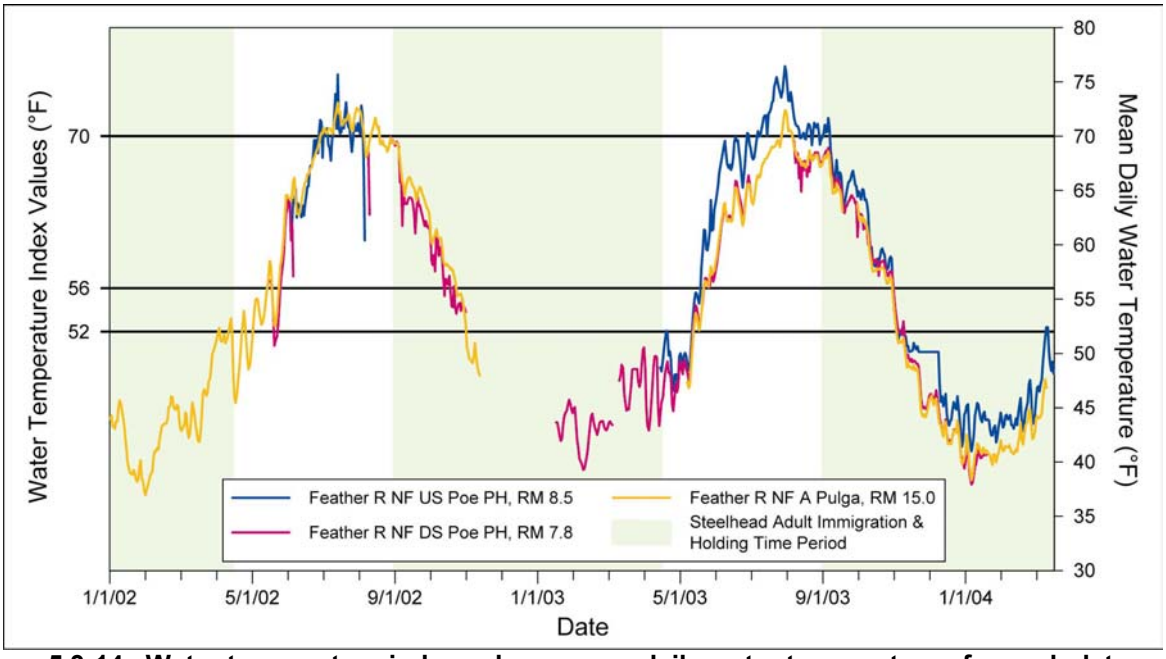


Figure 5.3-14. Water temperature index values, mean daily water temperatures for each data logger in the North Fork of the upper Feather River, and presence dates for the steelhead adult immigration and holding life stage.

