5.3.5 Steelhead Spawning and Embryo Incubation

During the time period corresponding with the steelhead spawning and embryo incubation life stage in the upper Feather River (December through May), mean daily water temperatures in the West Branch remained below 52°F (11.1°C) from December through late May at RM 2.2 and RM 7.9 (Figure 5.3-17). Annual variation in mean daily water temperatures was much greater at RM 3.1 and RM 5.3. At these two locations, mean daily water temperatures dropped below 52°F very rarely in 2002 (based on available data), and remained below 52°F generally from December through mid-March in 2003 and 2004. Mean daily water temperatures exceeded 60°F (15.6°C) briefly in May in 2002 and 2003. During 2003 and 2004, mean daily water temperatures remained below 54°F (12.2°C) generally from December through May 31. In the North Fork, mean daily water temperatures remained below 52°F from December through April to early May (Figure 5.3-18). Mean daily water temperatures exceeded 60°F occasionally in late May. In general, mean daily water temperatures remained below 54°F from December through early May. In the Middle Fork, mean daily water temperatures remained below 52°F from December through late May, and exceeded 60°F briefly at the end of May in 2002 (Figure 5.3-19). Mean daily water temperatures remained below 54°F from December through mid-May. In the South Fork, mean daily water temperatures remained below 52°F from December through early April in 2002, and through early May in 2003 (Figure 5.3-20). Mean daily water temperatures exceeded 60°F briefly in late May, and remained below 54°F generally from December through early May.

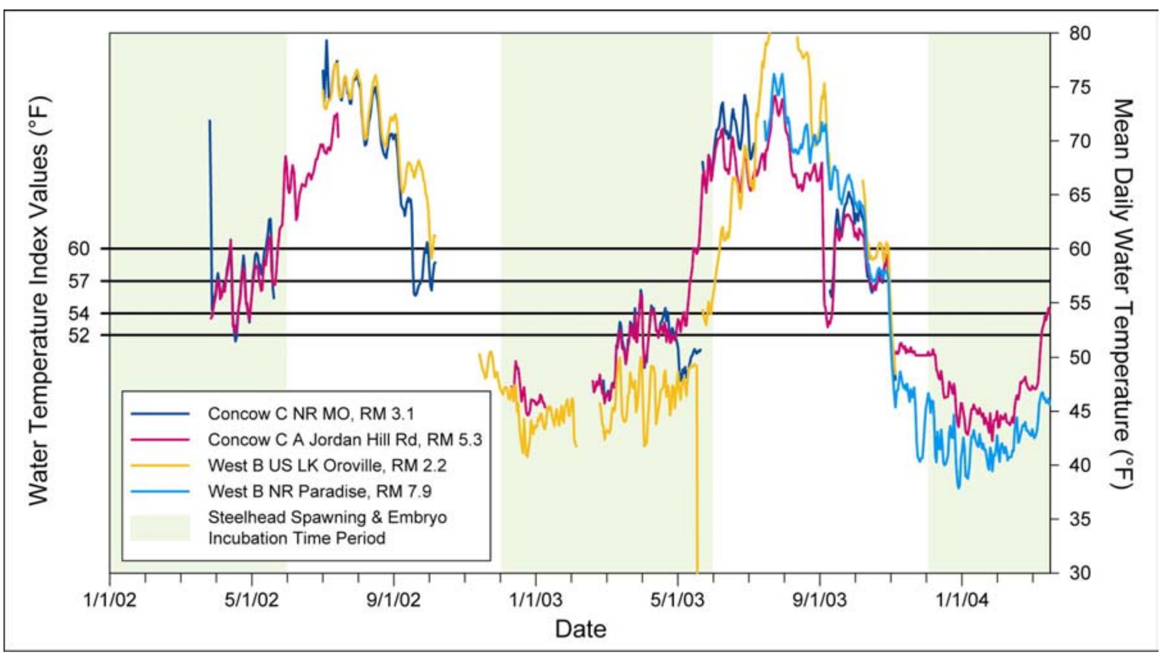

Figure 5.3-17. Water temperature index values, mean daily water temperatures for each data logger in the West Branch of the upper Feather River, and presence dates for the steelhead spawning and embryo incubation life stage.

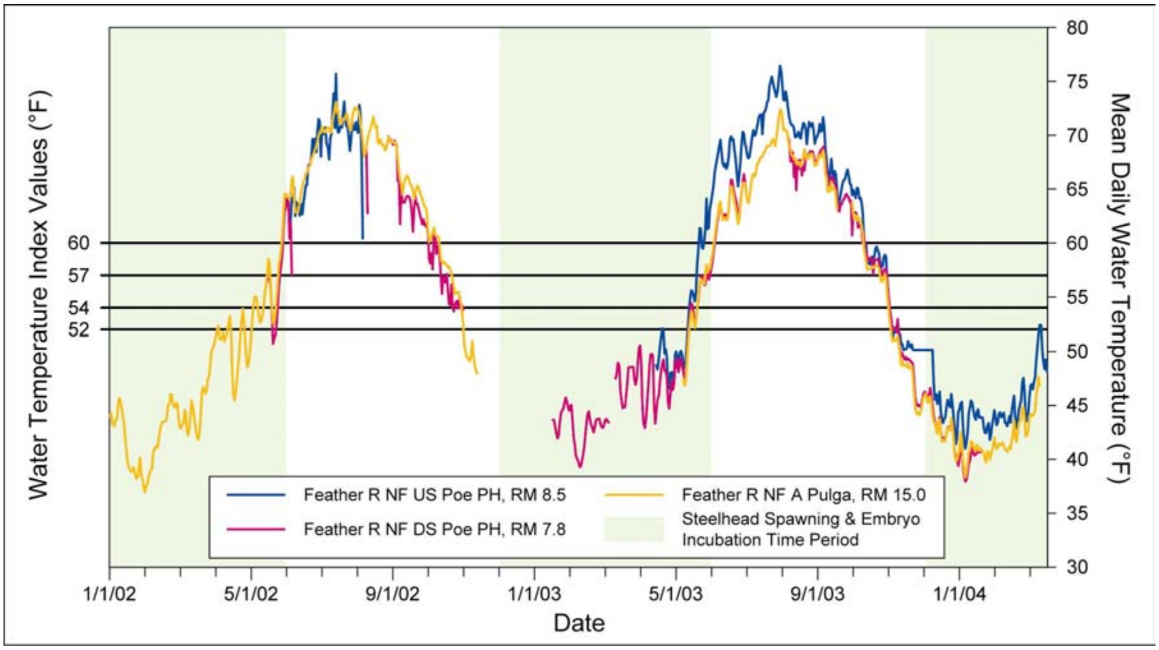

Figure 5.3-18. Water temperature index values, mean daily water temperatures for each data logger in the North Fork of the upper Feather River, and presence dates for the steelhead spawning and embryo incubation life stage.

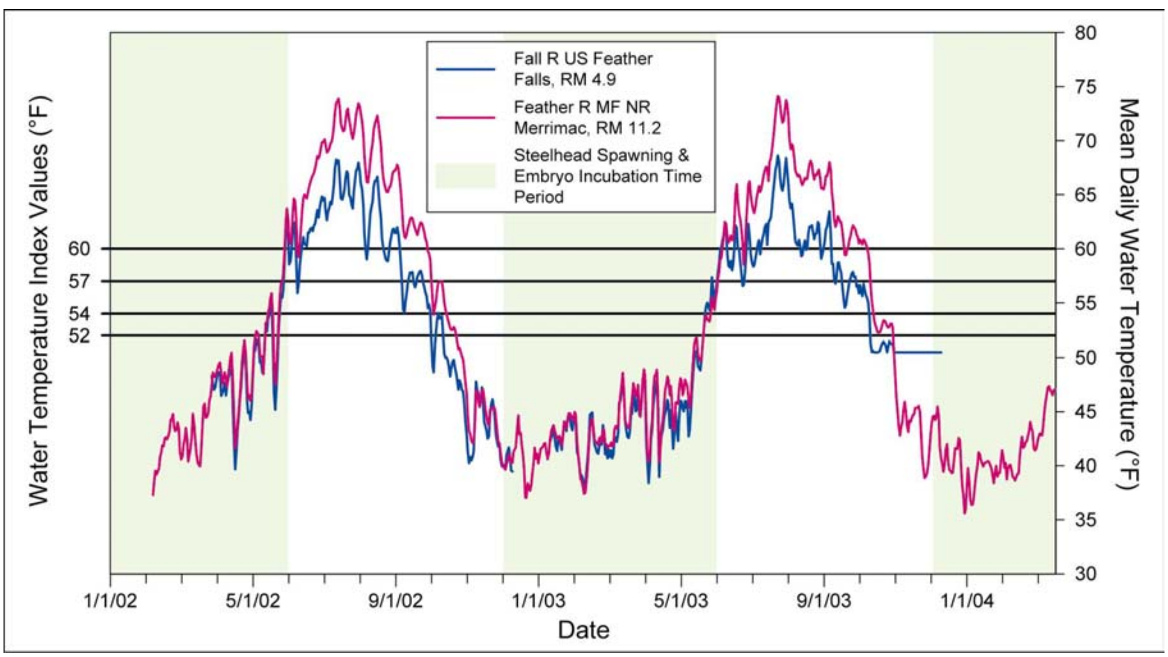

Figure 5.3-19. Water temperature index values, mean daily water temperatures for each data logger in the Middle Fork of the upper Feather River, and presence dates for the steelhead spawning and embryo incubation life stage.

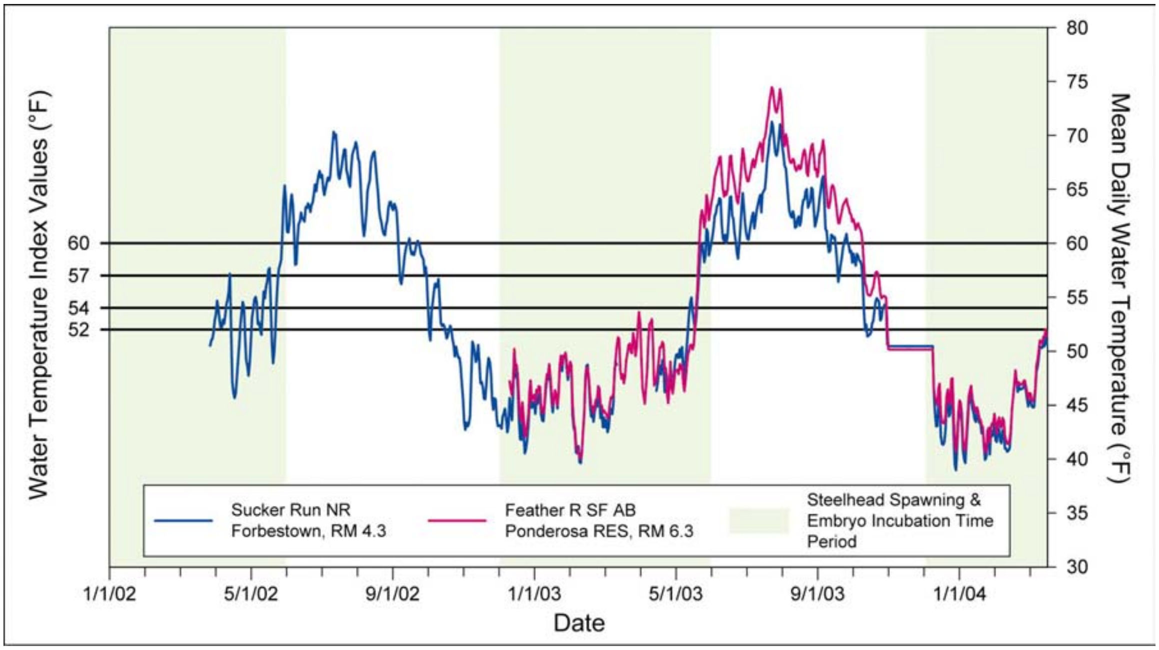

Figure 5.3-20. Water temperature index values, mean daily water temperatures for each data logger in the South Fork of the upper Feather River, and presence dates for the steelhead spawning and embryo incubation life stage.

5.3.6 Steelhead Fry and Fingerling Rearing and Downstream Movement

During the time period corresponding with the steelhead fry and fingerling life stage in the upper Feather River (year round), mean daily water temperatures in the West Branch remained below 65^{o}F (18.3^{o}C) from early September to early October through mid-May to mid-June (Figure 5.3-21). Mean daily water temperatures at most locations exceeded 75^{o}F (23.9^{o}C) occasionally from July through August. In the North Fork, mean daily water temperatures remained below 65^{o}F from approximately mid-September through approximately mid-June (Figure 5.3-22). Mean daily water temperatures exceeded 75^{o}F rarely in July, and remained below 68^{o}F (20^{o}C) generally from mid- to late September through May to early June. In the Middle Fork, mean daily water temperatures remained below 65^{o}F generally from early August through June to early July at RM 4.9, and from early September through approximately mid-June at RM 11.2 (Figure 5.3-23). Mean daily water temperatures did not exceed 75^{o}F, remained below 68^{o}F generally year round at RM 4.9, and remained below 68^{o}F generally from mid-August through late June at RM 11.2. In the South Fork, mean daily water temperatures remained below 65^{o}F generally from early August through late June to early July at RM 4.3, and from early September through early June at RM 6.3 (Figure 5.3-24). Mean daily water temperatures did not exceed 75^{o}F, remained below 68^{o}F generally from August through early July at RM 4.3, and remained below 68^{o}F generally from early September through June at RM 6.3.

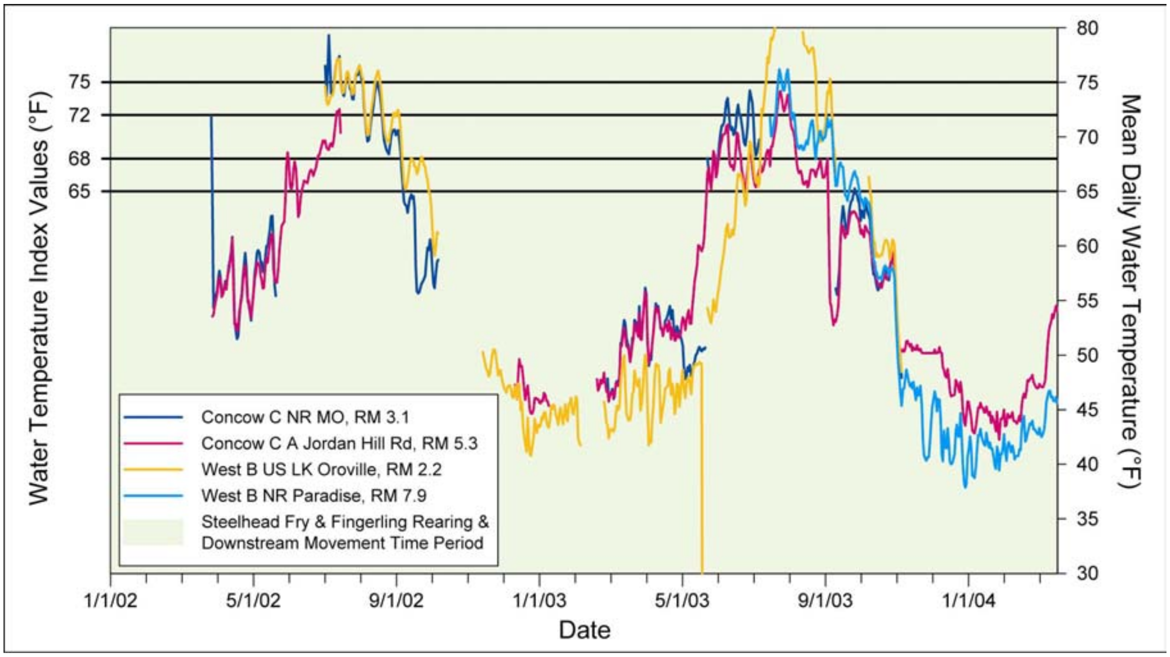

Figure 5.3-21. Water temperature index values, mean daily water temperatures for each data logger in the West Branch of the upper Feather River, and presence dates for the steelhead fry and fingerling rearing and downstream movement life stage.

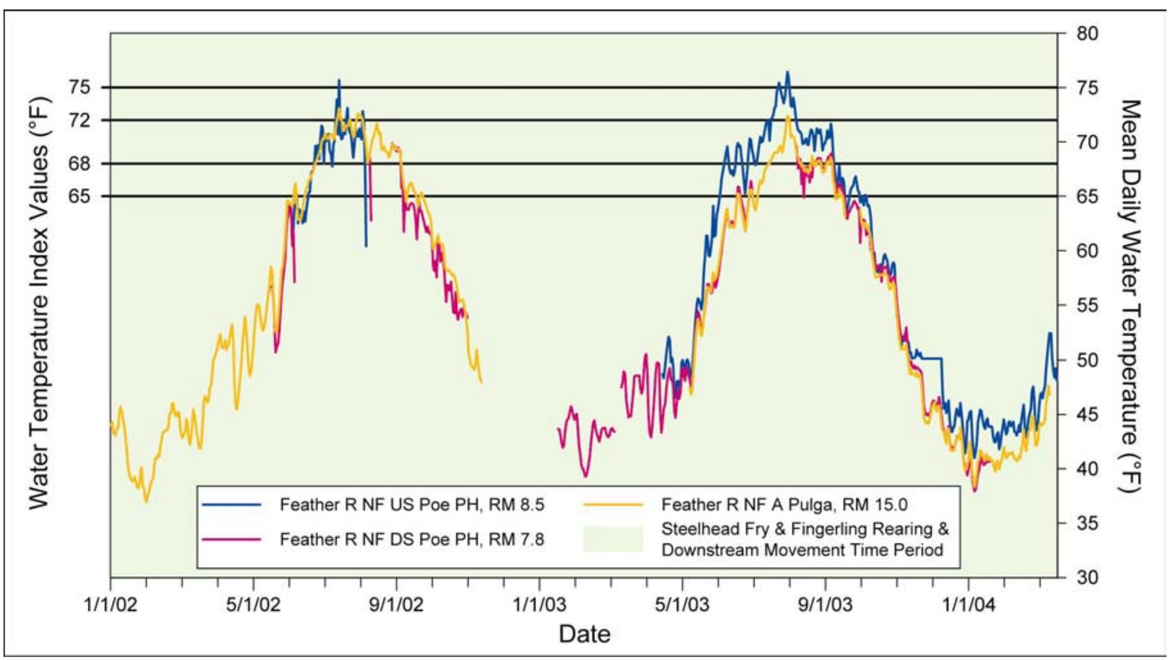

Figure 5.3-22. Water temperature index values, mean daily water temperatures for each data logger in the North Fork of the upper Feather River, and presence dates for the steelhead fry and fingerling rearing and downstream movement life stage.

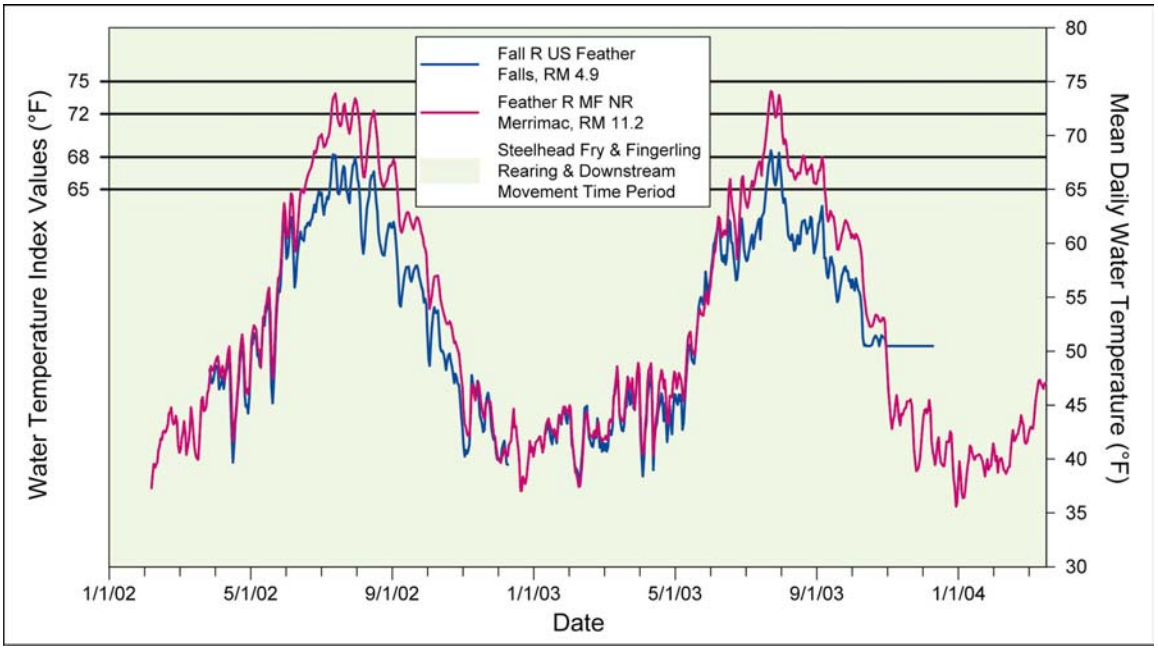

Figure 5.3-23. Water temperature index values, mean daily water temperatures for each data logger in the Middle Fork of the upper Feather River, and presence dates for the steelhead fry and fingerling rearing and downstream movement life stage.

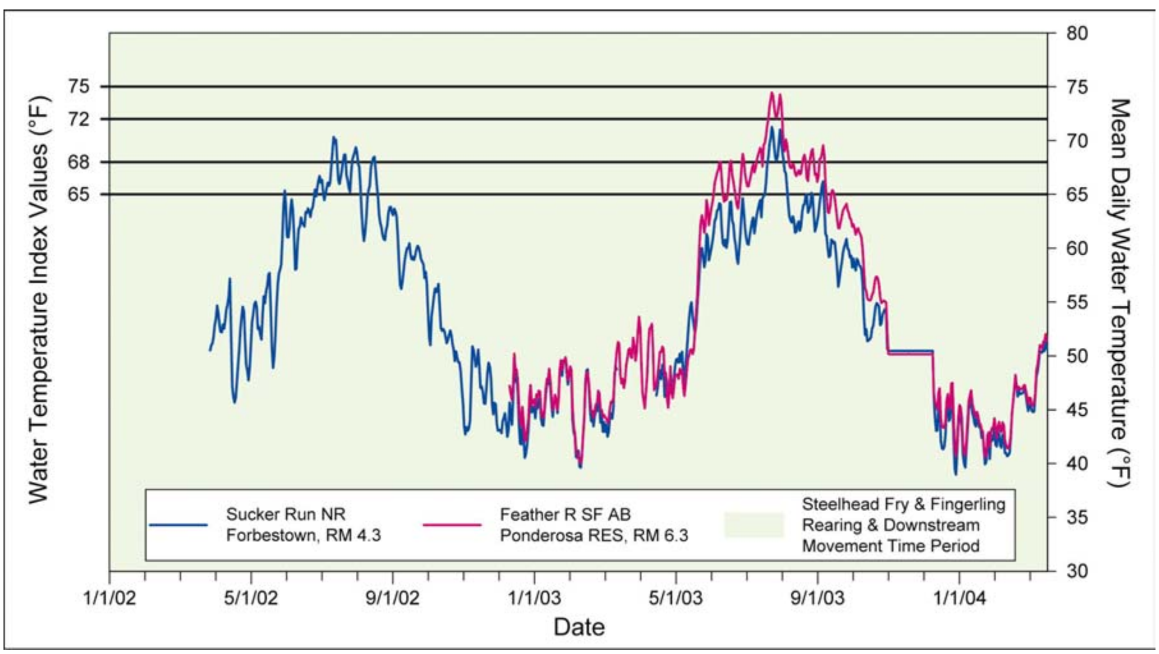

Figure 5.3-24. Water temperature index values, mean daily water temperatures for each data logger in the South Fork of the upper Feather River, and presence dates for the steelhead fry and fingerling rearing and downstream movement life stage.

