Merced River Water Temperature Feasibility Investigation

Reconnaissance Report

December 29, 2003

Prepared for:
The U.S. Fish and Wildlife Service
Anadromous Fish Restoration Program

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Introduction and Background

The Merced River (Figure 1) is presently the southern-most tributary stream in the Central Valley inhabited by anadromous salmonids and is consequently subject to longer warm seasonal periods than more northerly streams. The Merced River, its channel, watershed and riparian corridor, have been significantly altered by gold and gravel mining; dam construction for power production, irrigation, and flood control; agriculture; and urbanization (CDFG 1993, USFWS 1995a, USBR 1997), which influence the thermal regime of the river. Elevated water temperature, particularly during the early fall and late spring months, has been identified among a set of factors as one principal factor that can limit fall-run Chinook salmon (*Oncorhynchus tshawytscha*) production in the lower Merced River and at Merced River Hatchery (CDFG 1993, USFWS 1995a, USBR 1997, NMFS 1998, CALFED 1999a, CALFED 1999b). Maintaining protective water temperatures in the Merced River includes analyses of effects on food production, salmon growth, and ecological interactions. If river temperatures are too warm, salmon growth and smoltification as well as vulnerability to predation may be negatively affected. However, constraining temperatures too much or cooling long reaches of the river may restrict growth or limit access to relatively warmer conditions for older, more-tolerant juvenile salmon. Since the size of outmigrant salmon smolts has been implicated in survival and seawater tolerance, any temperature management scenarios for the Merced River should include analyses of balancing protection of early life stages and providing suitable conditions for juvenile salmon growth. Also, designated critical habitat within the San Joaquin Basin for the federally-listed threatened Central Valley ESU (evolutionarily significant unit) steelhead (*Oncorhynchus mykiss*) may be potentially affected by seasonally elevated water temperatures in the lower Merced River as defined by that federally mandated determination (NMFS 2000).

Dam construction has altered the flow and water temperature regime in river reaches downstream of the four mainstem dams on the Merced River. These alterations have changed the river's natural ecological processes and affected the habitat available for salmonids. Although water released into the Merced River is released from the hypolimnion at the bottom of Lake McClure, complex hydraulics and thermodynamics in the three downstream reservoirs from New Exchequer Dam significantly affect the ultimate water temperature regime in the salmon spawning and rearing reach of the lower Merced River. Effective conservation measures that avoid the impacts of warm water temperatures in the lower Merced River and at Merced River Hatchery have the potential to measurably improve Chinook salmon production.

Provision of suitable water temperatures in the Merced River, partially a function of reservoir operation conditions, may be affected by various demands on water supplies including ecosystem management flows such as the Vernalis Adaptive Management Plan (VAMP). Crocker-Huffman Dam along with three upstream dams (Merced Falls Dam, McSwain Dam, and New Exchequer Dam proceeding in an upstream direction) regulates flows in the lower Merced River (Figure 1). Reservoir storage levels, dam operations, and water discharge volumes have