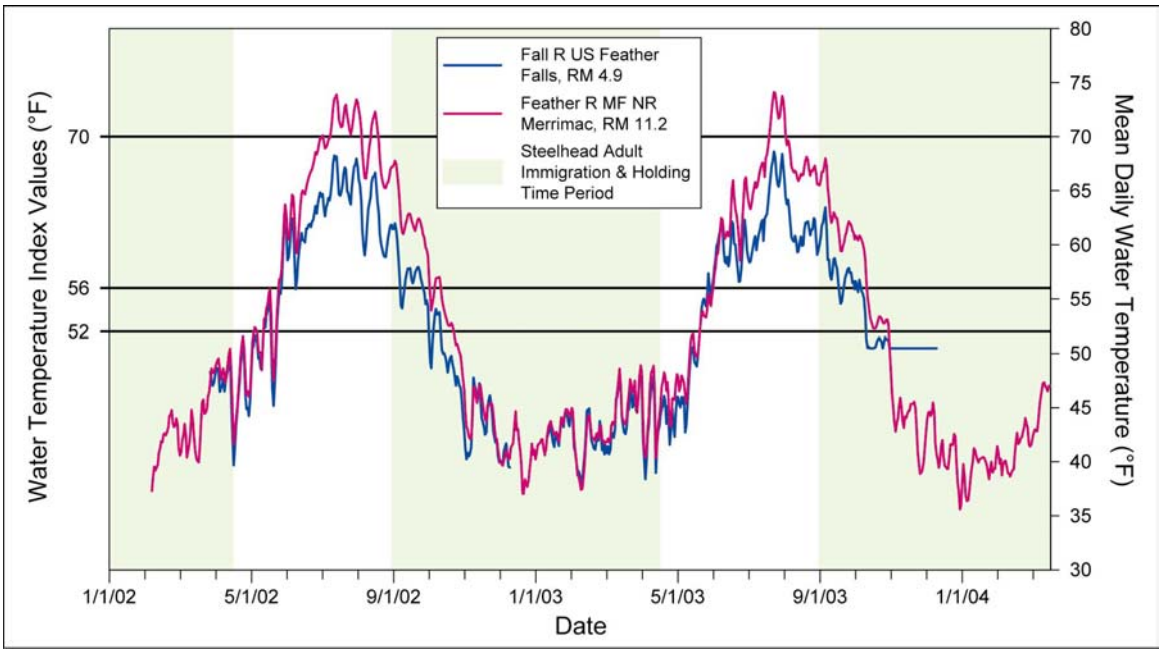


Figure 5.3-15. Water temperature index values, mean daily water temperatures for each data logger in the Middle Fork of the upper Feather River, and presence dates for the steelhead adult immigration and holding life stage.

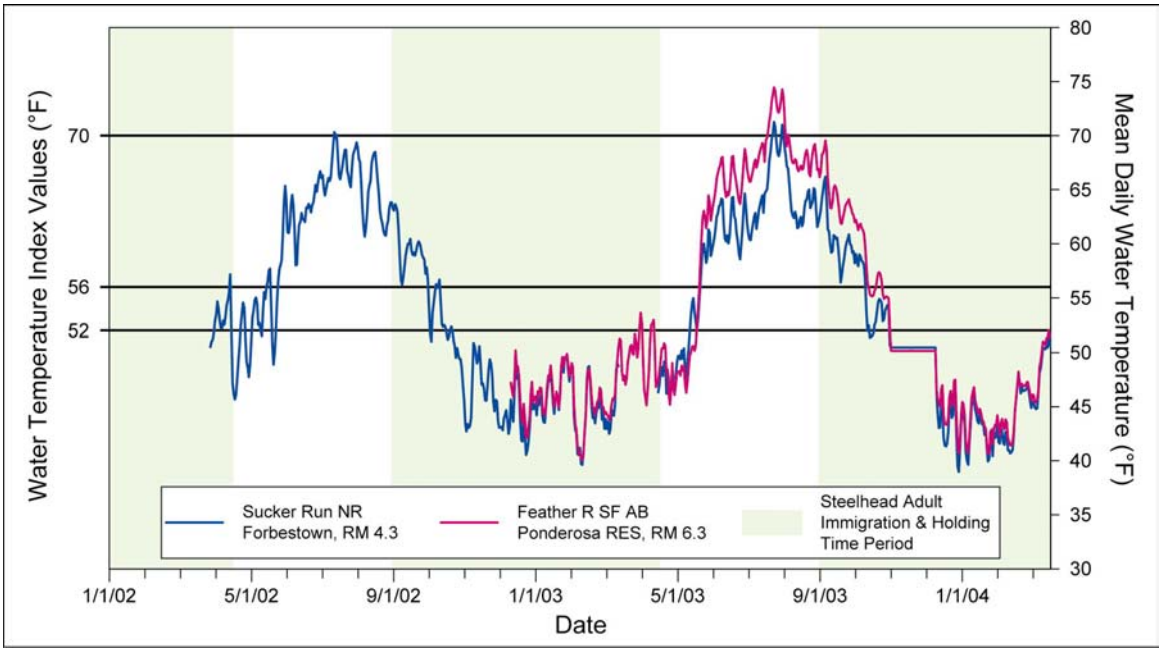


Figure 5.3-16. Water temperature index values, mean daily water temperatures for each data logger in the South Fork of the upper Feather River, and presence dates for the steelhead adult immigration and holding life stage.