5.3.7 Steelhead Smolt Emigration

During the time period corresponding with the steelhead smolt emigration life stage in the upper Feather River (January through June), mean daily water temperatures in the West Branch dropped below 52°F (11.1°C) rarely in 2002 (Figure 5.3-25). In 2003 and 2004, mean daily water temperatures remained below 52°F year-round at RM 2.2, and remained below 52°F generally from January through February at RM 3.1, RM 5.3, and RM 7.9. Mean daily water temperatures exceeded 55°F (12.8°C) from April through June in 2002, and from approximately mid-May through June in 2003. In the North Fork, mean daily water temperatures remained below 52°F generally from January through late April and late May, and exceeded 55°F generally from late May through June (Figure 5.3-26). In the Middle Fork, mean daily water temperatures remained below 52°F generally from January through late May, and exceeded 55°F during June (Figure 5.3-27). In the South Fork, mean daily water temperatures remained below 52°F generally from January through April, and exceeded 55°F from early to mid-May through June (Figure 5.3-28).

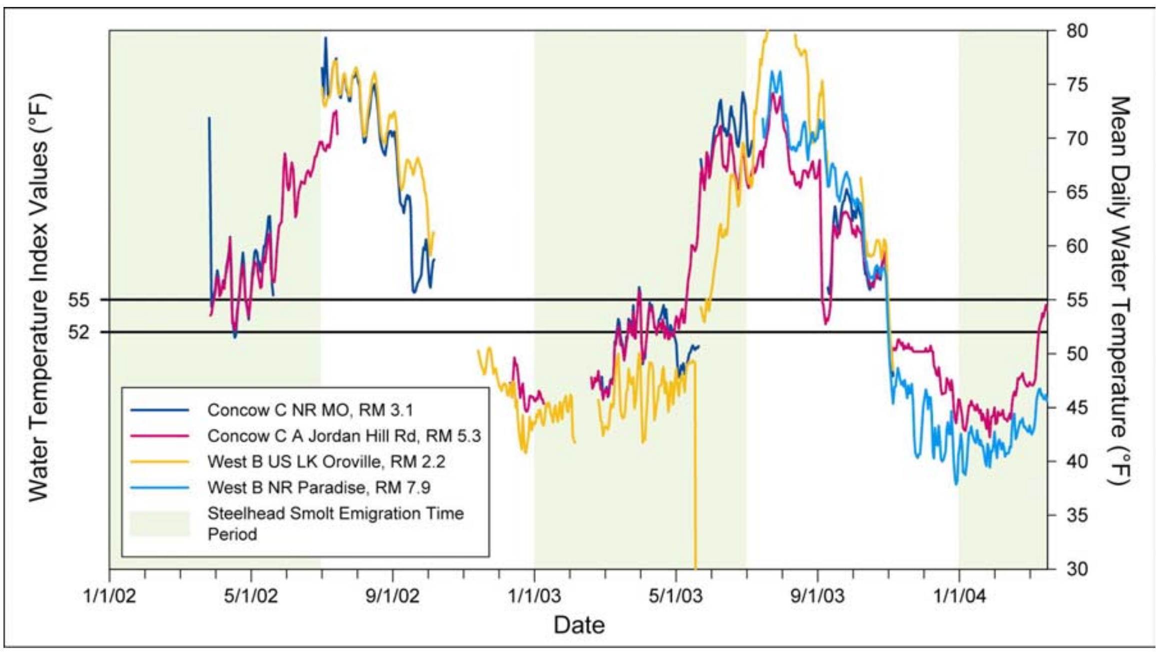

Figure 5.3-25. Water temperature index values, mean daily water temperatures for each data logger in the West Branch of the upper Feather River, and presence dates for the steelhead smolt emigration life stage.

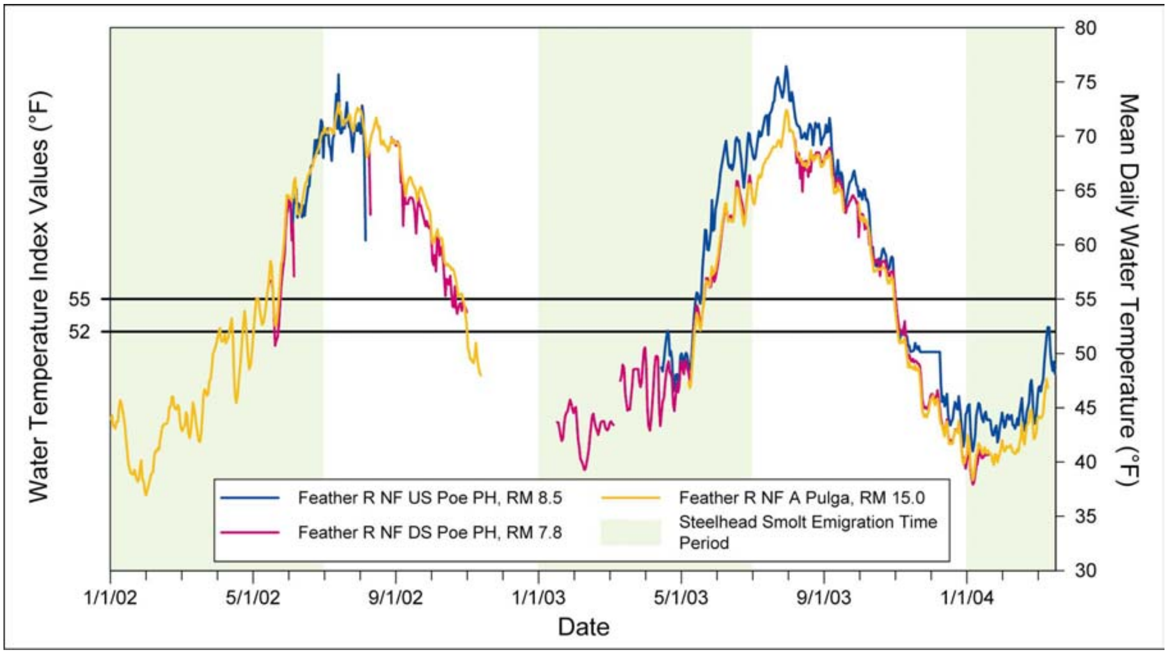

Figure 5.3-26. Water temperature index values, mean daily water temperatures for each data logger in the North Fork of the upper Feather River, and presence dates for the steelhead smolt emigration life stage.

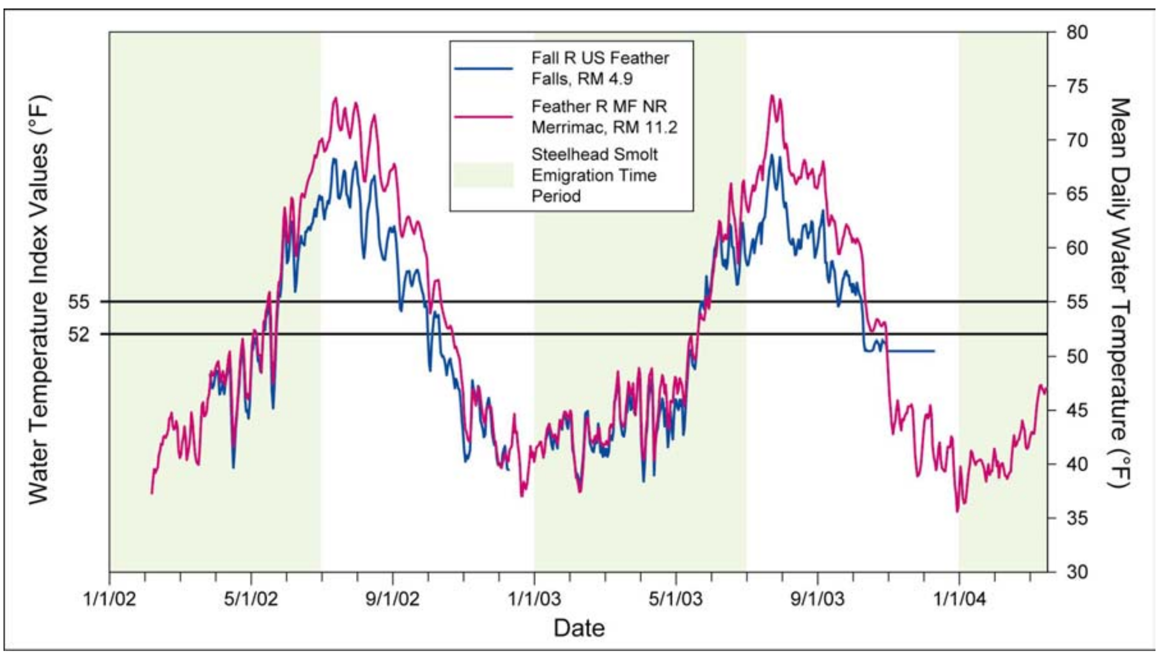

Figure 5.3-27. Water temperature index values, mean daily water temperatures for each data logger in the Middle Fork of the upper Feather River, and presence dates for the steelhead smolt emigration life stage.

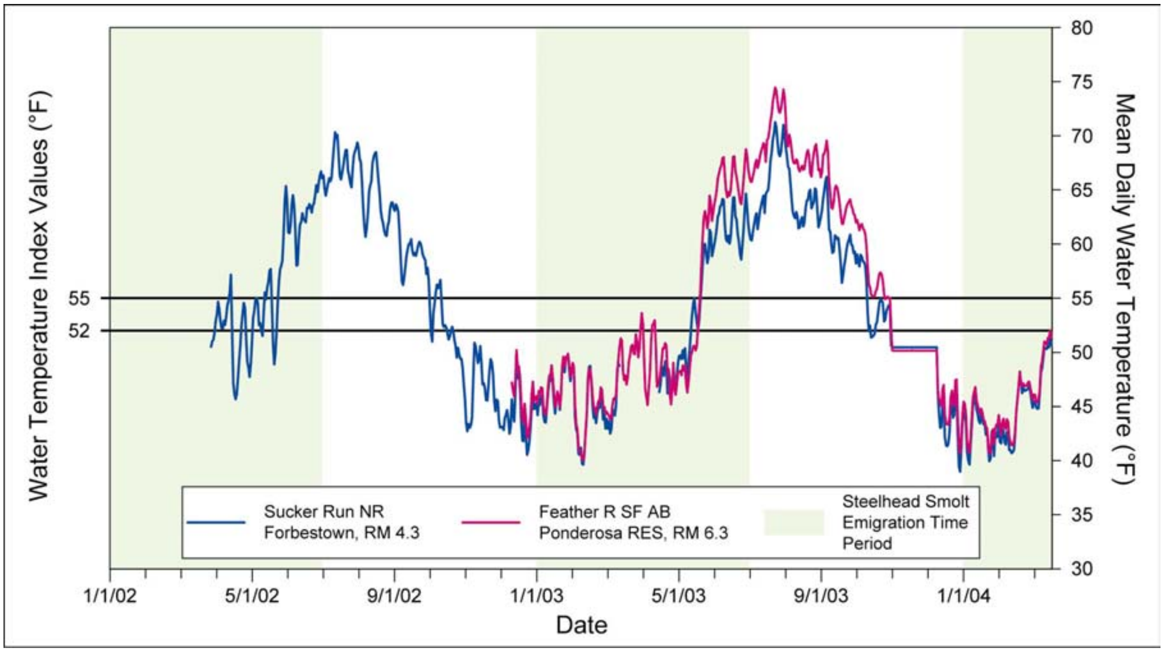

Figure 5.3-28. Water temperature index values, mean daily water temperatures for each data logger in the South Fork of the upper Feather River, and presence dates for the steelhead smolt emigration life stage.

5.4 INSTREAM FLOW IN THE UPPER FEATHER RIVER

Mean monthly instream flows (cfs) for each data logger (average of multiple years) and each life stage of Chinook salmon and steelhead, including presence dates, are shown in Figures 5.4-1 through 5.4-18. The presence dates for each life stage were based on data specific to the lower Feather River when such data were available. Instream flow data were not available for the South Fork. Mean monthly instream flows were highest in the North Fork and lowest in the West Branch. Mean monthly instream flows were highest generally from January through April, and lowest from July through October.

5.4.1 Chinook Salmon Adult Immigration and Holding

Instream flow data in the West Branch were collected at the *Miocene Canal* (MIC) data logging station. The MIC data logging station is located in Lake Oroville 3.7 miles downstream from the defined downstream boundary of the West Branch. Average monthly instream flow at the MIC station from March through December (the defined time period that Chinook salmon would be expected to be immigrating and holding in upper Feather River tributaries) ranged from a low of 22 cfs in March to a high of 47 cfs in May, and showed little variation between months (Figure 5.4-1). The average flow from March through December for all years for which data were available was 37 cfs. Instream flow data in the North Fork were collected at the *Feather NF at Pulga* (FPL) data logging station at RM 6.0. Instream flows during the Chinook salmon adult immigration and holding period showed a decreasing trend from March through

September, and an increasing trend from September through December (Figure 5.4-2). The average monthly instream flow was highest in March (4,761 cfs) and gradually decreased to an average monthly low of 1,602 cfs in September. Instream flow began increasing again during October. Instream flow data in the Middle Fork were collected at the *Feather R MF NR Merrimac* (MER) data logging station at RM 6.4. Instream flows from March through September showed a generally decreasing trend (except a slight increase from March through April), and showed an increasing trend from September through December (Figure 5.4-3). The average monthly instream flow during March was 2,918 cfs. Average flows were highest in April (3,293 cfs) and gradually decreased to an average monthly low of 289 cfs in September. Instream flow began increasing again during October, exhibiting a similar trend to the North Fork flows.

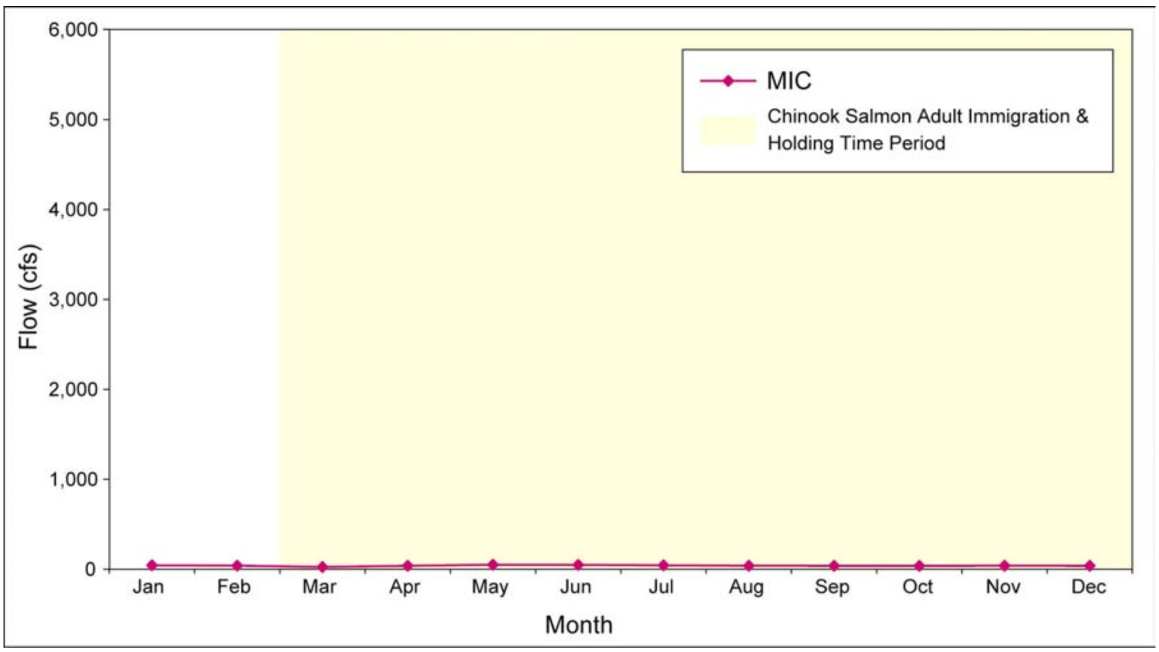

Figure 5.4-1. Mean monthly instream flows at the MIC data logger (average of multiple years) in the West Branch of the upper Feather River, and presence dates for the Chinook salmon adult immigration and holding life stage.

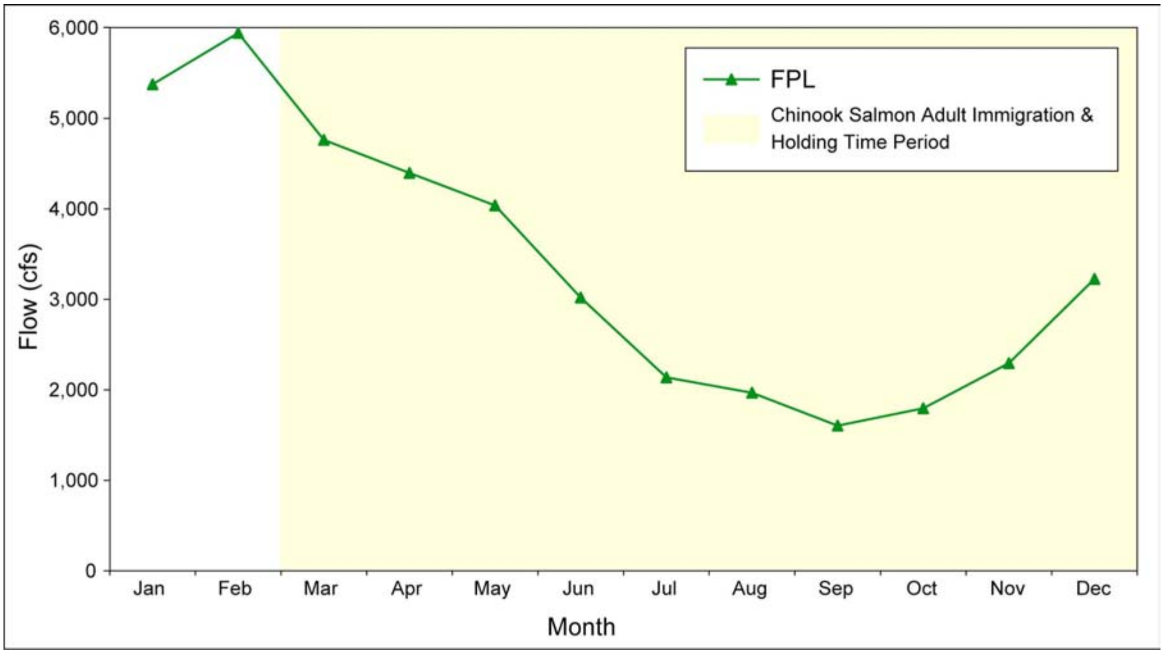

Figure 5.4-2. Mean monthly instream flows at the FPL data logger (average of multiple years) in the North Fork of the upper Feather River, and presence dates for the Chinook salmon adult immigration and holding life stage.

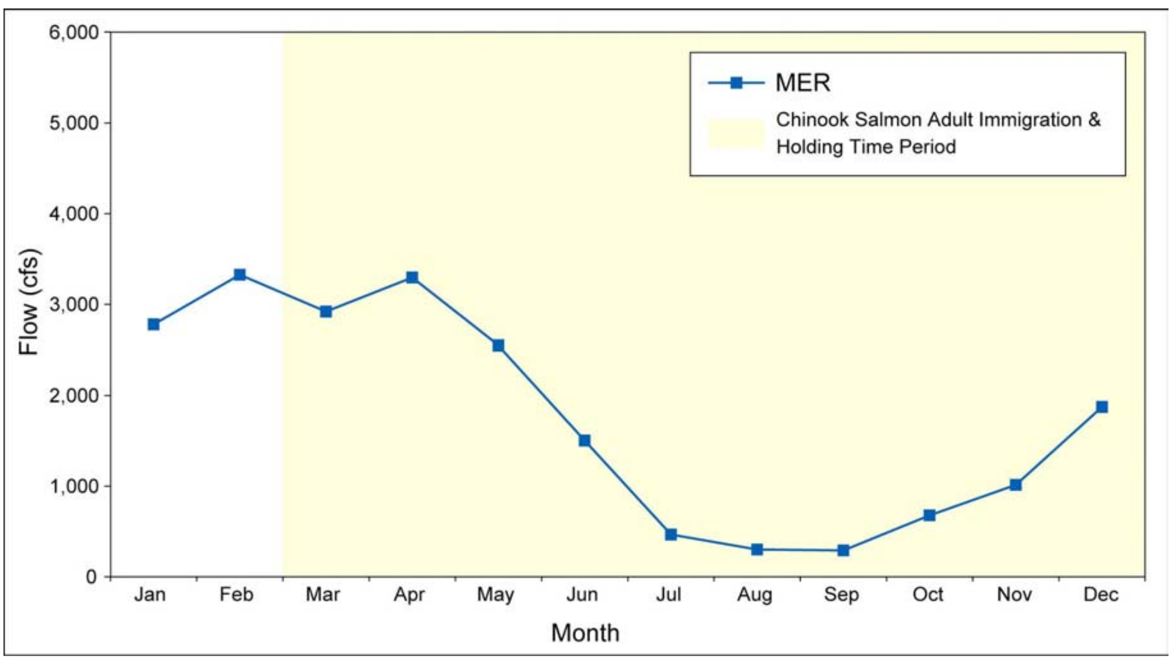

Figure 5.4-3. Mean monthly instream flows at the MER data logger (average of multiple years) in the Middle Fork of the upper Feather River, and presence dates for the Chinook salmon adult immigration and holding life stage.

5.4.2 Chinook Salmon Spawning and Embryo Incubation

Instream flow data in the West Branch were collected at the *Miocene Canal* (MIC) data logging station. The MIC data logging station is located in Lake Oroville 3.7 miles downstream from the defined downstream boundary of the West Branch. Average monthly instream flow at the MIC station from August 15 through February 15 (the defined time period for the Chinook salmon spawning and embryo incubation life stage) ranged from a low of 34 cfs in October to a high of 41 cfs in January, and showed little variation between months (Figure 5.4-4). The average flow from August through February was 37 cfs. Instream flow data in the North Fork were collected at the *Feather NF at Pulga* (FPL) data logging station at RM 6.0. Instream flows during the Chinook salmon spawning and embryo incubation period exhibited a decreasing trend from August through September, and an increasing trend from September through February (Figure 5.4-5). The average monthly instream flow was highest in February (5,942 cfs) and lowest in September at (1,602 cfs). Instream flow data in the Middle Fork were collected at the *Feather R MF NR Merrimac* (MER) data logging station at RM 6.4. Instream flows exhibited a generally increasing trend from August through February (Figure 5.4-6). The average monthly instream flow was highest in February (3,323 cfs) and lowest in September (289 cfs).

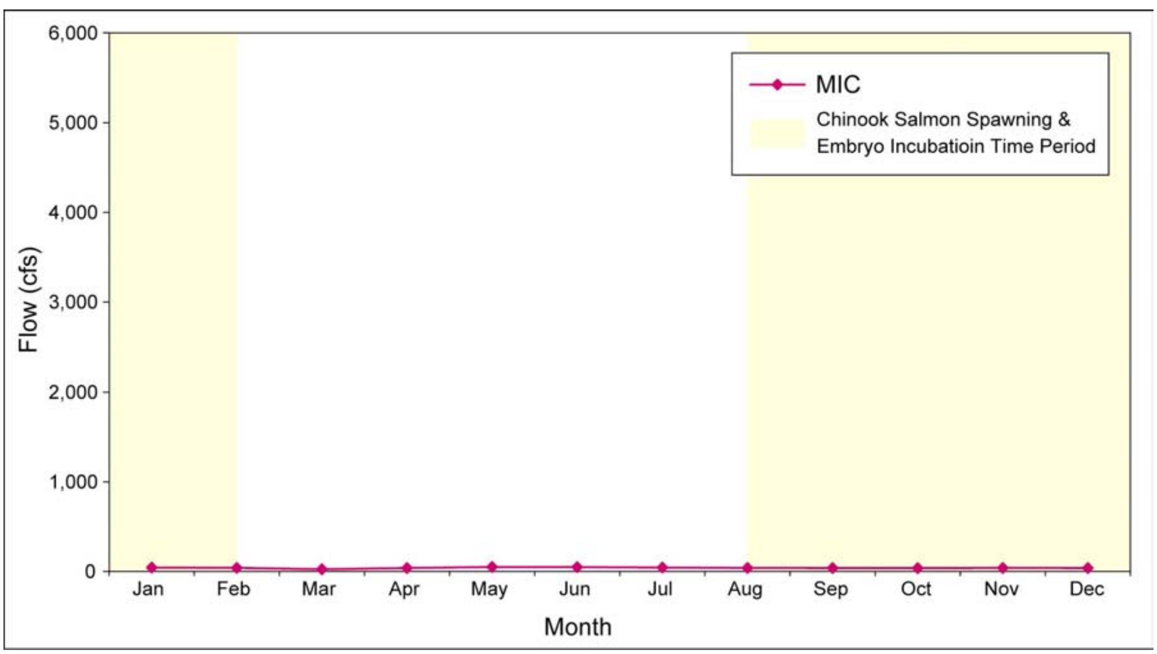

Figure 5.4-4. Mean monthly instream flows at the MIC data logger (average of multiple years) in the West Branch of the upper Feather River, and presence dates for the Chinook salmon spawning and embryo incubation life stage.

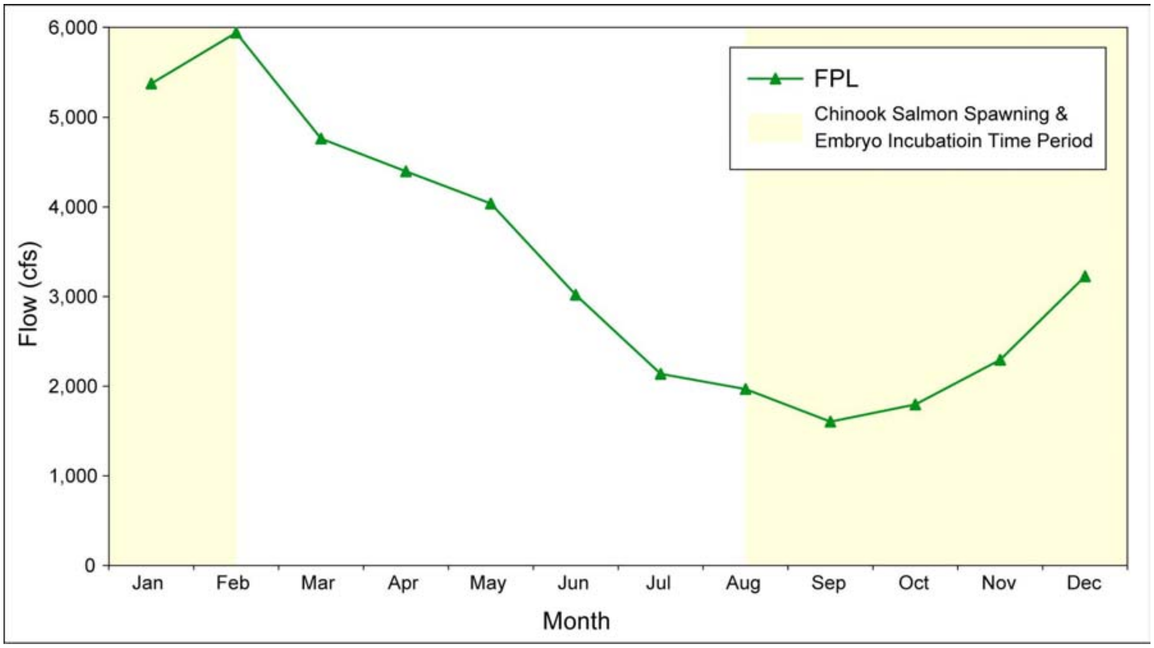

Figure 5.4-5. Mean monthly instream flows at the FPL data logger (average of multiple years) in the North Fork of the upper Feather River, and presence dates for the Chinook salmon spawning and embryo incubation life stage.

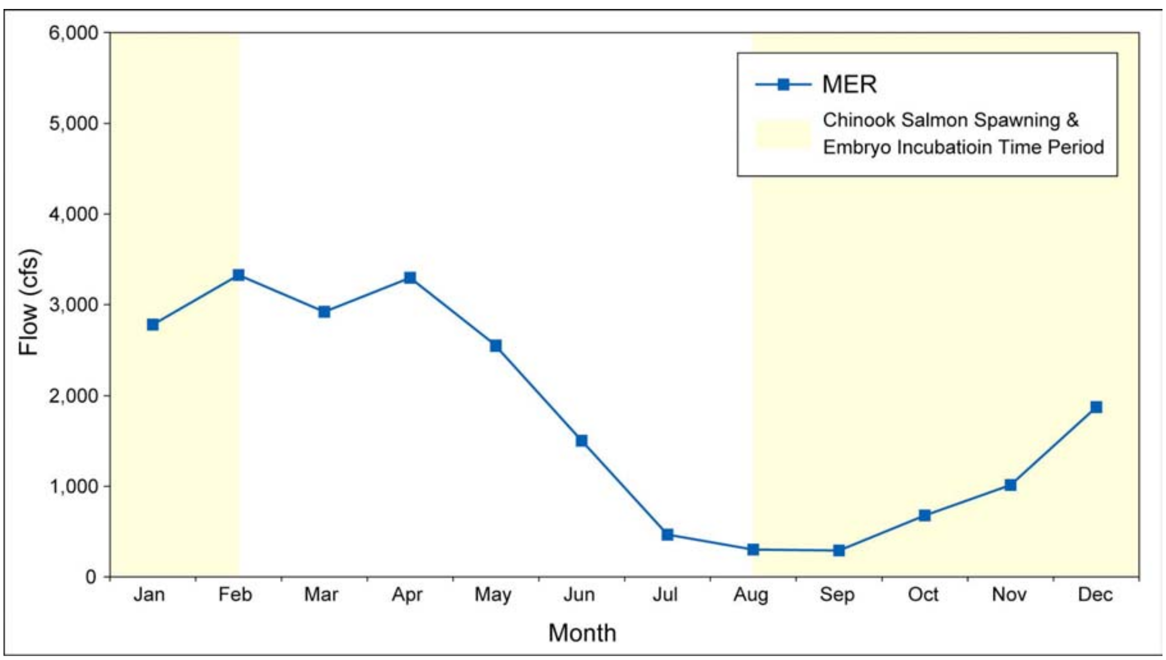

Figure 5.4-6. Mean monthly instream flows at the MER data logger (average of multiple years) in the Middle Fork of the upper Feather River, and presence dates for the Chinook salmon spawning and embryo incubation life stage.

5.4.3 Chinook Salmon Juvenile Rearing and Downstream Movement

Instream flow data in the West Branch were collected at the *Miocene Canal* (MIC) data logging station. The MIC data logging station is located in Lake Oroville 3.7 miles downstream from the defined downstream boundary of the West Branch. Average monthly instream flow at the MIC station from January through December (the defined time period for the Chinook salmon juvenile rearing and downstream movement life stage) ranged from a low of 22 cfs in March to a high of 47 cfs in May, and showed little variation between months (Figure 5.4-7). The average flow from January through December was 38 cfs. Instream flow data in the North Fork were collected at the *Feather NF at Pulga* (FPL) data logging station at RM 6.0. Instream flows during the Chinook salmon juvenile rearing and downstream movement period (year- round) exhibited a decreasing trend from February through September, and an increasing trend from September through February (Figure 5.4-8). The average monthly instream flow was highest in February (5,942 cfs) and lowest in September (1,602 cfs). Instream flow data in the Middle Fork were collected at the *Feather R MF NR Merrimac* (MER) data logging station at RM 6.4. Instream flows from January through April exhibited little variation, but showed a decreasing trend from April through September and an increasing trend from September through February (Figure 5.4-9). The average monthly instream flow was highest in February (3,323 cfs), and lowest in September (289 cfs).

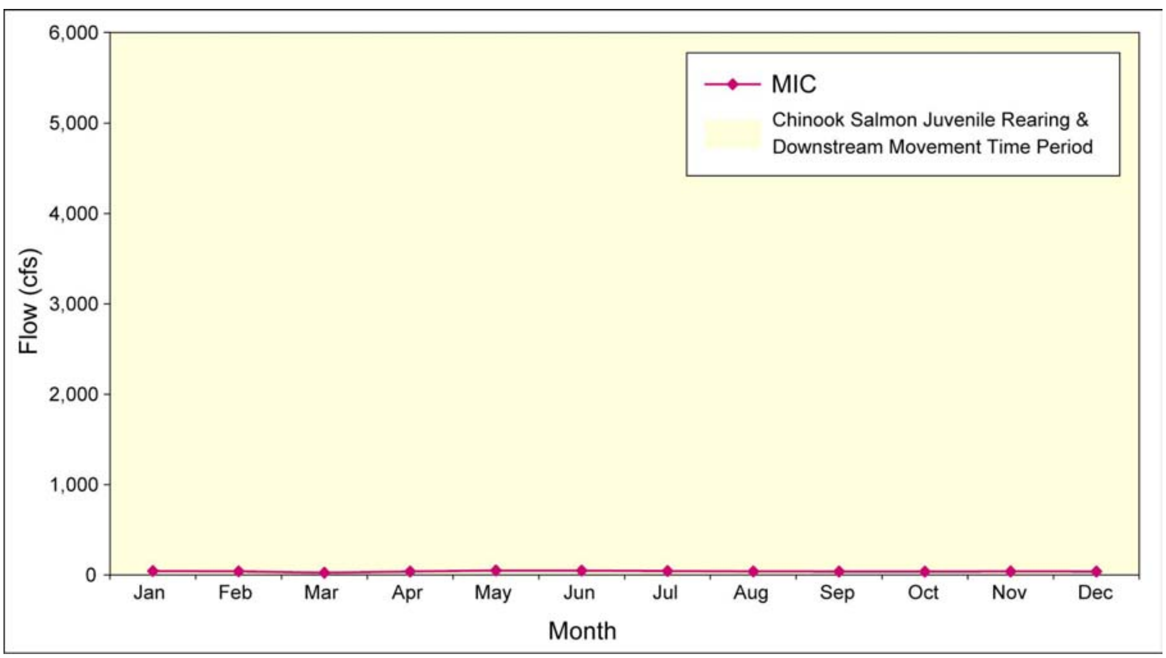

Figure 5.4-7. Mean monthly instream flows at the MIC data logger (average of multiple years) in the West Branch of the upper Feather River, and presence dates for the Chinook salmon juvenile rearing and downstream movement life stage.

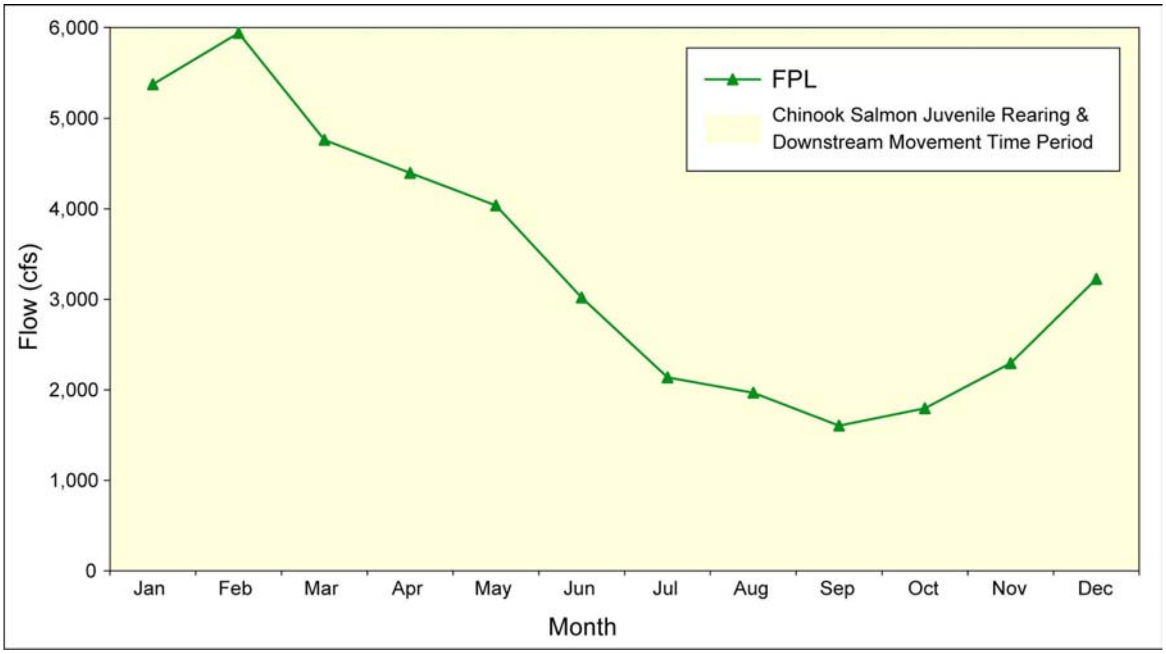

Figure 5.4-8. Mean monthly instream flows at the FPL data logger (average of multiple years) in the North Fork of the upper Feather River, and presence dates for the Chinook salmon juvenile rearing and downstream movement life stage.

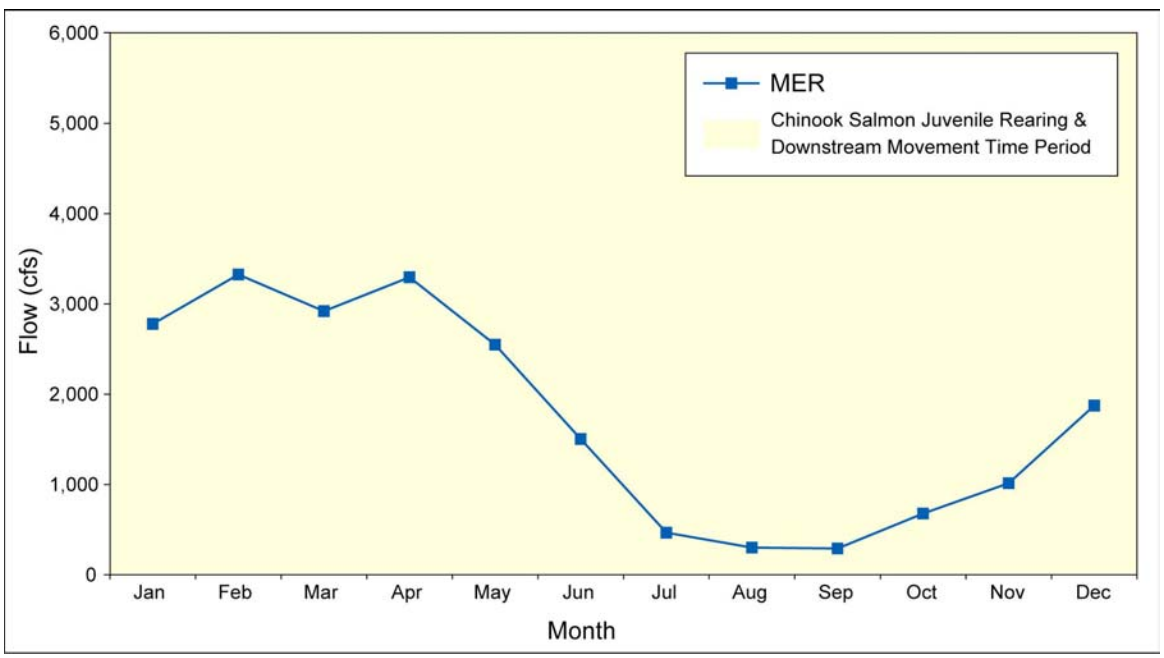

Figure 5.4-9. Mean monthly instream flows at the MER data logger (average of multiple years) in the Middle Fork of the upper Feather River, and presence dates for the Chinook salmon juvenile rearing and downstream movement life stage.

5.4.4 Steelhead Adult Immigration and Holding

Instream flow data in the West Branch were collected at the *Miocene Canal* (MIC) data logging station. The MIC data logging station is located in Lake Oroville 3.7 miles downstream from the defined downstream boundary of the West Branch. Average monthly instream flow at the MIC station from September through April 15 (the defined time period for the steelhead adult immigration and holding life stage) ranged from a low of 22 cfs in March to a high of 41 cfs in January, and showed little variation between months (Figure 5.4-10). The average flow from September through April was 35 cfs. Instream flow data in the North Fork were collected at the *Feather NF at Pulga* (FPL) data logging station at RM 6.0. Instream flows during the steelhead adult immigration and holding period showed an increasing trend from September through February, and a decreasing trend from February through April (Figure 5.4-11). The average monthly instream flow was highest in February (5,942 cfs) and lowest in September (1,602 cfs). Instream flow data in the Middle Fork were collected at the *Feather R MF NR Merrimac* (MER) data logging station at RM 6.4. Instream flows showed an increasing trend from September through February, a slight decrease from February through March, and a slight increase from March through April (Figure 5.4-12). The average monthly instream flow was highest in February (3,323 cfs) and lowest in September (289 cfs).

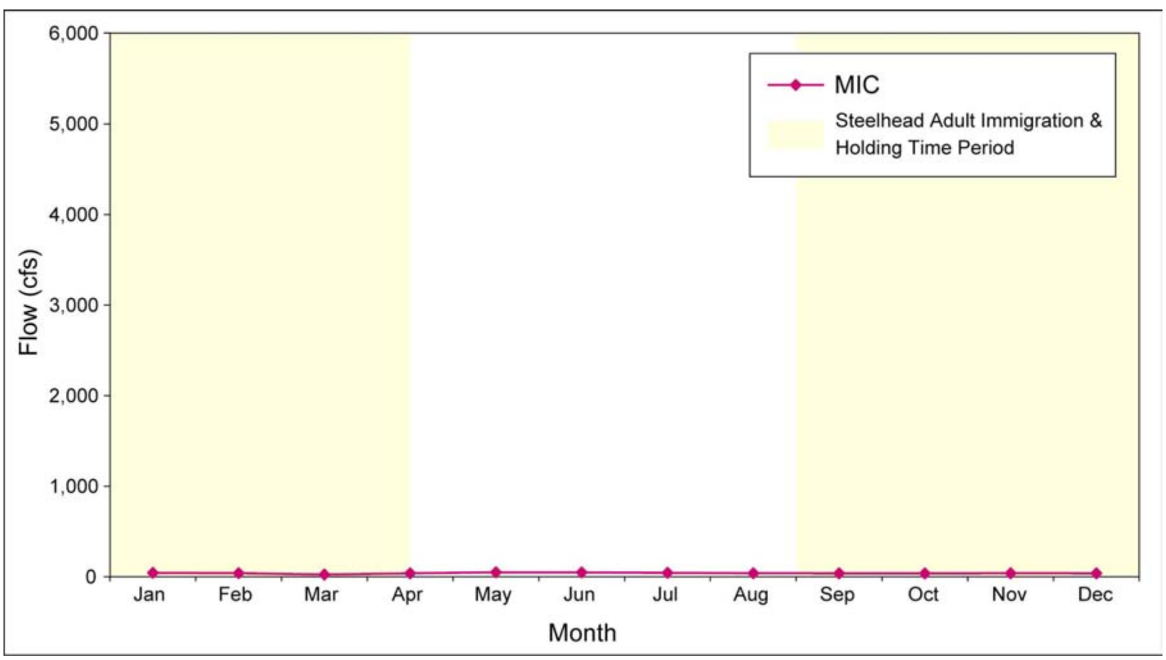

Figure 5.4-10. Mean monthly instream flows at the MIC data logger (average of multiple years) in the West Branch of the upper Feather River, and presence dates for the steelhead adult immigration and holding life stage.

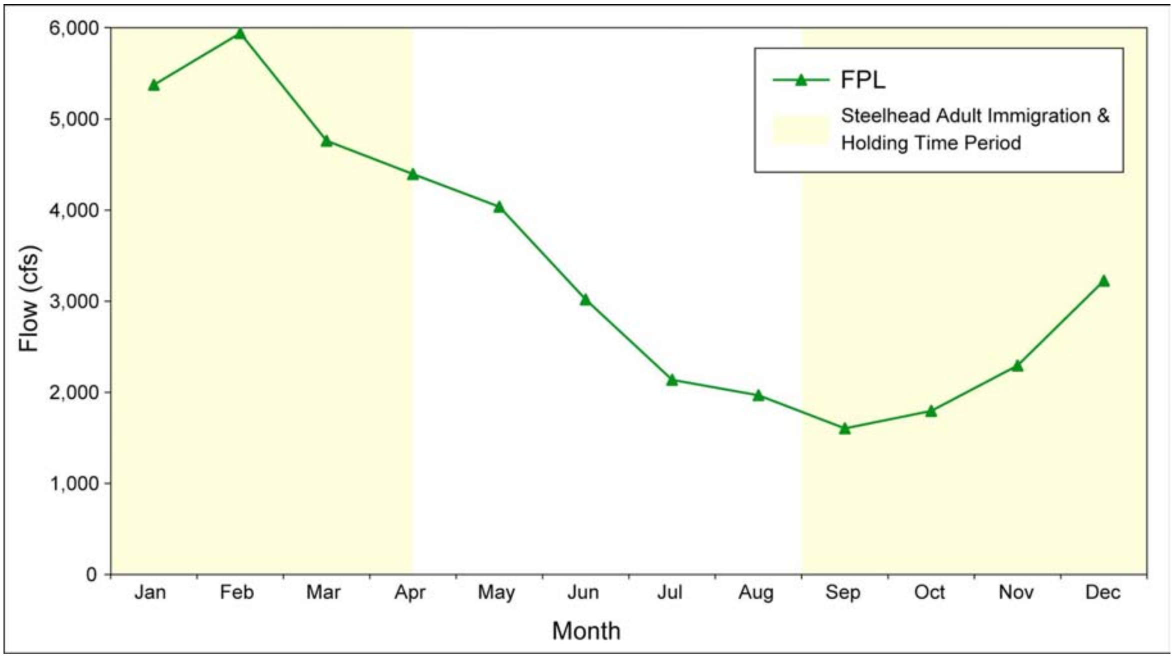

Figure 5.4-11. Mean monthly instream flows at the FPL data logger (average of multiple years) in the North Fork of the upper Feather River, and presence dates for the steelhead adult immigration and holding life stage.

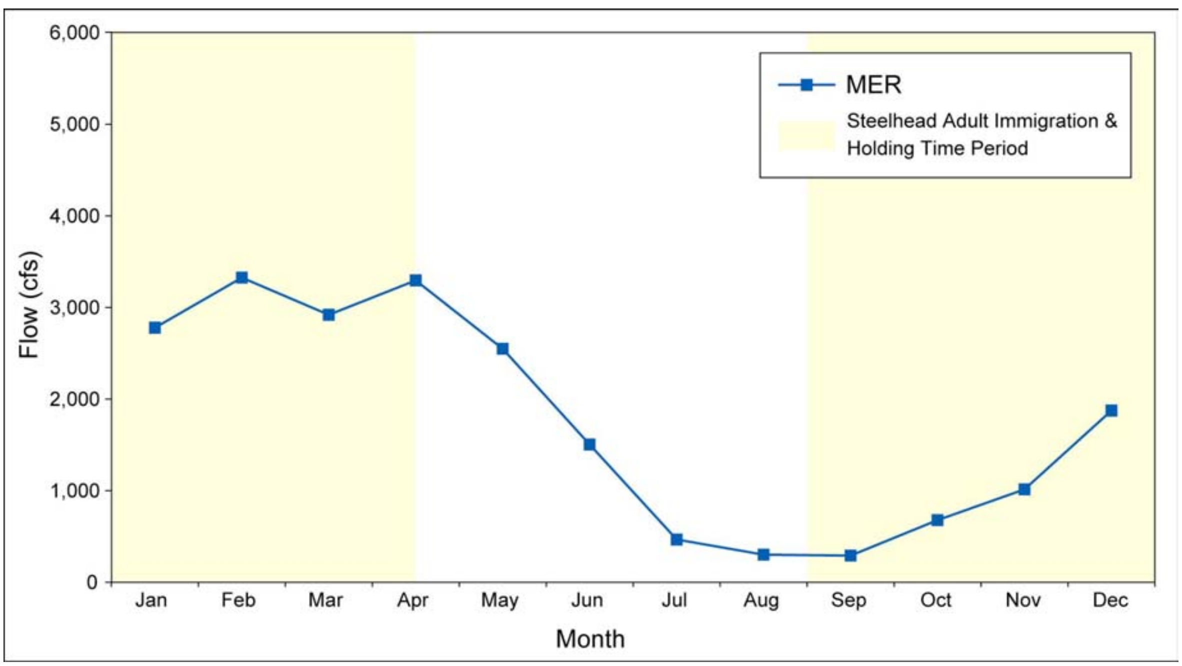

Figure 5.4-12. Mean monthly instream flows at the MER data logger (average of multiple years) in the West Branch of the upper Feather River, and presence dates for the steelhead adult immigration and holding life stage.

5.4.5 Steelhead Spawning and Embryo Incubation

Instream flow data in the West Branch were collected at the *Miocene Canal* (MIC) data logging station. The MIC data logging station is located in Lake Oroville 3.7 miles downstream from the defined downstream boundary of the West Branch. Average monthly instream flow at the MIC station from December through May (the defined time period for the steelhead spawning and embryo incubation life stage) ranged from a low of 22 cfs in March to a high of 47 cfs in May, and showed little variation between months (Figure 5.4-13). The average flow from December through May was 37 cfs. Instream flow data in the North Fork were collected at the *Feather NF at Pulga* (FPL) data logging station at RM 6.0. Instream flows during the steelhead spawning and embryo incubation period showed an increasing trend from December through February, and a decreasing trend from February through May (Figure 5.4-14). The average monthly instream flow was highest in February (5,942 cfs) and lowest in December (3,224 cfs). Instream flow data in the Middle Fork were collected at the *Feather R MF NR Merrimac* (MER) data logging station at RM 6.4. Instream flows during the spawning and embryo incubation period showed an increasing trend from December through February, and a generally decreasing trend from February through May (Figure 5.4-15). The average monthly instream flow was highest in February (3,323 cfs) and lowest in December (1,872 cfs).

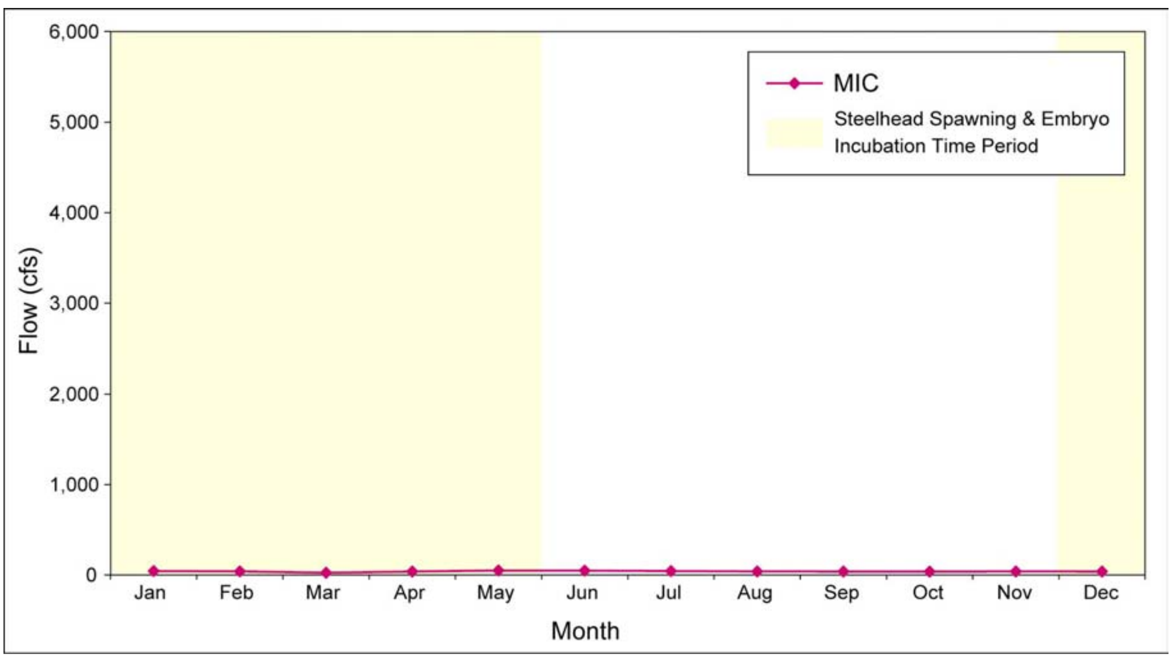

Figure 5.4-13. Mean monthly instream flows at the MIC data logger (average of multiple years) in the West Branch of the upper Feather River, and presence dates for the steelhead spawning and embryo incubation life stage.

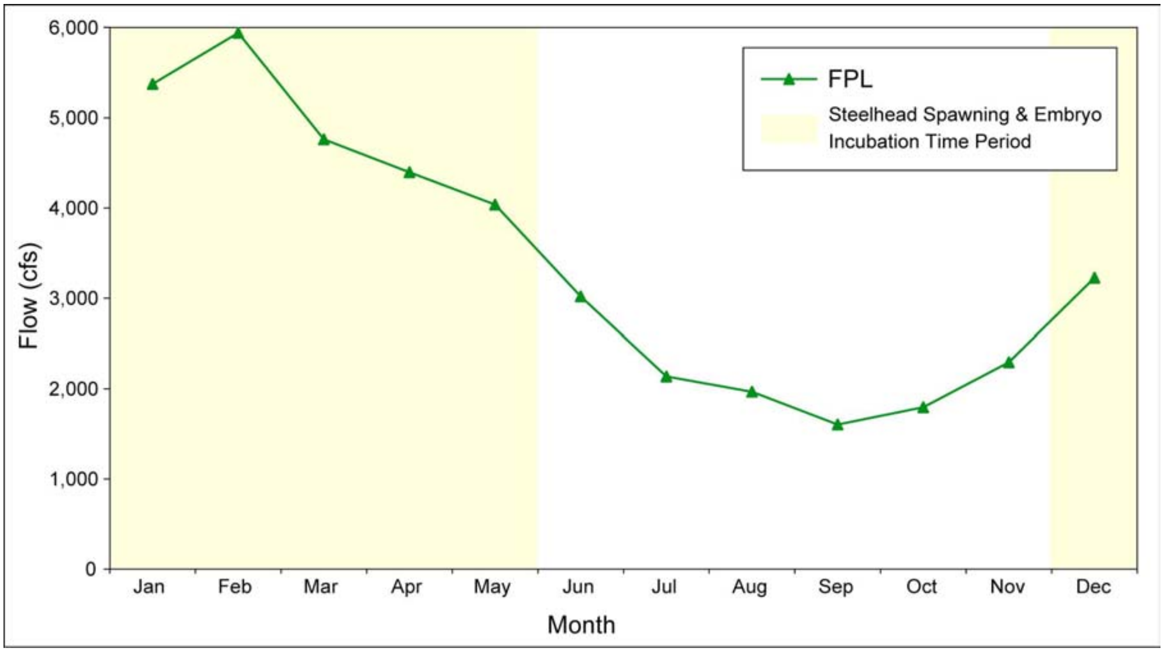

Figure 5.4-14. Mean monthly instream flows at the FPL data logger (average of multiple years) in the North Fork of the upper Feather River, and presence dates for the steelhead spawning and embryo incubation life stage.

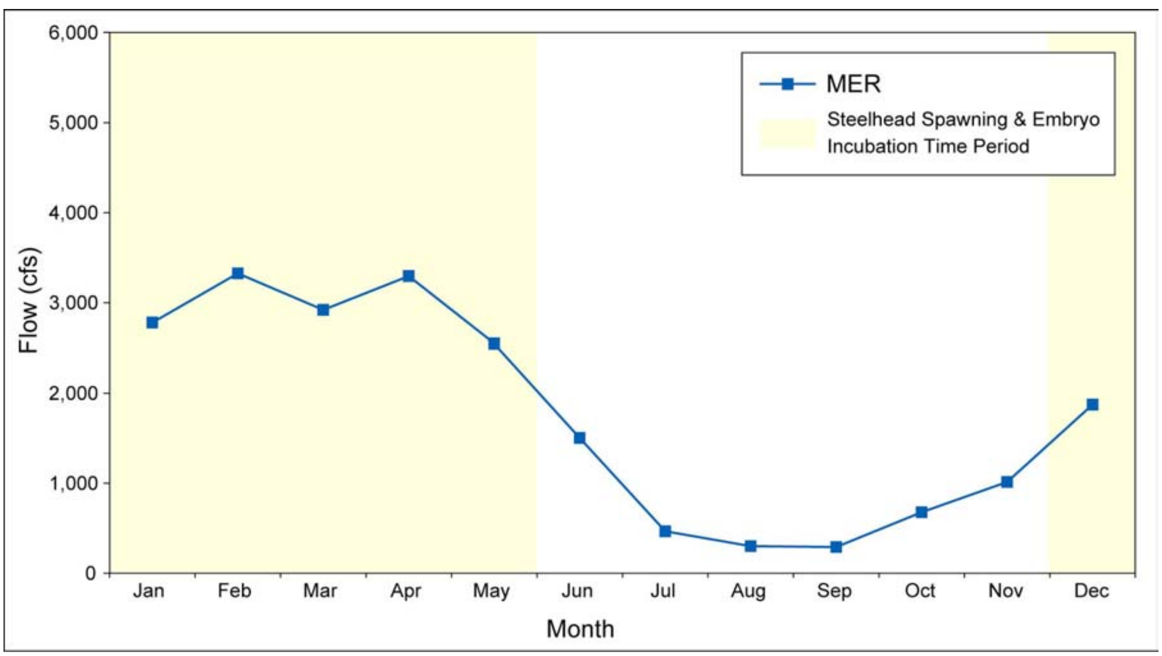

Figure 5.4-15. Mean monthly instream flows at the MER data logger (average of multiple years) in the Middle Fork of the upper Feather River, and presence dates for the steelhead spawning and embryo incubation life stage.

5.4.6 Steelhead Fry and Fingerling Rearing and Downstream Movement

Instream flow data in the West Branch were collected at the *Miocene Canal* (MIC) data logging station. The MIC data logging station is located in Lake Oroville 3.7 miles downstream from the defined downstream boundary of the West Branch. Average monthly instream flow at the MIC station from January through December (the defined time period for the steelhead fry and fingerling rearing and downstream movement life stage) ranged from a low of 22 cfs in March to a high of 47 cfs in May, and showed little variation between months (Figure 5.4-16). The average flow from January through December was 38 cfs. Instream flow data in the North Fork of the upper Feather River were collected at the *Feather NF at Pulga* (FPL) data logging station at RM 6.0. Instream flows during the steelhead fry and fingerling rearing and downstream movement period showed a decreasing trend from February through September, and an increasing trend from September to February (Figure 5.4-17). The average monthly instream flow was highest in February (5,942 cfs) and lowest in September (1,602 cfs). Instream flow data in the Middle Fork were collected at the *Feather R MF NR Merrimac* (MER) data logging station at RM 6.4. Instream flows from January through April showed little variation, but showed a decreasing trend from April through September and an increasing trend from September through February (Figure 5.4-18). The average monthly instream flow was highest in February (3,323 cfs) and lowest in September (289 cfs).

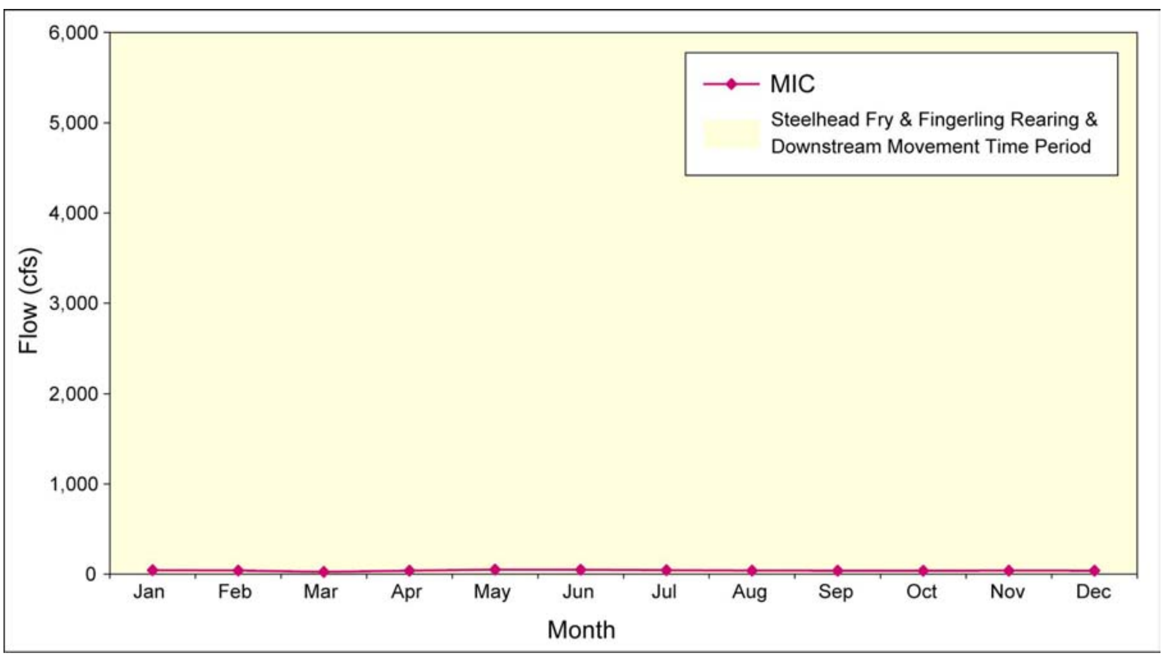

Figure 5.4-16. Mean monthly instream flows at the MIC data logger (average of multiple years) in the West Branch of the upper Feather River, and presence dates for the steelhead fry and fingerling rearing and downstream movement life stage.

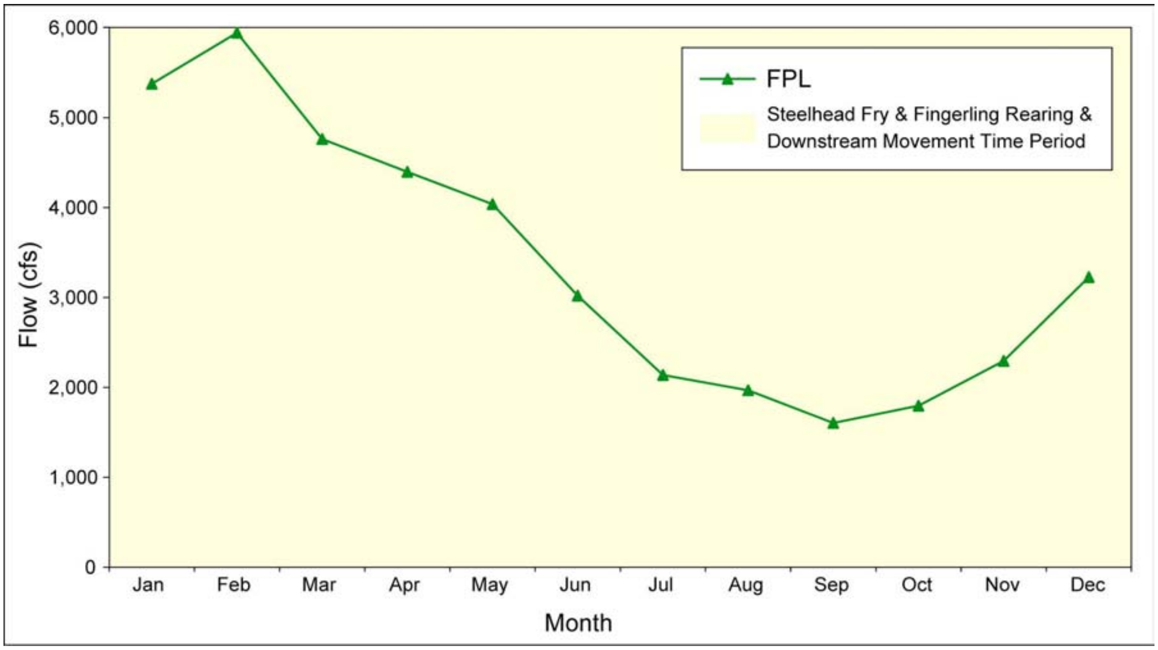

Figure 5.4-17. Mean monthly instream flows at the FPL data logger (average of multiple years) in the North Fork of the upper Feather River, and presence dates for the steelhead fry and fingerling rearing and downstream movement life stage.

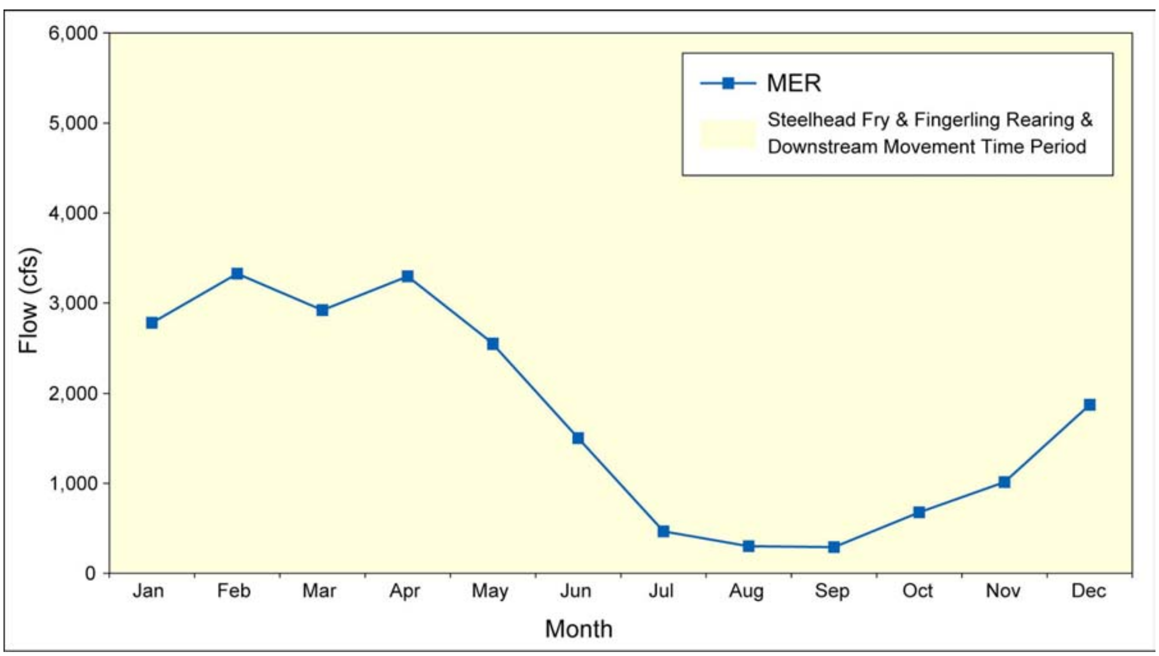

Figure 5.4-18. Mean monthly instream flows at the MER data logger (average of multiple years) in the Middle Fork of the upper Feather River, and presence dates for the steelhead fry and fingerling rearing and downstream movement life stage.

5.4.7 Steelhead Smolt Emigration

Instream flow data in the West Branch were collected at the *Miocene Canal* (MIC) data logging station. The MIC data logging station is located in Lake Oroville 3.7 miles downstream from the defined downstream boundary of the West Branch. Average monthly instream flow at the MIC station from January through June (the defined time period for the steelhead smolt emigration life stage) ranged from a low of 22 cfs in March to a high of 47 cfs in May, and showed little variation between months (Figure 5.4-19). The average flow from January through June was 38 cfs. Instream flow data in the North Fork were collected at the *Feather NF at Pulga* (FPL) data logging station at RM 6.0. Instream flows during the steelhead smolt immigration period generally increased from January through February, then showed a decreasing trend from February through June (Figure 5.4-20). The average monthly instream flow was highest in February (5,942 cfs) and lowest in June (3,108 cfs). Instream flow data in the Middle Fork were collected at the *Feather R MF NR Merrimac* (MER) data logging station at RM 6.4. Instream flows from January through April exhibited little variation, but exhibited a decreasing trend from April through June (Figure 5.4-21). The average monthly instream flow was highest in February (3,323 cfs) and lowest in June (1502 cfs).

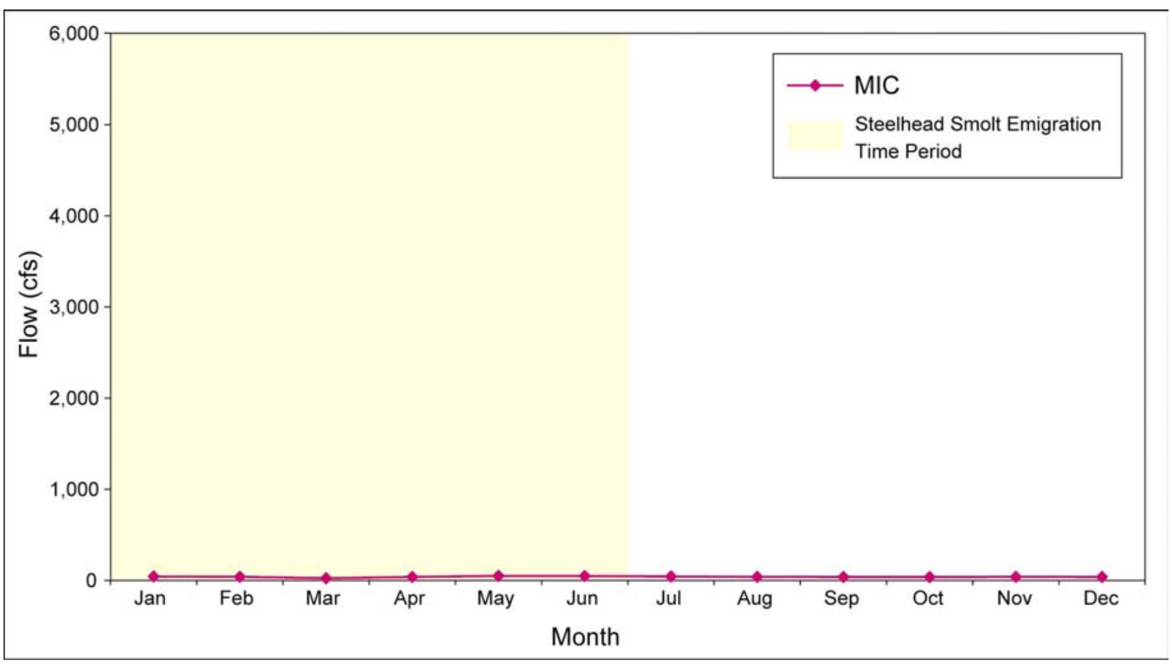

Figure 5.4-19. Mean monthly instream flows at the MIC data logger (average of multiple years) in the West Branch of the upper Feather River, and presence dates for the steelhead smolt emigration life stage.

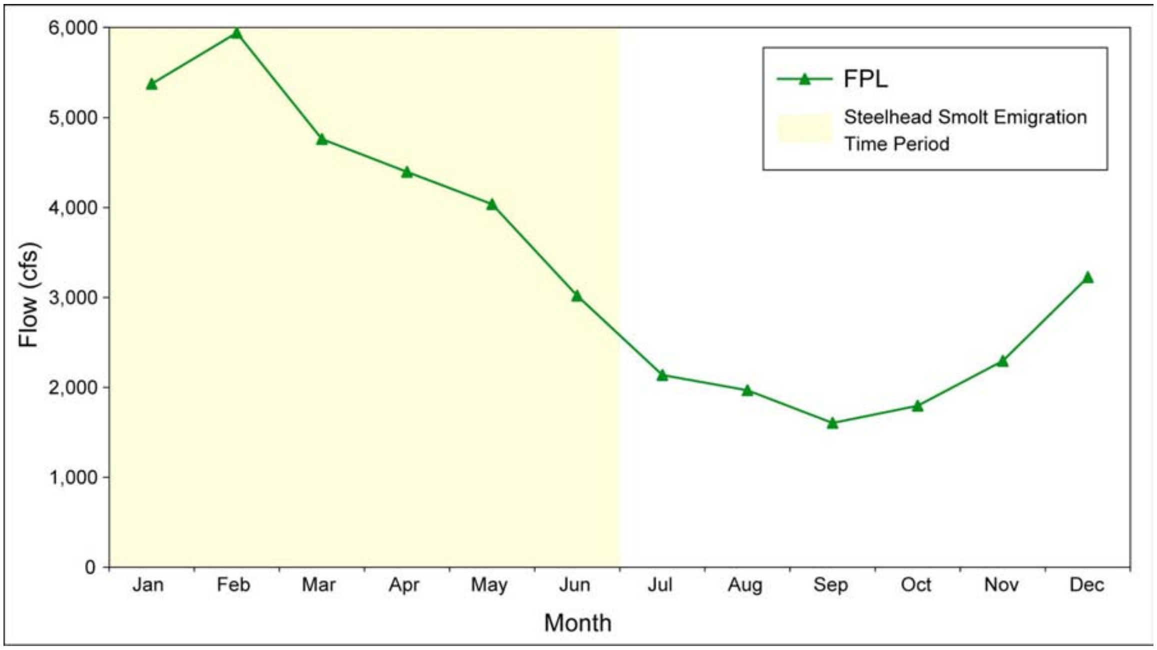

Figure 5.4-20. Mean monthly instream flows at the FPL data logger (average of multiple years) in the North Fork of the upper Feather River, and presence dates for the steelhead smolt emigration life stage.

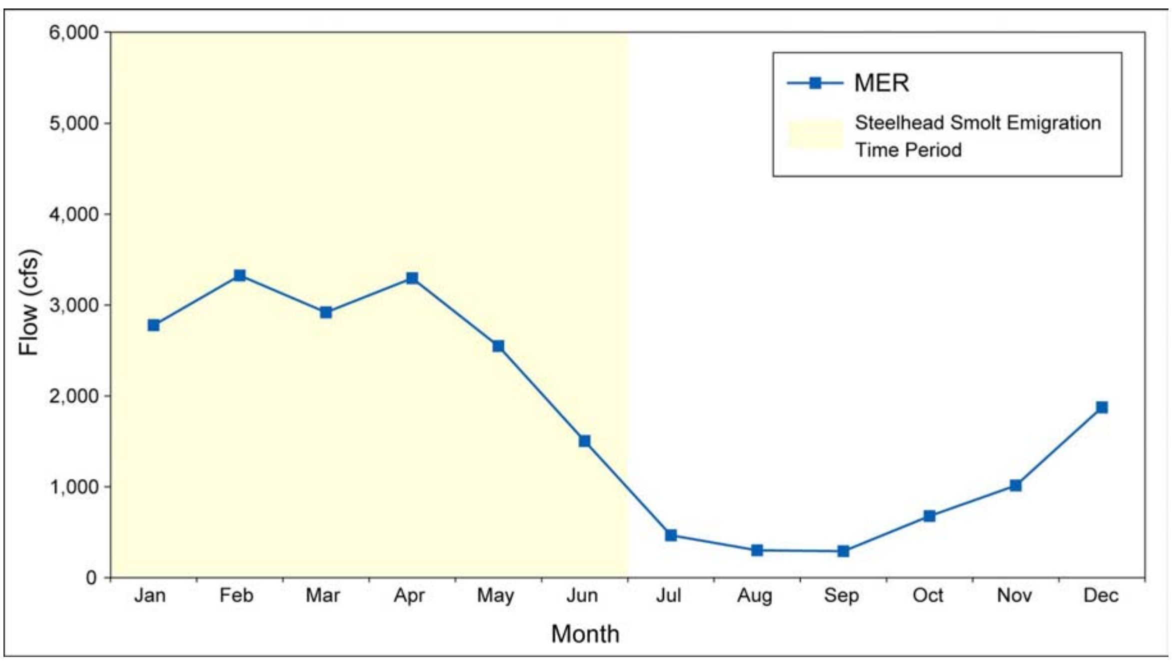

Figure 5.4-21. Mean monthly instream flows at the MER data logger (average of multiple years) in the Middle Fork of the upper Feather River, and presence dates for the steelhead smolt emigration life stage.

5.5 RESIDENT FISH DISTRIBUTION IN THE UPPER FEATHER RIVER

Table 5.5-1 summarizes, by tributary and length group, the numbers of individuals and fish species distribution observed during sampling efforts. Species listed are those expected to occupy the upper Feather River.

Results could not be compared between tributaries because sampling effort differed between tributaries. Rainbow trout were present at all sampling sites, and the number of individuals observed was negatively correlated with fish length. Small numbers of brown trout were observed in the South Fork and West Branch. In the Middle Fork, 19 rainbow trout 12 inches or greater were captured. Sacramento pikeminnow were captured at all sites except those sampled in the North Fork.

In general, few Centrarchids were captured during sampling events. Largemouth bass and green sunfish were not detected in the upper Feather River. Bluegill were detected in low numbers only in the South Fork, redeye bass and smallmouth bass were detected only in the Middle Fork, and spotted bass were detected in the South Fork and Middle Fork. Sucker sp. were detected in all tributaries, sculpin sp. were detected in the South Fork and North Fork, and California roach were detected in the Middle Fork and West Branch.

Table 5.5-1. Numbers of fish captured during sampling efforts, and fish species distribution by tributary and length group in the major tributaries of the upper Feather River.

Species	Length (inches)	South Fork	Middle Fork	North Fork	West Branch	Total
Rainbow Trout (*Oncorhynchus mykiss*)	0-5.9	121	5	8	21	155
	6-11.9	32	17	3	47	99
	12≤	2	19	0	1	22
Brown Trout (*Salmo trutta*)	0-5.9	22	0	0	0	22
	6-11.9	6	0	0	6	12
	12≤	0	0	0	8	8
Bluegill (*Lepomis macrochirus*)	0-5.9	9	0	0	0	9
	6-11.9	0	0	0	0	0
	12≤	0	0	0	0	0
Green Sunfish (*Lepomis cyanellus*)	0-5.9	0	0	0	0	0
	6-11.9	0	0	0	0	0
	12≤	0	0	0	0	0
Largemouth Bass (*Micropterus salmoides*)	0-5.9	0	0	0	0	0
	6-11.9	0	0	0	0	0
	12≤	0	0	0	0	0
Redeye Bass (*Micropterus coosae*)	0-5.9	0	0	0	0	0
	6-11.9	0	25	0	0	25
	12≤	0	0	0	0	0
Smallmouth Bass (*Micropterus dolomieui*)	0-5.9	0	0	0	0	0
	6-11.9	0	6	0	0	6
	12≤	0	0	0	0	0
Spotted Bass (*Micropterus punctulatus*)	0-5.9	64	224	0	0	288
	6-11.9	0	33	0	0	33

Species	Length (inches)	South Fork	Middle Fork	North Fork	West Branch	Total
	12≤	1	25	0	0	26
Carp (*Cyprinus carpio*)	0-5.9	0	0	0	0	0
	6-11.9	0	0	0	0	0
	12≤	0	1	0	0	1
Sacramento Pikeminnow (*Ptychocheilus grandis*)	0-5.9	1	53	0	10	64
	6-11.9	0	22	0	0	22
	12≤	0	30	0	1	31
Sucker sp. (*Catostomus* sp.)	0-5.9	34	1	0	0	35
	6-11.9	13	38	1	3	55
	12≤	0	45	0	0	45
Sculpin sp. (*Cottus* sp.)	0-5.9	45	0	1	0	46
	6-11.9	0	0	0	0	0
	12≤	0	0	0	0	0
Roach sp. (*Hesperoleucus symmetricus*)	0-5.9	0	100	0	1133	1233
	6-11.9	0	0	0	0	0
	12≤	0	0	0	0	0
Total		350	644	13	1230	2237

6.0 ANALYSES

6.1 EXISTING CONDITIONS/ENVIRONMENTAL SETTING

The subtasks of SP-F15, *Evaluation of the Feasibility to Provide Passage for Targeted Species of Migratory and Anadromous Fish Past Oroville Facility Dams*, and 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*, presented in this report, fulfill a portion of the FERC application requirements by inventorying and assessing the suitability of available habitat upstream from Lake Oroville for adult and juvenile anadromous salmonids, and by characterizing the fish habitat upstream from Lake Oroville to the first identified migration barrier. Additionally, data analyzed for these tasks could serve as bases for the development, and future evaluation of potential Resource Actions.

6.2 PROJECT-RELATED EFFECTS

6.2.1 Mesohabitat Suitability in the Upper Feather River by Life Stage

In order to assess habitat suitability in the upper Feather River for Chinook salmon and steelhead, a literature review was conducted to determine the mesohabitat types utilized by each life stage. Based on habitat descriptions in available literature and mesohabitat definitions described in DFG (1998b), the mesohabitat types identified in SP-G1, *Effects of Project Operations on Geomorphic Processes Upstream of Oroville Dam,* for assessment in this report were determined to be either suitable or unsuitable. Interpretation and presentation of this habitat suitability assessment should be made with caution due to data limitations. Small percentages of the linear extent of the major tributaries in the upper Feather River were surveyed for broad-scale habitat typing. The habitat suitability assessment assumes that the proportions of mesohabitat present in surveyed transects are representative of proportions of mesohabitat found throughout the upper Feather River tributaries. The literature review and suitability assessment are listed separately for each life stage.

6.2.1.1 Chinook Salmon Adult Immigration and Holding

Chinook salmon select suitable habitat for holding areas while migrating upriver to traditional spawning grounds (Moyle 2002). The immigration and holding period can be lengthy, occurring from approximately March through December (DWR 2003b). In general, Chinook salmon utilize all habitat types for travel corridors to spawning grounds. Therefore, holding habitat is the critical habitat element for this particular life stage. Chinook salmon reportedly hold in pools characterized by having a depth of 3.3 ft to 9.8 ft with bedrock substrate (Moyle 2002). Water velocities in appropriate holding habitat reportedly range from 0.5 ft/sec to 2.6 ft/sec (DWR and USBR 2000; Moyle et al.

1995; Moyle 2002). Holding pools usually have a large bubble curtain at the head, underwater rocky ledges, and shade cover throughout the day (Moyle et al. 1995).

Based on holding habitat criteria presented in available literature and the mesohabitat information provided in SP-G1, suitable mesohabitat in the upper Feather River for immigrating and holding Chinook salmon includes glides, pools, and runs. Pools, runs, and glides collectively account for 84 percent of surveyed areas in the West Branch, 78 percent of surveyed areas in the North Fork, 47 percent of surveyed areas in the Middle Fork, and 51 percent of surveyed areas in the South Fork (Figure 4.2-1). Suitable habitat for immigrating and holding adult Chinook salmon appears to be available in the major tributaries in the upper Feather River.

6.2.1.2 Chinook Salmon Spawning and Embryo Incubation

Reported suitable spawning habitat criteria varies for each stage associated with the spawning and embryo incubation life stage, and site selection is likely an intrinsic function involving multiple requirements (Moyle 2002). Suitable spawning habitat for successful redd construction reportedly is typically associated with gravel size (Kondolf 2000). Female Chinook salmon must be able to move gravels to excavate redds in the streambed. Available gravel size may limit successful spawning by salmon through physical limitations. The ability of salmon to physically move gravels can be of particular concern in systems where dams prevent or limit recruitment of smaller, mobile gravel sizes, leaving only bed material too large to be moved (Kondolf 2000). The process whereby mean gravel size gradually increases over time is known as armoring. The largest spawning individuals set the upper size limit of suitable gravel size because larger fish can move larger gravels. Kondolf (2000) suggested that spawning fish could move gravels with a median diameter up to approximately 10 percent of their body length. Nests are predominantly constructed in loose gravels or cobbles. Raleigh et al. (1986) reported that the diameter of spawning gravels ranged in size from 0.1 in. to 5.9 in. and averaged 1.7 in. in diameter, and that the preferred range was 0.8 in. to 4.2 in. diameter. Allen and Hassler (1986) reported that the optimal diameter of spawning gravel ranges from 0.5 in. to 4.0 in., with 80 percent of the gravel ranging from 0.5 in. to 2.0 in. and 20 percent of the gravel being larger than 2 in.

For successful embryo incubation, gravels should be sufficiently free of fine sediments to allow the flow of water through the gravel to bring adequate amounts of dissolved oxygen to the eggs and alevins, and to remove metabolic waste. Some authors suggest that site selection is, in part, influenced by a function of upwelling and downwelling subsurface flows, presumably because these areas may provide higher dissolved oxygen levels and better flushing qualities (Healey 1991; Moyle 2002). When gravels contain high levels of fine sediment, typical of drainages sustaining high levels of human disturbance activities, the permeability of gravels is lowered resulting in decreased intragravel dissolved oxygen levels and decreased egg and alevin survival (see discussions in (Groot and Margolis 1991). Chinook salmon reportedly spawn in areas where water velocities range from 0.5 ft/sec to 6.2 ft/sec (DWR and USBR 2000; Moyle 2002; Raleigh et al. 1986). The reported optimal water velocity for spawning ranges from 1 ft/sec to 3 ft/sec (Allen and Hassler 1986). Sommer et al. (2001) reported that in the lower Feather River, spawning occurred at velocities ranging from 0.4 ft/sec to 4.8 ft/sec. Moyle (2002) reported that Chinook salmon prefer to spawn in water depths from 0.8 ft to 3.3 ft. Sommer et al. (2001) reported that in the lower Feather River, Chinook salmon spawning occurred in depths from 0.4 ft to 4 ft, with the central 50 percent of observations occurring in the 1.6 ft to 2.6 ft range. Spawning depth reportedly was positively correlated with flows.

Describing suitable spawning habitat is not a simple process because many factors contribute to the quality of spawning habitat (Moyle 2002). Appropriate spawning habitat is probably best defined by a combination of variables including gravel size, dissolved oxygen, permeability, flow characteristics, and water temperature. Based on spawning and embryo incubation habitat criteria presented in available literature, suitable mesohabitat in the upper Feather River for the spawning and embryo incubation life stage of Chinook salmon includes riffles and runs. Riffles and runs collectively account 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 (Figure 4.2-1). Suitable habitat for the spawning and embryo incubation life stage of Chinook salmon appears to be available in the major tributaries in the upper Feather River.

6.2.1.3 Chinook Salmon Juvenile Rearing and Downstream Movement

For purposes of this report, the juvenile life stage includes fry, fingerlings (including parr), and smolts. Chinook salmon are considered fry from the time that juveniles emerge until skeletal development is complete, at which point they are considered fingerlings. Complete skeletal development for Chinook salmon occurs when individuals range from approximately 45 mm to 55 mm (DWR 2003e). Fry and fingerlings spend varying amounts of time rearing in natal streams and rivers prior to seaward migration (Moyle 2002). In the Sacramento-San Joaquin river system, the duration of time that juvenile Chinook salmon rear prior to emigration varies by run (Moyle 2002). Rearing Chinook salmon reportedly utilize a variety of habitat types. According to Moyle (2002), after emerging, fry generally are washed downstream into back- or edge-water areas, where velocities are low, cover is dense, and small food items are abundant. Juvenile Chinook salmon prefer habitats having abundant instream and overhead cover (i.e., undercut banks, submerged and emergent vegetation, logs, roots, other woody debris, and dense overhead vegetation) to provide refuge from predators, and a sustained, abundant supply of invertebrates and larval fish prey (DWR and USBR 2000). Rearing juveniles also may use low velocity areas where substrate irregularities and other habitat features create velocity refuges (DWR and USBR 2000). Water velocities selected by young-of-year Chinook salmon ranged from 0 ft/sec to 2.0 ft/sec, and preferred velocities were reported ranging from 0 ft/sec to 1.3 ft/sec (Raleigh et al. 1986). Allen et al. (1986) reported preferred water velocities of 0.2 ft/sec to 0.8 ft/sec. Based on habitat suitability curves provided in Raleigh et al. (1986), fry utilize water depths ranging from approximately 0.1 feet to 4.9 feet. The fingerling-smolt transformation involves morphological, physiological, and behavioral changes (DWR 2003c). During this transition, juvenile salmonids grow in size and spend more time utilizing deeper and higher velocity habitats for feeding and rearing (Moyle 2002). Rotary screw trap data suggest most downstream movement of juvenile salmonids occurs at night in faster, deeper sections of rivers (DWR 2002). During the day, near shore habitat is utilized for resting, protection, and feeding (Moyle 2002). Therefore, a variety of microhabitat types are utilized by emigrating juvenile salmonids.

The rearing and emigrating life stage of Chinook salmon includes multiple stages, each with specific habitat requirements. Based on the information presented in the literature and the data analyzed for this report, glides, pools, riffles, and runs are defined as suitable mesohabitat types for the Chinook salmon juvenile rearing and downstream movement life stage. Glides, pools, riffles, and runs collectively account for 93 percent of surveyed areas in the West Branch, 100 percent of surveyed areas in the North Fork, 93 percent of surveyed areas in the Middle Fork, and 85 percent of surveyed areas in the South Fork (Figure 4.2-1). Suitable habitat for rearing and emigrating Chinook salmon appears to be available in the major tributaries in the upper Feather River.

6.2.1.4 Steelhead Adult Immigration and Holding

Steelhead select suitable habitat for holding areas while migrating upriver to traditional spawning grounds (Moyle 2002). In general, steelhead utilize all habitat types as migration corridors. Therefore, holding habitat is an important habitat component for this particular life stage. DWR and USBR (2000) reported that adult steelhead require a minimum water depth of seven inches for passage. Moyle (2002) reported that steelhead prefer to hold in pools having water depths of 9.8 ft or more. Steelhead have been observed holding in areas with water velocities ranging from 0.4 in/sec to 13.4 in/sec, and averaging 3.7in/sec (DWR and USBR 2000; Nakamoto 1994). Nakamoto (1994) reported that in the New River, California, steelhead densities were highest at higher water velocities. Other key components of suitable holding habitat appear to include rock ledges and boulders, and areas with riparian vegetation providing shade (Nakamoto 1994).

Based on information provided in the literature and analysis of available data, suitable mesohabitat in the upper Feather River for immigrating and holding steelhead includes glides, pools, riffles, and runs. Glides, pools, riffles, and runs collectively account for 93 percent of surveyed areas in the West Branch, 100 percent of surveyed areas in the North Fork, 93 percent of surveyed areas in the Middle Fork, and 85 percent of surveyed areas in the South Fork (Figure 4.2-1). Suitable habitat for immigrating and holding steelhead appears to be available in the major tributaries in the upper Feather River.

6.2.1.5 Steelhead Spawning and Embryo Incubation

Moyle (2002) reported that steelhead spawn in the tail of a pool or riffle where gravels range in diameter from 0.5 in. to 5.1 in. USFWS (1995) reported that steelhead prefer gravels ranging in diameter of 0.25 in. to 3.0 in. for spawning, with less than 5 percent sand and silt by weight. In the Clearwater and Salmon river watersheds in Idaho, approximately 70 percent of gravels sampled from 68 steelhead redds ranged in diameter of 0.5 in. to 4.0 in. (Orcutt et al. 1968). Water velocities in areas where steelhead redds have been observed range from 0.5 ft/sec to 5.1 ft/sec, and the preferred water velocity reportedly ranges from 1.5 ft/sec to 2.0 ft/sec (Moyle 2002; USFWS 1995). Steelhead redds typically are constructed at water depths between 0.3 ft and 4.9 ft, with the average depth reportedly being 14 in. (Moyle 2002; USFWS 1995). Information regarding the habitat requirements for steelhead embryo incubation was unavailable.

Based on information presented in the literature and analysis of available data, suitable mesohabitat in the upper Feather River for spawning and incubating steelhead includes riffles and runs. Riffles and runs collectively account 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 (Figure 4.2-1). Suitable habitat for the spawning and embryo incubation life stage of steelhead appears to be available in the major tributaries in the upper Feather River.

6.2.1.6 Steelhead Fry and Fingerling Rearing and Downstream Movement

For the first year or two after hatching, fry and fingerling steelhead reportedly are found in cool, clear, fast-flowing, permanent water courses where riffles predominate over pools, ample cover in the form of undercut banks and riparian vegetation exists, and invertebrates are abundant (Moyle 2002). Following emergence, steelhead fry reportedly usually live in small schools in shallow water along stream banks. As steelhead grow, individuals establish feeding territories, typically in riffles. With continued growth, steelhead utilize deeper and faster pools to exploit a wider variety of food sources (USFWS 1995). Moyle (2002) reported that the optimal water velocities for steelhead fry (<2 in or <50mm) range from 0.03 ft/sec to 0.82 ft/sec, and for juveniles (2.0 in. to 3.9 in.; 50.8 mm to 99.1 mm) ranges from 0.33 ft/sec to 0.98 ft/sec. USFWS (1995) reported that the optimal water velocity for steelhead fry is 0.6 ft/sec, and for juveniles is 0.9 ft/sec. In the Feather River, young-of-year steelhead were observed in areas with water velocities ranging from zero to greater than 3.0 ft/sec (DWR 2003d). The greatest proportion of juvenile steelhead were observed in water velocities of 2.0 ft/sec to 3.0 ft/sec in the lower Feather River. From February through August, young-of-year steelhead in the Feather River were observed at increasingly greater water depths. In February, 100 percent of observed juveniles were reportedly observed at depths between 0.0 in. and 9.4 in. In March, over 60 percent of juveniles remained at depths between 0.0 in. and 9.4 in., and approximately 30 percent of juveniles utilized depths between 9.8 in. and 19.3 in. The general depth distribution in April was similar to that in March, with the addition of a small proportion of juvenile steelhead utilizing depths greater than 39.4 in. In May, increasing numbers of juvenile steelhead were observed at depths of 9.8 in. to 19.3 in. In June, the largest proportion of fish were observed at depths of 9.8 in. to 19.3 in. In July, juvenile steelhead primarily utilized water depths from 0.0 in. to 19.1 in., with few observations in depths of 29.5 in. to 38.1 in. (DWR 2003d).

Juvenile steelhead rear in freshwater for extended periods prior to ocean entry (Moyle 2002). The study results reported above suggest habitat utilization differentiation exists between length classes of steelhead. Therefore, many different types of habitat are utilized by steelhead during the fry and fingerling rearing and downstream movement life stage. Based on information presented in the literature and analysis of available data, suitable mesohabitat in the upper Feather River for rearing steelhead fry and fingerlings includes glides, pools, riffles, and runs. Glides, pools, riffles, and runs collectively account for 93 percent of surveyed areas in the West Branch, 100 percent of surveyed areas in the North Fork, 93 percent of surveyed areas in the Middle Fork, and 85 percent of surveyed areas in the South Fork (Figure 4.2-1). Suitable habitat for rearing fry and fingerling steelhead appears to be available in the major tributaries in the upper Feather River.

6.2.1.7 Steelhead Smolt Emigration

The steelhead smolt emigration life stage and the steelhead fry and fingerling life stage both involve downstream movements of juveniles. The differences between the two life stages are that downstream migrations of smolting juvenile steelhead are true seaward migrations, and that smolting juveniles have begun physiological change designed to allow survival in saltwater. The smoltification process also involves morphological and behavioral changes. In general, these changes gradually occur while juvenile steelhead are en-route from natal streams to the ocean.

Steelhead smolts reportedly migrate at night, and during the spring when instream flows are high (Newcomb and Coon 2001). Literature is limited concerning the habitat requirements and utilization of smolting steelhead. For purposes of this report, it was assumed that emigrating steelhead smolts utilize the same habitat types as rearing steelhead fry and fingerlings. Based on information presented in the literature concerning habitat utilization of rearing steelhead fry and fingerlings, and analysis of available data, suitable mesohabitat in the upper Feather River for emigrating steelhead smolts includes glides, pools, riffles, and runs. Glides, pools, riffles, and runs collectively account for 93 percent of surveyed areas in the West Branch, 100 percent of surveyed areas in the North Fork, 93 percent of surveyed areas in the Middle Fork, and 85 percent of surveyed areas in the South Fork (Figure 4.2-1). Suitable habitat for emigrating steelhead smolts appears to be available in the major tributaries in the upper Feather River.

6.2.2 Summary of Mesohabitat Suitability in the Upper Feather River

Based on broad-scale mesohabitat surveys, the major tributaries in the upper Feather River, in general, provide suitable habitat for all life stages of Chinook salmon and steelhead. The cumulative percentages of available suitable mesohabitat for each tributary, and the associated life stage are summarized in Table 6.2-1.

Table 6.2-1. Cumulative percentage of available mesohabitat, by tributary and salmonid life stage, in the major tributaries of the upper Feather River.

Life stage	West Branch	North Fork	Middle Fork	South Fork	Grand Mean
Chinook Salmon Adult Immigration and Holding	84	78	47	51	**65**
Steelhead Adult Immigration and Holding	93	100	93	85	**93**
Chinook Salmon Spawning and Embryo Incubation	28	97	62	44	**58**
Steelhead Spawning and Embryo Incubation	28	97	62	44	**58**
Chinook Salmon Juvenile Rearing and Downstream Movement	93	100	93	85	**93**
Steelhead Fry and Fingerling Rearing and Downstream Movement	93	100	93	85	**93**
Steelhead Smolt Emigration	93	100	93	85	**93**
Grand Mean	**73**	**96**	**78**	**68**	N/A

In the upper Feather River, the least amount of suitable habitat is available (58 percent) for the spawning and embryo incubation life stage for both Chinook salmon and steelhead. The most amount of suitable habitat (93 percent) is available for Chinook salmon juvenile rearing and downstream movement, steelhead adult immigration and holding, steelhead fry and fingerling downstream movement, and steelhead smolt emigration. Overall, the North Fork appears to be the most suitable for Chinook salmon and steelhead occupancy, while the South Fork appears to be the least suitable. Due to data limitations, the results from this assessment offer a very general characterization of the potential habitat suitability of the major tributaries in the upper Feather River for Chinook salmon and steelhead.

The mesohabitat sampling methodology was implemented on a broad scale because access limitations and safety concerns prohibited a finer, more detailed assessment. It should be noted that finer scale surveys could potentially alter the conclusions of mesohabitat suitability for anadromous salmonids.

The amount of available spawning gravels in the North Fork has been previously reported as one of the limiting factors controlling rainbow trout populations (Pacific Gas and Electric Company 2003). Rainbow trout and steelhead are the same species (they are separated by some authors at the sub-specific level), and systematic work indicates that rainbow trout are closely related to Pacific salmon (Moyle 2002). Therefore, factors that limit rainbow trout populations also may limit steelhead and Chinook salmon populations. PG &E conducted various types of surveys in the Poe Reach of the North Fork of the upper Feather River in response to the FERC relicensing process for the Poe Hydroelectric Project (Pacific Gas and Electric Company 2003). Spawning gravel and adult spawning surveys were conducted in 1992, 1999, and 2003 in the Poe Reach. PG&E concluded that limited amounts of spawning habitat were available, although no redds or spawning adult rainbow trout were observed. In 2000, observational surveys were conducted in Flea Valley Creek and Mill Creek, two tributaries to the Poe Reach. In Flea Valley Creek, surveyors detected many adult fish and 58 redds. Similar surveys in Mill Creek were unsuccessful at locating redds, but adult rainbow trout reportedly were observed. Based on four years of surveys in the Poe Reach of the North Fork Feather River and two tributaries to the Poe Reach, PG&E concluded that adult rainbow trout were assumed to be migrating into the smaller tributaries to spawn. Spawning habitat for anadromous salmonids likely is available in the upper Feather River based on available information and observations, and similarities between rainbow trout, steelhead, and Chinook salmon.

6.2.3 Water Temperature Suitability in the Upper Feather River by Life Stage

In order to assess water temperature suitability in the upper Feather River for Chinook salmon and steelhead, a literature review was conducted to determine thermal tolerance values for each life stage. An assessment of water temperature suitability was performed using data collected in the upper Feather River. However, interpretation and presentation of this water temperature suitability assessment should be made with caution due to data limitations. Data were available from few water temperature data loggers in the upper Feather River, and it is unknown whether the water temperatures obtained from the data loggers, and utilized in the habitat suitability assessment, reflect spatial (including elevational) variation in water temperatures in the upper Feather River. However, water temperature data loggers were located generally in the lower sections of each tributary at relatively low elevations, and therefore, may represent the highest water temperatures experienced in each tributary based on the generally positive correlation of water temperatures and distance traveled downstream during warmer months. Application of this assessment to the linear extent of the upper Feather River assumes available data are representative of the entire system.

In the North Fork, PG&E currently is investigating the feasibility of enhancing coldwater withdrawal from the Prattville Intake at Lake Almanor, and this modification potentially could decrease water temperatures within the Oroville Facilities FERC project boundary. 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 was not included in the water temperature suitability assessment in this report.

6.2.3.1 Chinook Salmon Adult Immigration and Holding

The defined immigration and holding period for Chinook salmon occurs from March through December. The lowest water temperature index value selected for this life stage was 60°F (15.6°C) because much of the literature agrees that thermal stress does not occur to immigrating and holding adult Chinook salmon at water temperatures ≤60°F (NOAA Fisheries 1997; ODEQ 1995). In general, mean daily water temperatures in the upper Feather River remained below 60°F from March through May and again from October through December. Berman (1990) suggested that the effects of thermal stress to pre-spawning adults are evident at water temperatures near 64°F (17.8°C). In general, mean daily water temperatures in the upper Feather River exceeded 64°F from June through August. Available literature suggests that thermal stress at water temperatures ≥ 68°F is pronounced, and severe adverse effects to immigrating and holding pre-spawning adults, including mortality, can be expected (Berman 1990; Marine 1997; NOAA Fisheries 1997). Because significant impacts to immigrating and holding adult Chinook salmon occur at water temperatures ≥68°F, it was not necessary to select an index value higher than 68°F (20°C). At most data loggers, water temperatures exceeded or were very near 68°F from June through August to early September (Figure 5.3-1 through Figure 5.3-4). Based on analysis of water temperatures recorded in the upper Feather River, thermal stress to immigrating and holding Chinook salmon likely occurs from June through early September. For this report, it is assumed that a potential fish passage program would transport adult Chinook salmon above Oroville Dam from March through June. Therefore, all 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.

Chinook salmon undergo long and rigorous migrations en route to natal rivers, and encounter many stressors along the way. The effects from stressors are magnified at higher water temperatures. Typically, stress from high water temperatures results in adult pre-spawn mortality, reduced embryo survival, and increased incidence of disease (McCullough 1999). The effects from exposure to elevated water temperatures also are positively correlated with exposure time (McCullough 1999), and the cumulative effects may be delayed until adults arrive on spawning grounds. Adult pre-spawn mortality is a potential effect of thermal stress that is of particular concern. McCullough (1999) stated that adult salmon, which fast during a long upstream journey, exhaust virtually all energy reserves prior to spawning. High water temperatures during immigration and holding can increase the rate at which limited energy is consumed for standard metabolism, and can influence the rate of pre-spawn mortality. Water temperatures can invoke immediate or delayed mortalities and also can create thermal environments conducive to other causative pre-spawn mortality factors. Many freshwater diseases that affect Chinook salmon are most virulent within specific water temperature ranges. McCullough (1999) stated that many of the diseases that commonly affect Chinook salmon become highly infectious and virulent at water temperatures above 59.9°F

(15.5°C), and that both the percentage of survival and time to death decrease as water temperatures increase beyond this threshold. When water temperatures are at the lower end of the infectious range, mortalities may not occur for days or weeks after exposure. McCullough (1999) concluded that water temperatures in the range of 55°F to 59°F (12.8-15°C) appear to be the most appropriate for adult salmonids with respect to resisting freshwater diseases. USFWS (1995) reported that mature female Chinook salmon subjected to prolonged exposure to water temperatures above 60°F (15.6°C) have poor survival rates and produce fewer viable eggs than females exposed to lower water temperatures. Elevated water temperatures in the upper Feather from June through September may cause thermal stress to immigrating and holding Chinook salmon, potentially leading to increased adult pre-spawn mortality rates and decreased egg viability. However, it is important to note that the Oroville Facilities are not able to manipulate water temperatures in the upper Feather River through operational procedures because DWR does not own facilities capable of altering water temperature regimes upstream from the Oroville Dam. Therefore, water temperatures in the upper Feather River are influenced by natural processes, water diversions, and hydroelectric facilities not owned or operated by DWR.

Water temperature data recorded at multiple data loggers in tributaries of the upper Feather River revealed that, from June through early September, water temperatures were high enough to cause thermal stress to immigrating and holding Chinook salmon. However, the specific location within the vertical water column and the habitat type in which each water temperature data logger was located is unknown. It is likely that the data available for this analysis does not account for thermal refugia potentially present within the upper Feather River. A thermal refuge is defined as any habitat providing cooler water temperatures than the ambient stream conditions that also provides relief and escape from elevated, stressful water temperatures. In general, it is a mix of physical characteristics present in certain pools and other deep-water areas that attract immigrating salmon, and provide relief to holding individuals from thermally induced stress. DWR and USBR (2000) reported that pools should provide appropriate depths, and well-oxygenated cool water to allow over-summer survival of spring-run Chinook salmon. Moyle (2002) reported that Chinook salmon select pools that are usually greater than 2 meters (6.6 ft) deep, typically with bedrock bottoms, and water velocities ranging from 15-80 cm/sec. Adult Chinook salmon reportedly utilize overhanging ledges, deep pockets, and “bubble curtains” created by high velocity inflow as cover during the day (DFG 1998a; DWR and USBR 2000; Moyle 2002). Riparian vegetation also is important for providing and maintaining thermal refugia because the resultant shade maintains cool water temperatures. The presence of thermal refugia depends on many variables, but one key component is thermal stratification. In systems where surface water temperatures are high, thermal stratification often provides cool water refugia in the bottom water layers within the deepest habitat such as pools. Vertical stratification can provide habitat in otherwise unsuitably warm waters. Studies conducted in northern California indicate that thermal stratification occurs under several conditions. In Redwood Creek and Rancheria Creek, thermal stratification in pools occurred under similar conditions, while conditions under which stratification occurred in the Middle Fork Eel River were somewhat different from the other two systems. The gradients of Redwood Creek and Rancheria Creek were 0.18 percent and <0.1 percent, respectively (Nielsen et al. 1994). The study reaches in the Middle Fork Eel River were comparatively steep (gradients exceeded 2 percent) (Nielsen et al. 1994). One parameter that was similar between all three systems was that all were characterized by low summer flows. Instream flows in the Middle Fork Eel River reportedly decreased to 3.5 cfs during the 1990 drought, the minimum discharge in Redwood Creek was 28.3 cfs in 1985, and mean summer discharge in Rancheria Creek was reported to be 74.2 cfs (Nielsen et al. 1994). Other factors that reportedly contributed to water temperature stratification in Redwood and Rancheria creeks included encroachment of gravel bars into pools, and inflow from one or more coldwater sources including groundwater seepage, tributary inflow, and intragravel flow (Nielsen et al. 1994). Stratification of pools in the Middle Fork Eel River occurred without the apparent influence of a source of coldwater inflow or structural elements that isolated pool water from inflow. In this river, pools reportedly became stratified by virtue of the low intensities of turbulence, resulting from low summer discharge relative to the size of the channel (Nielsen et al. 1994). In some cases, thermal stratification appears to be associated with systems having low instream flows. Instream flows were available for three of the four major tributaries that comprise the upper Feather River. Data were not available for the South Fork. Instream flows in the West Branch, North Fork, and Middle Fork averaged 40 cfs, 2,180 cfs, and 638 cfs, respectively, during months when water temperatures were highest, typically June through September. Average instream flow in the West Branch and Middle Fork of the upper Feather River appears to be low enough to potentially provide conditions necessary for the development of thermal stratification during the warmest months of the year. Average instream flow in the North Fork appears to be too high for thermal stratification to develop during the warmest months of the year. However, it is important to note that these speculations are based on average instream flows from one instream flow data logger in each tributary, and it is uncertain if data are reflective of the temporal and spatial variation of instream flows in each tributary. Therefore, it is uncertain if conditions exist in the upper Feather River to provide potential thermal refugia.

6.2.3.2 Chinook Salmon Spawning and Embryo Incubation

The Chinook salmon spawning and embryo incubation life stage is defined as the time period from redd construction through fry emergence (August 15 through February 15). The effects to spawning adults from elevated water temperatures are considered to be 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 were addressed in discussions of that life stage. The analysis of the influence of water temperatures on the Chinook salmon spawning and embryo incubation life stage will focus on potential effects to embryos. Relative to the large body of literature pertaining to water temperature effects on

Chinook salmon embryos, there are few laboratory experiments that specifically examine Chinook salmon embryo survival under different constant or fluctuating water temperature treatments (Combs et al. 1957; Hinze 1959; Johnson and Brice 1953; Seymour 1956; USFWS 1999). Supporting evidence for index value selections was derived mainly from available literature describing laboratory studies, and from regulatory documents, such as reports produced by NOAA Fisheries, USFWS, and USBR. Many authors and documents have reported that negative impacts do not occur at water temperatures below 56°F (13.3°C), and such water temperatures are suitable for spawning and embryo incubation (NOAA Fisheries 1993; NOAA Fisheries 1997; NOAA Fisheries 2002; USBR Unpublished Work; USFWS 1995; USFWS 1999). Some literature suggests that water temperatures must be less than or equal to 56°F for maximum survival of Chinook salmon embryos (i.e. eggs and alevins) during spawning and incubation. NOAA Fisheries (1993) reported that optimum water temperatures for egg development are between 43°F and 56°F. USBR (2003) reports that water temperatures less than 56°F results in a natural rate of mortality for fertilized Chinook salmon eggs. USFWS (1995) reported a water temperature range of 41°F to 56°F for maximum survival of eggs and yolk-sac larvae in the Central Valley of California. NOAA Fisheries (1997) suggested a preferred water temperature range of 42°F to 56°F for Chinook salmon egg incubation in the Sacramento River. Alevin mortality reportedly is significantly higher when Chinook salmon embryos are incubated at water temperatures above 56°F (USFWS 1999). NOAA Fisheries (2002) reported 56°F as the upper limit of suitable water temperatures for spring-run Chinook salmon spawning in the Sacramento River. Water temperatures in the upper Feather River were below the index value reported in a majority of the literature as suitable for spawning and incubation for much of the Chinook salmon spawning and embryo incubation period, remaining below 56°F from mid-October to early November through February 15 (Figure 5.3-5 through Figure 5.3-8). At water temperatures above 62°F, high mortality rates of fertilized eggs and alevins reportedly are expected (Hinze 1959; Seymour 1956; USBR Unpublished Work; USFWS 1999). Water temperatures in the upper Feather River exceeded 62°F (17.8°C), generally from August 15 through early September to mid-October. Therefore, high water temperatures in the upper Feather River could potentially have negative impacts on incubating eggs and alevins from August 15 through early September to mid-October. In addition, elevated water temperatures during the immigration and holding life stage may magnify the effects from elevated water temperatures during the spawning and embryo incubation life stage.

6.2.3.3 Chinook Salmon Juvenile Rearing and Downstream Movement

The defined presence dates for the Chinook salmon juvenile rearing and downstream movement life stage are January through December (i.e. emigration and downstream movement occurs year-round). Water temperature is a major limiting factor for juvenile Chinook salmon because it affects both survival and growth (Moyle 2002). High water temperatures reportedly can be lethal or cause sub-lethal effects such as reduced appetite and growth, increased incidence of disease, increased metabolic costs, decreased ability to avoid predators, and decreased saltwater adaptability (McCullough 1999). Growth reportedly is an important component to both rearing and smolting juveniles, and a positive correlation has been shown between survivability and body length (Folmar et al. 1982). The lowest index value selected for this life stage was 60°F (15.6°C) because regulatory documents and several source studies report that water temperatures ≤60°F are optimal for growth (Banks et al. 1971; Brett et al. 1982; Marine 1997; NOAA Fisheries 1997; NOAA Fisheries 2000; NOAA Fisheries 2002; Rich 1987). Juvenile Chinook salmon rear year round. Water temperatures in the upper Feather River exceeded 60°F generally from mid-May through early August to late September (Figure 5.3-9 through Figure 5.3-12). During this period elevated water temperatures may decrease survivability and increase mortality of rearing juvenile Chinook salmon.

In addition to affecting growth, water temperature affects homeostatic processes, including smoltification. Smoltification is the process by which physiological changes occur enabling juvenile salmonids to transition from living in freshwater to living in saltwater. The physiological changes take place during seaward emigration, and are sequential through time, designed to peak when smolts reach saltwater (DWR 2003c). Elevated water temperatures have been shown to alter the timing and key physiological mechanisms associated with smoltification (Marine 1997). An important component of smoltification is an increase in gill ATPase activity that increases the hypo-osmoregulatory capabilities of emigrating juvenile salmonids. Elevated water temperature has been reported to inhibit gill ATPase activity, which reduces saltwater tolerance, potentially decreasing survivability and increasing mortality rates (Marine 1997; Zaugg and Wagner 1973). In aquatic systems where current water temperatures have increased compared to historic water temperature regimes, the synchronization of emigration timing and hypo-osmoregulation may be altered, resulting in emigrating juvenile salmonids reaching peak hypo-osmoregulatory capability prior to reaching saltwater, with a reversal of the smoltification process (desmoltification) occurring (DWR 2003c). The ramifications of desmoltification are a decreased ability to live in saltwater, higher mortality rates for emigrating juvenile salmonids, and decreased escapement. Marine (1997) concluded that acceleration and inhibition of Sacramento River Chinook salmon smolt development may occur at water temperatures above 62.6°F (17°C). The 63°F (17.2°C) index value was chosen based, in part, on this study. In general, water temperatures in the upper Feather River exceeded 63°F from early May to early June through early September to early October.(Figure 5.3-9 through Figure 5.3-12). 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 (DWR 2002). 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 (DWR 2002). In addition, a potential fish passage program may capture and transport juveniles downstream and release them below the Oroville Dam prior to the onset of smoltification. Marine (1997) reported that significant inhibition of gill sodium ATPase activity and associated reductions of hypo-osmoregulatory capacity, and significant reductions in growth rates, may occur when chronic elevated water temperatures exceed 68°F (20°C). The 68°F index value was chosen, in part, based on this study. Water temperatures in the upper Feather River exceeded 68°F generally from June through mid-September. However, the impacts to emigrating smolts from high water temperatures during this time period would probably be minimal due to rapid emigration after emergence and transport below Oroville Dam shortly after emergence.

6.2.3.4 Steelhead Adult Immigration and Holding

The defined steelhead adult immigration and holding period occurs from September through April 15. Water temperatures reportedly can control the timing of adult spawning migrations, and can affect the viability of eggs in holding females (NOAA Fisheries 2000). Few studies were found that examined the effects of water temperature on either steelhead immigration or holding (Bruin and Waldsdorf 1975; McCullough et al. 2001; Smith et al. 1983). The available studies reported adverse effects occurring to immigrating and holding steelhead at water temperatures exceeding the mid-fifty degree range, and that immigration may be delayed if water temperatures approach approximately 70°F (21.1°C). Water temperature index values of 52°F (11.1°C), 56°F(13.3°C), and 70°F were chosen because they incorporate a range of values supported by available literature that represent conditions ranging from appropriate to adverse. NOAA Fisheries (2000, 2002) reported that the preferred range for adult steelhead immigration was 46°F to 52.1°F (7.8°C to 11.2°C). 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 remained below 52°F generally from late October through April 15 (Figure 5.3-13 through 5.3-16). Holding migratory fish at constant water temperatures above 55.4°F to 60.1°F (13-15.6°C) reportedly may impede spawning success (McCullough et al. 2001). Mean daily water temperatures in the upper Feather River exceeded 56°F generally from September through October, and negative impacts (immediate and/or delayed) to immigrating and holding steelhead from thermal stress may occur during this period.

Water temperature data recorded at multiple data loggers in tributaries of the upper Feather River showed that during portions of the time period that steelhead immigrate and hold in appropriate habitat, water temperatures were high enough to cause thermal stress. However, the specific location within the water column and the habitat type that each water temperature data logger was located is unknown, and it is likely that the data do not account for thermal refugia potentially present within the upper Feather River. A thermal refuge is defined as any habitat providing cooler water temperatures than ambient stream temperatures that also provides relief and escape from elevated, stressful water temperatures. In general, it is a mix of physical characteristics present in certain pools and other deep water areas that attract immigrating salmon, and provide thermal refugia to holding individuals. Characteristics of steelhead holding habitat were described in section 6.2.1.4. A key component of thermal refugia is thermal stratification, which occurs in some systems under specific conditions described in section 6.2.3.1. Average instream flow in the West Branch and Middle Fork appear to be low enough to potentially provide conditions necessary for the development of thermal stratification and potential presence of cool water thermal refugia during the warmest months of the year. Average instream flow in the North Fork appears to be too high for thermal stratification to develop during the warmest months of the year. However, it is important to note that these speculations are based on average instream flows from one instream flow data logger in each tributary, and it is uncertain if data are reflective of the temporal and spatial variation of instream flows in each tributary. Therefore, it is uncertain whether or not conditions exist in the upper Feather River to provide for thermal refugia.

6.2.3.5 Steelhead Spawning and Embryo Incubation

The defined presence dates for the steelhead spawning and embryo incubation life stage are December through May. Few studies have been published regarding the effects of water temperature on steelhead spawning and embryo incubation (Redding and Schreck 1979; Rombough 1988). Because anadromous steelhead and non-anadromous rainbow trout are genetically identical, and because of the paucity of information regarding effects of water temperature on steelhead spawning and embryo incubation, studies on non-anadromous rainbow trout were considered in the development of water temperature index values for this life stage. Available literature suggests that water temperatures in the low-fifty degree range support high embryo survival, and substantial mortality to steelhead eggs occurs at water temperatures at or above the high-fifty degree range (Humpesch 1985; Kwain 1975; McCullough et al. 2001). Water temperature index values of 52^{o}F (11.1^{o}C), 54^{o}F (12.2^{o}C), 57^{o}F (13.9^{o}C), and 60^{o}F (15.6^{o}C) were selected because available literature provided the strongest support for water temperature index values at or near 52^{o}F, 54^{o}F, 57^{o}F, and 60^{o}F, and the index values reflect an evenly distributed range representing conditions reported as optimal to adverse for steelhead spawning and embryo incubation. Optimum water temperatures for spawning steelhead in the Central Valley reportedly range from 46^{o}F to 52^{o}F (7.8^{o}C to 11.1^{o}C) (USFWS 1995), and for embryo incubation range from 48.0^{o}F to 52.1^{o}F (8.9^{o}C to 11.2^{o}C) (USBR 1997). During the time period corresponding with the steelhead spawning and embryo incubation life stage (December through May) (DWR 2003a; Moyle 2002), available mean daily water temperatures at most of the data logger locations exceeded 52^{o}F rarely (Figure 5.3-17 through Figure 5.3-20). From December through April, available mean daily water temperatures did not exceed 57^{o}F. Mean daily water temperatures in the upper Feather River appear to be suitable for the steelhead spawning and embryo incubation life stage.

6.2.3.6 Steelhead Fry and Fingerling Rearing and Downstream Movement

The steelhead fry and fingerling rearing and downstream movement period occurs from January through December. Like other salmonids, growth and survival of fry and fingerling steelhead is controlled largely by water temperature. The duration of freshwater residence for juvenile steelhead is long relative to that of Chinook salmon, making steelhead more vulnerable to changes in the natural water temperature regime. Central Valley juvenile steelhead have high growth rates at water temperatures in the mid 60°F range (Cech and Myrick 1999). Water temperature index values of 65°F (18.3°C), 68°F (20°C), 72°F (22.2°C), and 75°F (23.9°C) were selected to represent an evenly distributed range of water temperatures that provide optimal to lethal conditions for steelhead fry and fingerling rearing and downstream movement. The lowest water temperature index value selected was 65°F because NOAA Fisheries (2002) reported 65°F as the upper limit preferred for growth and development of Sacramento River and American River juvenile steelhead. Also, 65°F was found to be within the preferred water temperature range (i.e., 62.6°F to 68.0°F) of Nimbus strain steelhead (Cech and Myrick 1999). Additionally, 65°F reportedly supported high growth of Nimbus strain juvenile steelhead (Cech and Myrick 1999). During the time period corresponding with the steelhead fry and fingerling life stage (year-round), mean daily water temperatures remained below 65°F generally from early August to early September through early June to early July depending on the tributary (Figure 5.3-21 through Figure 5.3-24). Cherry et al. (1977) and Kaya et al. (1977) both observed an upper preference water temperature near 68°F for juvenile rainbow trout, duplicating the upper preferred limit for juvenile steelhead observed by Cech and Myrick (1999). Because of the strength of evidence supporting 68°F as the upper preferred limit for juvenile *Oncorhynchus mykiss*, 68°F was selected as a water temperature index value. Symptoms of thermal stress in juvenile steelhead have been reported at water temperatures approaching 72°F. For example, physiological stress to juvenile steelhead in Northern California streams was demonstrated by increased gill flare rates, decreased foraging activity, and increased agonistic activity as stream temperatures rose above 71.6°F (Nielsen et al. 1994). Also, 72°F was selected as a water temperature index value because 71.6°F has been reported as an upper avoidance water temperature (Kaya et al. 1977), and an upper thermal tolerance water temperature (EPA 2002) for juvenile rainbow trout. Mean daily water temperatures in the upper Feather River exceeded 72°F generally from June through August in the West Branch, and only occasionally in July in the North Fork, Middle Fork, and South Fork. The highest water temperature index value selected was 75°F because NOAA Fisheries and EPA report that direct mortality to rearing juvenile steelhead results when stream temperatures reach 75°F (EPA 2002; NOAA Fisheries 2001). Mean daily water temperatures exceeded 75°F only in the West Branch and the North Fork from July through early September (mostly in the West Branch). Based on available water temperature data, 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.

6.2.3.7 Steelhead Smolt Emigration

For purposes of this report, emigration can be defined as a true seaward migration, and would be expected to occur in the upper Feather River from January through June. Smoltification is the distinguishing characteristic of this life stage. Smoltification involves physiological, morphological and behavioral changes that enable juvenile salmonids to transition from living in freshwater to saltwater. The physiological changes take place during seaward emigration and are sequential through time, designed to peak when emigrating individuals reach saltwater. Elevated water temperatures have been shown to alter the timing and key physiological mechanisms associated with smoltification (Marine 1997). Wagner (1974) concluded that steelhead exposed to elevated water temperatures completed the physiological changes sooner than those exposed to colder water. In aquatic systems where historic water temperature regimes have increased, the synchronization of emigration timing and hypo-osmoregulation may be altered, resulting in emigrating juvenile salmonids reaching peak hypo-osmoregulatory capability prior to reaching saltwater, with a reversal of the smoltification process (desmoltification) potentially occurring. The ramifications of desmoltification are a decreased ability to live in saltwater and higher mortality rate in emigrating juvenile salmonid populations. An important component of smoltification is an increase in gill ATPase activity that increases the hypo-osmoregulatory capabilities in emigrating juvenile salmonids. Elevated water temperature has been reported to inhibit gill ATPase activity (Marine 1997; Zaugg and Wagner 1973). Inhibition of gill ATPase activity reduces saltwater tolerance, potentially decreasing survivability and increasing mortality rates.

Fingerling steelhead become smolts when the physiological changes occur that allow saltwater survival. Salmonid smolts can be distinguished from pre-smolts by their silvery appearance and relatively slim, streamlined body (Hoar 1988). Steelhead smolts migrate out to sea at 1 to 3 years of age and at body lengths of 10 to 25 cm FL (Moyle 2002). In the Feather River, steelhead smolt emigration occurs from January through June (pers. com. B. Cavallo, 2004; McEwan 2001; Newcomb and Coon 2001; Snider and Titus 2000; USFWS 1995).

Laboratory data suggest that smoltification, which directly affects the ability of steelhead to successfully emigrate, is directly controlled by water temperature (Adams et al. 1973; Adams et al. 1975). Water temperature index values of 52°F (11.1°C) and 55°F (12.8°C) were selected to evaluate the steelhead smolt emigration life stage because most literature on the effects of water temperature to steelhead smolting suggest that water temperatures less than 52°F (Adams et al. 1975; Myrick and Cech 2001; Rich 1987) or less than 55°F (EPA 2003; McCullough et al. 2001; Wedemeyer et al. 1980; Zaugg and Wagner 1973) are required for successful smoltification to occur. Adams et al. (1973) tested the effect of water temperature (43.7°F, 50.0°F, 59.0°F or 68.0°F) on the increase of gill microsomal Na^+-K^+-stimulated ATPase activity associated with parr-smolt transformation in steelhead, and found a twofold increase in Na^+-K^+-ATPase at 43.7°F and 50.0°F, but no increase at 59.0°F or 68.0°F. In a subsequent study, the highest water temperature where a parr-smolt transformation occurred was at 52.3°F (Adams et al. 1975). The results of Adams et al. (1975) were reviewed in Myrick and Cech (2001) and Rich (1987), and both authors recommended that water temperatures below 52.3°F are required to successfully complete the parr-smolt transformation.

Zaugg and Wagner (1973) examined the influence of water temperature on gill ATPase activity related to parr-smolt transformation and migration in steelhead and found ATPase activity was decreased and migration reduced when juveniles were exposed to water temperatures of 55.4°F or greater. In a technical document prepared by EPA to provide temperature water quality standards for the protection of Northwest native salmonids, water temperatures less than or equal to 54.5°F were recommended for emigrating juvenile steelhead (EPA 2003). Delineating the time period that mean daily water temperatures exceeded 52°F and 55°F in the upper Feather River is difficult because of the amount of variation in water temperature between years, data loggers, and tributaries. Water temperatures in the West Branch exceeded both index values earlier in the year than in the other tributaries. However, 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 would likely not be substantial. Studies conducted in the lower Feather River suggest the peak of steelhead emigration occurs from March through mid-April, with few fish emigrating in May and June (DWR 2002; DWR 2003c). Also, it is assumed that a fish passage program would collect post-emergent juvenile steelhead and transport them downstream of Oroville Dam prior to May and June, which is when water temperatures in the upper Feather River increase to potentially stressful levels above 52°F and 55°F.

6.2.4 Comparison of Water Temperatures in Mill Creek, Deer Creek, and the North Fork of the Upper Feather River

Water temperature data were available at three locations (RM 7.8, 8.5, and 15) in the North Fork, a tributary in which there currently are no migratory anadromous salmonids present. Mill Creek and Deer Creek, both of which are tributaries to the upper Sacramento River, were chosen as surrogates for assessing the potential suitability of water temperatures in the upper Feather River for occupancy and survival of migratory anadromous salmonids. Deer Creek and Mill Creek were chosen as representative systems because the geographic location, aspect, slope, and geomorphology of these creeks are similar to that of the upper Feather River, and because migratory anadromous salmonids currently are present in both Deer and Mill creeks. Water temperature data at similar elevations were compared between the upper Feather River, and Mill and Deer creeks. Two main assumptions are associated with this comparative suitability assessment. First, if available water temperature profiles in the upper Feather River are similar to Deer and Mill creeks at those elevations where water temperature data were available, then water temperatures at elevations where water temperature data were unavailable also may be similar because of the similarities between systems with respect to physical characteristics. Second, if water temperature profiles in the upper Feather River are similar to those in Deer Creek and Mill Creek, then water temperatures in the upper Feather River may be suitable for migratory anadromous salmonids because populations of anadromous salmonids currently exist in Deer and Mill creeks.

Mean daily water temperature (ºF) at approximately 1000 ft msl in the North Fork Feather River and in Mill Creek is shown in Figure 6.2-1. Comparative interpretations should be made with caution because the water temperatures shown in Figure 6.2-1 are represented by data obtained in different years between data loggers, and annual weather patterns can strongly influence water temperatures. The water temperatures from the North Fork represent data obtained in 2003 and 2004, and the water temperatures from Mill Creek represent data obtained in 1998. Mean daily water temperatures in the North Fork, from January through early May, generally were slightly cooler than mean daily water temperatures in Mill Creek. From May 10 through October 27, mean daily water temperatures in the North Fork noticeably exceeded mean daily water temperatures in Mill Creek. The differences in mean daily water temperatures from May 10 through October 27 ranged from a low of 1^{o}F to a high of 17^{o}F, and averaged 8^{o}F. Mean daily water temperatures from May 26 through July 14 in the North Fork were particularly high when compared to Mill Creek. Differences ranged from a low of 7^{o}F to a high of 17^{o}F, and averaged 12^{o}F.

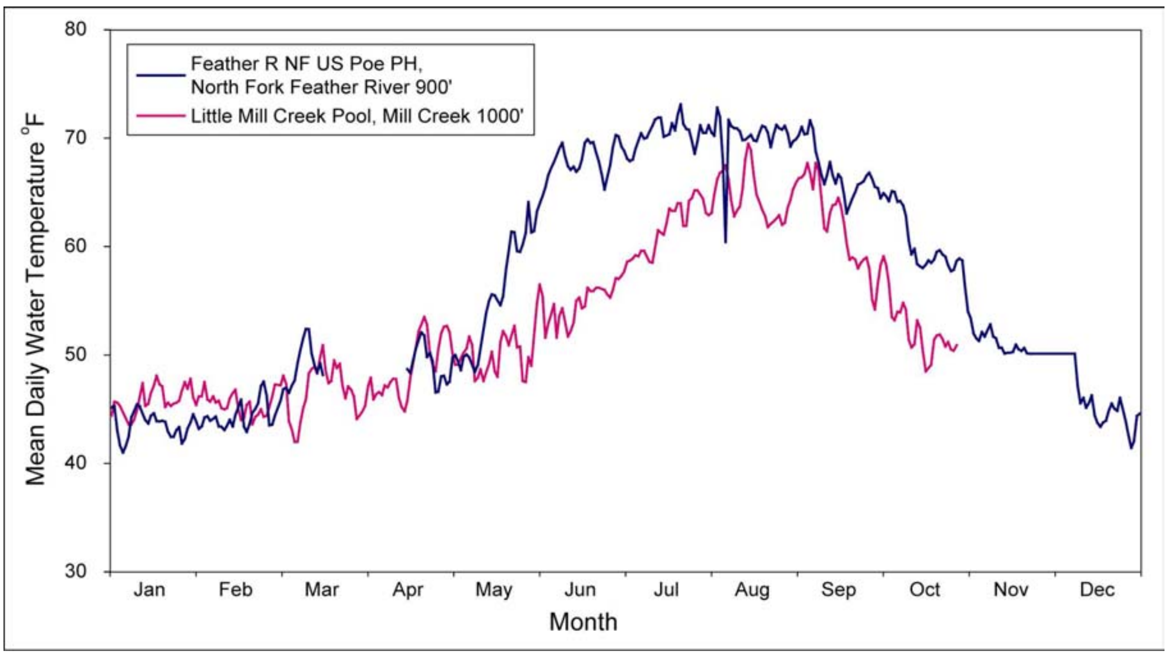

Figure 6.2-1. Mean daily water temperature (ºF) at approximately 1000 ft msl in Mill Creek and the North Fork Feather River.

Mean daily water temperature (ºF) at approximately 1500 ft msl in the North Fork Feather River, Mill Creek, and Deer Creek are shown in Figure 6.2-2. Comparative interpretations should be made with caution because the water temperatures shown in Figure 6.2-2 are represented by data obtained in different years between data loggers. The water temperatures from the North Fork represent data obtained in 2003 and 2004, and the water temperatures from Mill and Deer creek represent data obtained in 2002. Mean daily water temperatures in the North Fork generally were similar to mean daily water temperatures in Mill and Deer creeks from January through mid-August, and from late November through December. Water temperatures were highest in Deer Creek, in general, during these periods. Mean daily water temperatures in the North Fork exceeded mean daily water temperatures in Mill and Deer creeks from late August through mid-November. Differences in water temperatures, during this time period, between the North Fork and Mill and Deer creeks ranged from a low of 1°F to a high of 13°F, and averaged 6°F.

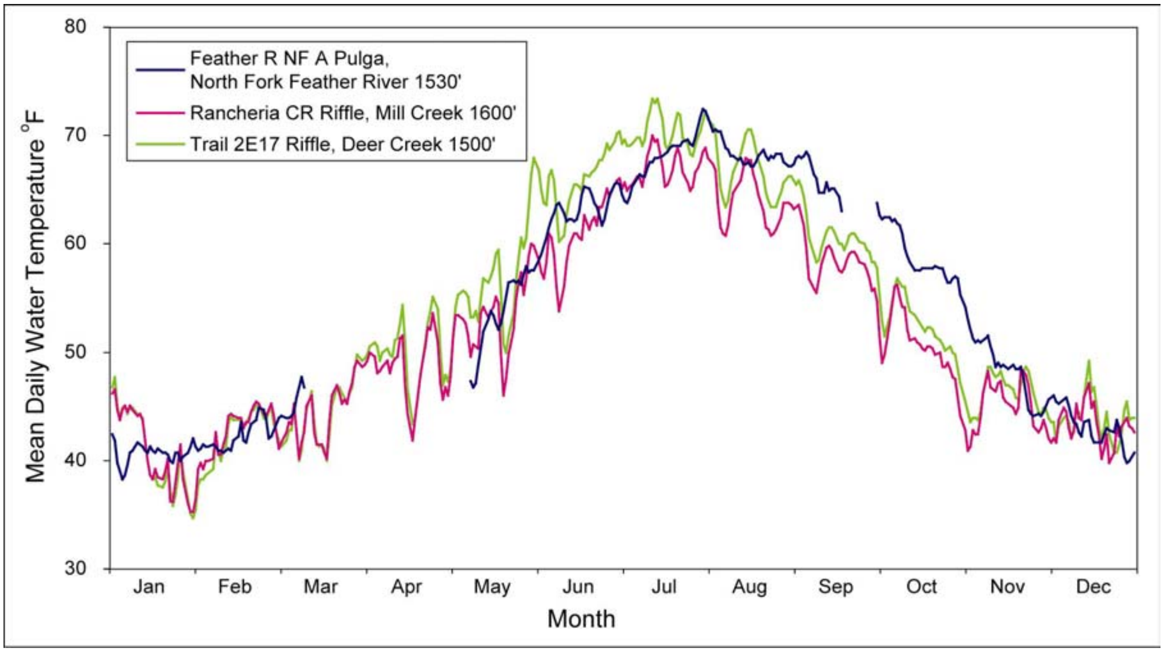

Figure 6.2-2. Mean daily water temperature (ºF) at approximately 1500 ft msl in Mill Creek, Deer Creek, and the North Fork Feather River.

Mean daily water temperatures in the North Fork Feather River differed significantly from mean daily water temperatures in Mill and Deer Creek from mid-May through mid-November. Based on the definitions and presence dates provided in section 5.2 for each life stage of Chinook salmon and steelhead, all life stages would be expected to be present, at some point, from mid-May through mid-November. Thermal tolerances and associated effects are life stage specific, and it is uncertain if water temperatures in the North Fork exceed those of Mill and Deer creeks by a margin large enough to preclude occupancy by anadromous salmonid stocks.

6.2.5 Instream Flow Suitability in the Upper Feather River by Life Stage

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 unavailable for the upper Feather River tributary reaches considered in this analysis. Evaluation of the suitability of flows specific to species and life stage is typically performed utilizing the Instream Flow Incremental Methodology (IFIM) approach. IFIM is a tool used by resource managers to assess the effects of flow manipulation on riverine habitats. The IFIM includes a wide variety of methods of varying complexity, including sophisticated models such as Physical Habitat Simulation (PHABSIM). PHABSIM was developed to calculate the quantity and usage of physical habitat within a stream or river system given the channel structure, flow, and aquatic species criteria. The PHABSIM model calculates a statistic called weighted useable area (WUA), which represents the available habitat for the species and life stage in question at various flows. The WUA index value takes into account water depth and velocity, channel substrate, and sometimes cover data. WUA is calculated at various flow regimes, and curves are produced predicting incremental changes in useable habitat with incremental changes in flow (Williams 1996). Used appropriately, IFIM, PHABSIM, and WUA are an excellent decision-support system designed to help natural resource managers and their constituencies determine the benefits or consequences of different water management alternatives (Bovee et al. 1998). IFIM analyses are available for the lower Feather River in SP-F16, *Evaluation of Project Effects on Instream Flows and Fish Habitat*. However, IFIM incorporates site specific geomorphic variables, and utilizing the results from one system as a surrogate for evaluating flows in another system is inappropriate. IFIM analyses are not available for the upper Feather River, and relevant information in available literature was unavailable. Therefore, a discussion detailing the temporal and spatial suitability of flows in the upper Feather River, for each life stage of Chinook salmon and steelhead, will not be provided in this report.

6.2.6 Resident Fish Distribution in the Upper Feather River

The general distribution of resident fish in the upper Feather River was determined primarily through the use of backpack electrofishing gear. The spatial scale of fish distribution was limited to each tributary because of the methodologies associated with data collection. The primary purpose of the resident fish sampling was to determine the presence or absence of rainbow trout (*Oncorhynchus mykiss*) in the upper Feather River. One 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. Rainbow trout were used as a surrogate representative for Chinook salmon and steelhead because migratory anadromous salmonids currently are absent from the upper Feather River. Rainbow trout were found in all the major tributaries sampled. In general, rainbow trout are considered sexually mature at body lengths $\geq$5.1 in (13 cm) (Moyle 2002). Based on body length, sexually mature rainbow trout may be present in the upper Feather River, however, the breeding status of rainbow trout could not be determined from the resident fish distribution surveys. PG&E conducted various types of surveys in the Poe Reach of the North Fork Feather River to satisfy the requirements of the FERC relicensing process for the Poe Hydroelectric Project (Pacific Gas and Electric Company 2003). In 2000, surveys along Flea Valley Creek, a tributary to the Poe Reach, detected many adult fish and 58 redds. Similar surveys in Mill Creek were unsuccessful at locating redds, but adult rainbow trout were observed. The adult rainbow trout known to be present in the Poe Reach were assumed to be migrating into the smaller tributaries to spawn. Based on the observations of redds and adult rainbow trout made by PG&E surveyors in the Poe Reach as well as the observations of adult rainbow trout by DWR biologists in the West Branch Feather River, Middle Fork Feather River, Berry Creek, and Sucker Run Creek, a self-sustaining rainbow trout population likely exists in the upper Feather River. Also, the presence of what appeared to be young-of-year rainbow trout (0 in. to 5.9 in.) in all tributaries surveyed supports this hypothesis. Because rainbow trout, steelhead, and Chinook salmon are closely related, and because habitat suitable for a self-sustaining rainbow trout population exists, suitable habitat likely exists for anadromous steelhead and Chinook salmon in the upper Feather River.

As reported by Moyle (2002), sexually mature rainbow trout can be fairly small. However, the spawning population generally is assumed to be represented by larger individuals. During the resident fish distribution surveys relatively few rainbow trout exceeding 12 in. were observed. Typically, size bias is associated with some sampling techniques. Electrofishing was the primary sampling technique used, and capture efficiency of electrofishing is positively correlated with fish size (Reynolds 1996). Therefore, it is unlikely that sampling technique accounted for the lack of larger rainbow trout in the samples. Assuming the length frequency distribution observed in the data are not reflective of population parameters, sampling design and location may be responsible for the disproportionate size class structure. Rainbow trout reportedly have seasonal migrations and seasonal habitat preferences, and such preferences differ between length groups. Additionally, rainbow trout are reported to favor higher elevation streams (Moyle 2002). The resident fish distribution surveys were not conducted year round, and as such, surveys may have been conducted in areas and habitat types not used by larger individuals during the sampling dates. Also, most of the surveyed transects were located in low elevation areas near the tributary/reservoir interface where the size class distribution may have differed from other portions of the upper Feather River. Assuming that the size classes observed in the samples reflect true population parameters, high predation and differential growth rates may be responsible for the disproportionate size class structure. Many of the detected species in the upper Feather River are considered predators of salmonids, but Sacramento pikeminnow represent the most likely significant predator. Rieman et al. (1991) estimated that overall juvenile salmonid mortality ranges from 9 percent to 19 percent during downstream migration through the John Day Reservoir in Oregon, and that pikeminnow accounted for 78 percent of this mortality. Bennett (1998) reported that pikeminnow account for 78 percent of losses due to predation in the Snake River system of Idaho. Poe et al. (1991) showed that juvenile salmonids account for 67 percent of the diet of pikeminnow during the out-migration period. Predation rates reportedly increase with increased water temperatures, with the greatest predation occurring at water temperatures >63^{o}F (17.2^{o}C) (Normandeau Associates 2001). Sacramento pikeminnow was detected in all tributaries except the North Fork Feather River. However, PG&E (2003) detected large numbers of Sacramento pikeminnow in the Poe Reach of the North Fork. Therefore, predation may influence the size structure of rainbow trout present in the samples collected by DWR, but it also may be that physical conditions in the upper Feather River limit growth such that larger individuals are rare. Although estimates of the number of spawning rainbow trout in the upper Feather River are unavailable, available information and data suggest that natural reproduction occurs. However, rainbow trout populations may be limited by predation.

Fish distribution surveys determined that rainbow trout are present in the South Fork, Middle Fork, North Fork, and West Branch. Rainbow trout are closely related to steelhead and Chinook salmon, and the habitat requirements of the three species likely are similar. A self-sustaining rainbow trout population appears to be established in the upper Feather River. The physical and environmental conditions necessary for self-sustaining rainbow trout populations also may be conducive to steelhead and Chinook salmon occupancy. Thus, the upper Feather River may offer suitable habitat for steelhead and Chinook salmon. However, steelhead and Chinook salmon populations may be limited by available spawning gravels and high predation rates.

7.0 REFERENCES

Adams, B. L., W. S. Zaugg, and L. R. McLain. 1973. Temperature Effect on Parr-Smolt Transformation in Steelhead Trout (*Salmo gairdneri*) As Measured by Gill Sodium-Potassium Stimulated Adenosine Triphosphatase. Comparative Biochemistry and Physiology 44A:1333-1339.

Adams, B. L., W. S. Zaugg, and L. R. McLain. 1975. Inhibition of Salt Water Survival and Na-K-ATPase Elevation in Steelhead Trout (*Salmo gairdneri*) by Moderate Water Temperatures. Transactions of the American Fisheries Society 104:766-769.

Allen, M. A. and Hassler T.J. 1986. Species Profiles: Life Histories and Environmental Requirements of Coast Fishes and Invertebrates (Pacific Southwest) -- Chinook Salmon. U.S. Fish and Wildlife Service Biology Report 82(11.49). U.S. Army Corps of Engineers, TR EL-82-4.

Banks, J. L., L. G. Fowler, and J. W. Elliot. 1971. Effects of Rearing Temperature on Growth, Body Form, and Hematology on Fall Chinook Fingerlings. The Progressive Fish-Culturist 33:20-26.

Bennett, D. H. 1998. So Many Predatory Resident Fishes - What Needs to Be Done? *in* Management Implications of Co-occurring Native and Introduced Fishes: Proceedings of the Workshop October 27-28, 1998. Portland, OR: NOAA, pp 197-202.

Berman, C. H. 1990. The Effect of Holding Temperatures on Adult Spring Chinook Salmon Reproductive Success. University of Washington.

Bovee, K. D., B. L. Lamb, J. M. Bartholow, C. B. Stalnaker, J. Taylor, and J. Henriksen. 1998. Stream Habitat Analysis Using the Instream Flow Incremental Methodology. Report No. USGS/BRD-1998-0004. U.S. Geological Survey, Biological Resources Division Information and Technology Report.

Brett, J. R., W. C. Clarke, and J. E. Shelbourn. 1982. Experiments on Thermal Requirements for Growth and Food Conversion Efficiency of Juvenile Chinook Salmon, *Oncorhynchus tshawytscha*. Canadian Technical Report of Fisheries and Aquatic Sciences No. 1127:1-28.

Bruin, D. and B. Waldsdorf. 1975. Some Effects on Rainbow Trout Broodstock, of Reducing Water Temperature From 59 F to 52 F. Hagerman, ID: U.S. Fish and Wildlife Service, National Fish Hatchery.

Carl Mesick Consultants. 2002. Knights Ferry Gravel Replenishment Project -Final Report. Work Authority #1469-8520, Project #97-N21.

Cavallo, B. 2002. Feather River Snorkeling Study Microhabitat Field Protocols and Intermediate Snorkel Survey Reach Selection Criteria - Memorandum. Sacramento, CA: California Department of Water Resources.

Cavallo, B., Environmental Scientist, DWR, Sacramento, CA; verbal communication with B. Ellrott, Fisheries Biologist; Establishment of Instream Flow and Water Temperature Targets for the Feather River. February 4, 2004.

Cech Jr., J. J. and C. A. Myrick. 1999. Steelhead and Chinook Salmon Bioenergetics: Temperature, Ration, and Genetic Effects. Technical Completion Report- Project No. UCAL-WRC-W-885. University of California Water Resources Center.

Clark, G. H. 1929. Sacramento-San Joaquin Salmon (*Oncorhynchus tshawytscha*) Fishery of California. Fish Bulletin 17:1-73.

Combs, B. D., R. E. Burrows, and U.S. Fish and Wildlife Service. 1957. Threshold Temperatures for the Normal Development of Chinook Salmon Eggs. Progressive Fish Culturist 19:

DFG. 1952. Fisheries Problems of the Feather River With Special Reference to the Proposed Oroville Dam.

DFG. 1960. Oroville Dam Hatchery Facilities. Sacramento, CA: California Department of Fish and Game.

DFG. 1993. Restoring Central Valley Streams: A Plan for Action.

DFG. 1998a. A Status Review of the Spring-Run Chinook Salmon (*Oncorhynchus tshawytscha*) in the Sacramento River Drainage. Candidate Species Status Report 98-01. Sacramento, CA: Department of Fish and Game.

DFG. 1998b. California Salmonid Stream Habitat Restoration Manual. California Department of Fish and Game.

DWR. 2002. Emigration of Juvenile Chinook Salmon in the Feather River, 1998-2001. Sacramento: DWR, Division of Environmental Services.

DWR. 2003a. 2003 Lower Feather River Steelhead (*Oncorhynchus mykiss*) Redd Survey: SP-F10, Task 2B Report. Oroville Facilities Relicensing FERC Project No. 2100.

DWR. 2003b. Interim Report SP-F10 Task 1E. Oroville Facilities Relicensing FERC Project No. 2100.

DWR. 2003c. Interim Report, Timing, Thermal Tolerance Ranges, and Potential Water Temperature Effects on Emigrating Juvenile Salmonids in the Lower Feather River, SP-F10, Task 4B. Oroville Facilities Relicensing FERC Project No. 2100.

DWR. 2003d. Redd Dewatering and Juvenile Steelhead and Chinook Salmon Stranding in the Lower Feather River , 2002-2003: Interim Report SP-F10, Task 3C. Sacramento, CA: DWR, Division of Environmental Services.

DWR. 2003e. SP F-16 Evaluation of Project Effects on Instream Flows and Fish Habitat- Phase 2 Draft Final Report. Oroville Facilities Relicensing FERC Project No. 2100.

DWR. 2003f. Transfer of Energy and Nutrients by Anadromous Fish Migrations: Draft SP-F8. Oroville Facilities Relicensing FERC Project No. 2100.

DWR. 2004. Potential Effects of Facility Operations on Spawning Chinook Salmon-Interim Draft, SP-F10, Task 2B.

DWR and USBR. 2000. Biological Assessment- Effects of the Central Valley Project and State Water Project on Steelhead and Spring-Run Chinook Salmon.

EPA. 2002. National Recommended Water Quality Criteria: 2002. Report No. EPA-822-R-02-047.

EPA. 2003. EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards. EPA 910-B-03-002. Seattle, WA: Region 10 Office of Water.

FERC. 2001. Conservation of Power and Water Resources. 18 CFR 4.51. April 1, 2001.

Fisher, F. W. 1994. Past and Present Status of Central Valley Chinook Salmon. Conservation Biology 8:870-873.

Folmar, L. C., W. W. Dickhoff, C. V. W. Mahnken, and F. W. Waknitz. 1982. Stunting and Parr-Reversion During Smoltification of Coho Salmon (*Oncorhynchus kisutch*). Aquaculture 28:91-104.

Fry Jr., D. H. 1961. King Salmon Spawning Stocks of the California Central Valley, 1940-1959. Calif. Fish and Game 47:55-71.

Greene, S. 1992. Daily Fork-Length Table From Data by Frank Fisher, California Department of Fish and Game. Sacramento: DWR, Environmental Services Department,

Groot, C. and L. Margolis. Groot, C and Margolis, L (ed.) 1991. Pacific Salmon Life Histories.

Healey, M. C. 1991. Life History of Chinook Salmon (*Oncorhynchus tshawytscha*) *in* Pacific Salmon Life Histories. Groot, C. and Margolis, L. (ed.), Vancouver B.C.: UBC Press, pp 311-393.

Hedgecock, D., M. A. Banks, V. K. Rashbrook, C. A. Dean, and S. M. Blankenship. 2001. Applications of Population Genetics to Conservation of Chinook Salmon Diversity in the Central Valley *in* Contributions to the Biology of Central Valley Salmonids. Brown, R. L. (ed.), Sacramento, CA: California Department of Fish and Game, pp 45-70.

Hinze, J. A. 1959. Nimbus Salmon and Steelhead Hatchery: Annual Report, Fiscal Year 1957-1958. CDFG Inland Fisheries Administrative Report No. 59-4.

Hoar, W. S. 1988. The Physiology of Smolting Salmonids. Fish Physiology 11:275-343.

Humpesch, U. H. 1985. Inter- and Intra-Specific Variation in Hatching Success and Embryonic Development of Five Species of Salmonids and *Thymallus thymallus*. Archiwum Hydrobiologia 104:129-144.

Johnson, H. E. and R. F. Brice. 1953. Effects of Transportation of Green Eggs, and of Water Temperature During Incubation, on the Mortality of Chinook Salmon. The Progressive Fish-Culturist 15:

Kaya, C. M., L. R. Kaeding, and D. E. Burkhalter. 1977. Use of Cold-Water by Rainbow and Brown Trout in a Geothemally Heated Stream. The Progressive Fish-Culturist 39:37-38.

Kondolf, G. M. 2000. Assessing Salmonid Spawning Gravel Quality. Transaction of the American Fisheries Society 129:262-281.

Kwain, W. 1975. Effects of Temperature on Development and Survival of Rainbow Trout, *Salmo Gairdneri*, in Acid Waters. Journal of the Fisheries Research Board of Canada 32:493-497.

Marine, K. R. 1997. Effects of Elevated Water Temperature on Some Aspects of the Physiological and Ecological Performance of Juvenile Chinook Salmon (*Oncorhynchus tshawytscha*): Implications for Management of California's Central Valley Salmon Stocks. University of California, Davis.

McCullough, D. A. 1999. A Review and Synthesis of Effects of Alterations to the Water Temperature Regime on Freshwater Life Stages of Salmonids, With Special Reference to Chinook Salmon. Report No. EPA 910-R-99-010. Seattle, WA: EPA, Region 10.

McCullough, D. A., S. Spalding, D. Sturdevant, and M. Hicks. 2001. Summary of Technical Literature Examining the Physiological Effects of Temperature on

Salmonids - Issue Paper 5. Report No. EPA-910-D-01-005. United States Environmental Protection Agency.

McEwan, D. 2001. Central Valley Steelhead *in* Contributions to the Biology of Central Valley Salmonids. Brown, R. L. (ed.), Sacramento, CA: California Department of Fish and Game, pp 1-43.

Moyle, P. B.2002. Inland Fishes of California. Berkeley: University of California Press, Los Angeles.

Moyle, P. B., R. M. Yoshiyama, J. E. Williams, and E. D. Wikramanayake.1995. Fish Species of Special Concern in California. Sacramento, CA: California Department of Fish and Game.

Myrick, C. A. and J. J. Cech Jr. 2001. Temperature Effects on Chinook Salmon and Steelhead: A Review Focusing on California's Central Valley Populations. Bay-Delta Modeling Forum Technical Publication 01-1.

Nakamoto, R. J. 1994. Characteristics of Pools Used by Adult Summer Steelhead Oversummering in the New River, California. Transactions of the American Fisheries Society 123:757-765.

Newcomb, T. J. and T. G. Coon. 2001. Evaluation of Three Methods for Estimating Numbers of Steelhead Smolts Emigrating From Great Lakes Tributaries. North American Journal of Fisheries Management 21:548-560.

Nielsen, J. L., T. E. Lisle, and V. Ozaki. 1994. Thermally Stratified Pools and Their Use by Steelhead in Northern California Streams. Transactions of the American Fisheries Society 123:613-626.

NOAA Fisheries. 1993. Biological Opinion for the Operation of the Federal Central Valley Project and the California State Water Project.

NOAA Fisheries. 1997. NMFS Proposed Recovery Plan for the Sacramento River Winter-Run Chinook Salmon. Long Beach, CA: National Marine Fisheries Service, Southwest Region.

NOAA Fisheries. 1998. Final Rule: Notice of Determination. Endangered and Threatened Species: Threatened Status for Two ESUs of Steelhead in Washington, Oregon, and California. 63(53):13347-13371. March 19, 1998.

NOAA Fisheries. 1999. Final Rule: Notice of Determination. Endangered and Threatened Species: Threatened Status for Two Chinook Salmon Evolutionarily Significant Units (ESUs) in California. 64(179):50394-50415. September 16, 1999.

NOAA Fisheries. 2000. Biological Opinion for the Proposed Operation of the Federal Central Valley Project and the State Water Project for December 1, 1999 Through March 31, 2000. NOAA Fisheries.

NOAA Fisheries. 2001. The Effects of Summer Dams on Salmon and Steelhead in California Coastal Watersheds and Recommendations for Mitigating Their Impacts. Santa Rosa, CA: National Marine Fisheries Service, Southwest Region.

NOAA Fisheries. 2002. Biological Opinion on Interim Operations of the CVP and SWP Between April 2000 and March 2004 on Federally Listed Threatened Central Valley Spring-Run Chinook Salmon and Threatened Central Valley Steelhead in Accordance With Section 7 of the ESA.

Normandeau Associates. 2001. Summary of Existing Information (Supplementary Report) and Estimation of Predation Potential on Juvenile Salmonids at the Willamette Falls Project, Willamette River, Oregon.

ODEQ. 1995. Temperature: 1992-1994 Water Quality Standards Review. Final Issue Paper. Portland, OR: Department of Environmental Quality Standards.

Orcutt, D. R., B. R. Pulliam, and A. Arp. 1968. Transactions of the American Fisheries Society, vol. 97.

Pacific Gas and Electric Company. 2003. Fish, Wildlife, and Botanical Resources. E3. Pacific Gas and Electric Company.

Painter, R. E., L. H. Wixom, and S. N. Taylor. 1977. An Evaluation of Fish Populations and Fisheries in the Post-Oroville Project Feather River.

Poe, T. P., H. C. Hansel, S. Vigg, D. E. Palmer, and L. A. Prendergast. 1991. Feeding of Predaceous Fishes on Out-Migrating Juvenile Salmonids in John Day Reservoir, Columbia River. Transaction of the American Fisheries Society 120:405-420.

Raleigh R.F., Zuckerman L.D., and P. C. Nelson. 1986. Habitat Suitability Index Models and Instream Flow Suitability Curves: Brown Trout. U.S. Fish Wildl. Serv. Biol. Rep. 82(10.124). U.S. Fish Wildl. Serv.

Redding, J. M. and C. B. Schreck. 1979. Possible Adaptive Significance of Certain Enzyme Polymorphisms in Steelhead Trout (*Salmo gairdneri*). Journal of the Fisheries Research Board of Canada 36:544-551.

Reynolds, J. 1996. Chapter No. 8. Electrofishing *in* Fisheries Techniques. Second Edition. Murphy, B. R. and Willis, D. W. (ed.), American Fisheries Society, pp 221-253.

Rich, A. A. 1987. Water Temperatures Which Optimize Growth and Survival of the Anadromous Fishery Resources of the Lower American River.

Rieman, B. E., R. C. Beamesderfer, S. Vigg, and T. P. Poe. 1991. Estimated Loss of Juvenile Salmonids to Predation by Northern Squawfish, Walleyes, and Smallmouth Bass in John Day Reservoir, Columbia River. Transaction of the American Fisheries Society 120:448-458.

Rombough, P. J. 1988. Growth, Aerobic Metabolism, and Dissolved Oxygen Requirements of Embryos and Alevins of Steelhead, *Salmo gairdneri*. Canadian Journal of Zoology 66:651-660.

Seymour, A. H. 1956. Effects of Temperature on Young Chinook Salmon. University of Washington, Seattle, WA.

Smith, C. E., W. P. Dwyer, and R. G. Piper. 1983. Effect of Water Temperature on Egg Quality of Cutthroat Trout. The Progressive Fish-Culturist 45:176-178.

Snider, B. and R. G. Titus. 2000. Lower American River Emigration Survey October 1996-September 1997. Stream Evaluation Program Technical Report No. 00-2. California Department of Fish and Game.

Sommer, T., D. McEwan, and R. Brown. 2001. Factors Affecting Chinook Salmon Spawning in the Lower Feather River *in* Contributions to the Biology of Central Valley Salmonids. Brown, R. L. (ed.), Sacramento, CA: California Department of Fish and Game, pp 269-297.

Souza, K., Pagliughi, S., Daily Fork Length Tables- E-Mail Communication. August 20, 2003.

USBR. 1997. Central Valley Improvement Act, Draft Programmatic Environmental Impact Statement: Technical Appendix, Volume III. Sacramento, CA: U.S. Bureau of Reclamation.

USBR. 2003. Summary of USBR Chinook Salmon Temperature Mortality Models for Use With CALSIM II- Unpublished Work.

USFWS. 1995. Working Paper on Restoration Needs: Habitat Restoration Actions to Double Natural Production of Anadromous Fish in the Central Valley of California. Vol 2. Stockton, CA: U.S. Fish and Wildlife Service.

USFWS. 1999. Effect of Temperature on Early-Life Survival of Sacramento River Fall- and Winter-Run Chinook Salmon. Final Report.

Visser, R., D. D. Dauble, and D. R. Geist. 2002. Use of Aerial Photography to Monitor Fall Chinook Salmon Spawning in the Columbia River. Transactions of the American Fisheries Society 131:1173-1179.

Wagner, H. H. 1974. Photoperiod and Temperature Regulation of Smolting in Steelhead Trout (*Salmo gairdneri*). Canadian Journal of Zoology 52:219-234.

Wedemeyer, G. A., R. L. Saunders, and W. C. Clarke. 1980. Environmental Factors Affecting Smoltification and Early Marine Survival of Anadromous Salmonids. Marine Fisheries Review 42:1-14.

Williams, J. G. 1996. Lost in Space: Minimum Confidence Intervals for Idealized PHABSIM Studies. Transaction of the American Fisheries Society 125:458-465.

Yoshiyama, R. M., F. W. Fisher, and P. B. Moyle. 1998. Historical Abundance and Decline of Chinook Salmon in the Central Valley Region of California. North American Journal of Fisheries Management 18:487-521.

Yoshiyama, R. M., E. R. Gerstung, F. W. Fisher, and P. B. Moyle. 2001. Historical and Present Distribution of Chinook Salmon in the Central Valley Drainage of California *in* Contributions to the Biology of Central Valley Salmonids. Brown, R. L. (ed.), Sacramento, CA: California Department of Fish and Game, pp 71-176.

Zaugg, W. S. and H. H. Wagner. 1973. Gill ATPase Activity Related to Parr-Smolt Transformation and Migration in Steelhead Trout (*Salmo Gairdneri*): Influence of Photoperiod and Temperature. Comparative Biochemistry and Physiology 45B:955-965.