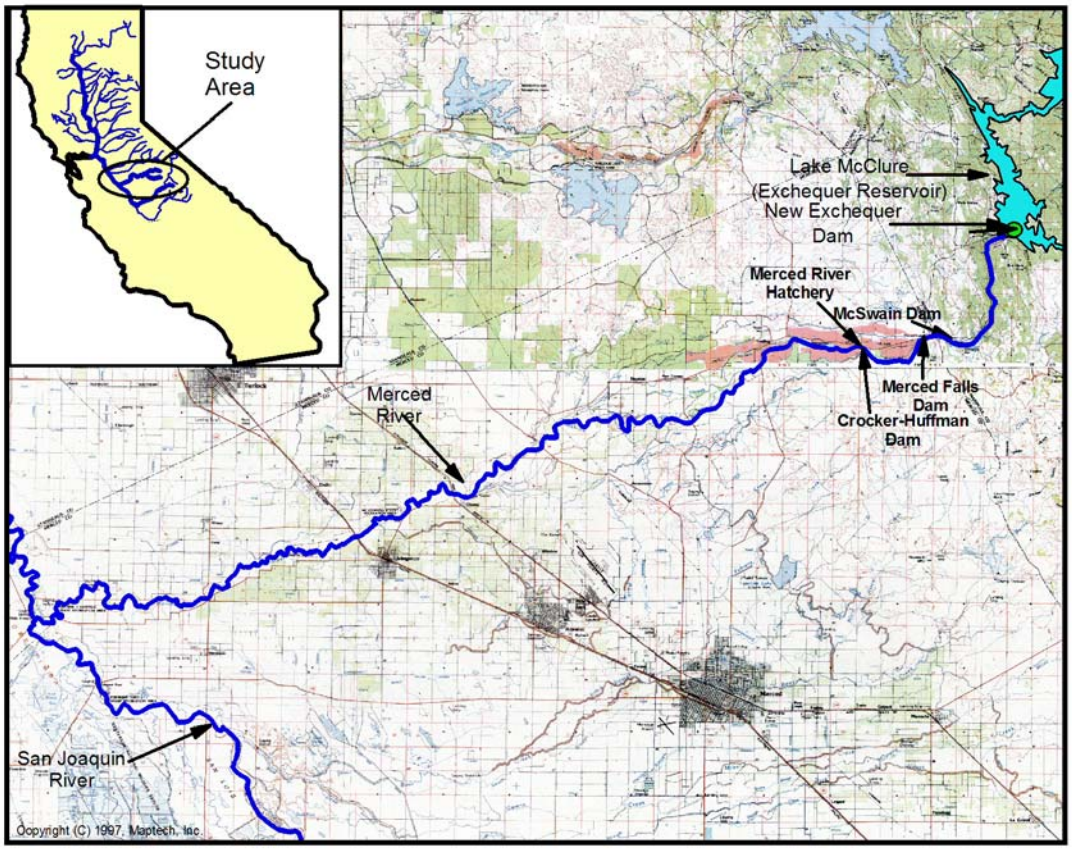

Figure 1. The Merced River and its four dams.

important interactive effects on reservoir thermal conditions, and thus directly affect river temperatures along with other environmental conditions such as: solar radiation, air temperatures, riparian shade, accretion volumes and temperatures, depletion or diversions, channel width and depth, wind, humidity, and ground conduction. Identification of effective temperature management measures and complementary restoration actions for the Merced River corridor will require a suite of analytical tools to discern the differential effects of these interactive factors affecting water temperature in the reservoir-river system. Such analytic tools would also help to resolve uncertainties associated with predicting effects of these interactions on potential temperature management measures.

However, existing records, data, and modeling efforts addressing water temperature issues for the Merced River are insufficient at this time to allow comprehensive quantitative analysis of the potential for impacts of proposed conservation/restoration actions on Merced River temperatures. Unlike other large Central Valley reservoirs that are relatively easy to model and control water temperatures in downstream salmon reaches (e.g., Shasta Reservoir), the three re-regulating reservoirs downstream of Lake McClure significantly increase the complexity for controlling and managing water temperatures to benefit salmon in the Merced River. Therefore, the U.S. Fish and Wildlife Service (USFWS) Anadromous Fisheries Restoration Program (AFRP) initiated this project by funding an initial study phase to compile and summarize pertinent Merced River Development Project (Project) physical features, operating strategies and requirements, related agreements, and existing thermal and flow information and biological monitoring activities in the four Merced River reservoirs and the lower Merced River.

This initial report (Phase I) is the first step in development of a potential comprehensive water temperature management plan for the lower Merced River. This first phase compiled available pertinent information and data. Information developed for Merced ID's reservoir characteristics and operations plan(s), and associated physical information, requirements and agreements are summarized within this report. Detailed data, such as hourly water temperatures, are provided in electronic format (Excel spreadsheet files) on an enclosed CD. No analyses are provided in this first report. The intent is to use this information to pursue a proposed next phase which is development of water temperature models for the four reservoirs and lower Merced River (Phase II). The results of water temperature modeling and analytical efforts would lead to an engineering feasibility investigation to determine the operational and/or structural measures, if any, that could be implemented to improve the water temperature regime for anadromous salmonids in the lower Merced River while concurrently ensuring reliability in Merced ID's water supplies (Phase III). Assuming the outcome of Phase III reveals measures that can feasibly be implemented, the final phase would be seeking and securing funding for those measures and implementing the project (Phase IV).

- Phase I: Compilation of existing information (this report)
- Phase II: Development of reservoir and river water temperature models
- Phase III: Engineering feasibility study
- Phase IV: Securing funding and implementing water temperature improvements

The Merced River Development Project

History

The following brief history of the establishment of Merced Irrigation District (MERCED, District, Merced ID) and the development of the Project is extracted from (Selb 1992).

"MERCED was founded to provide water to the farms in the central portion of the dry San Joaquin Valley, centered around the city of Merced, and is in large part responsible for the development of the east side of Merced County. The present District originally began in about 1870 as the Robla Canal Company, and water was running in the first canal by March of 1876. That same year the Robla Canal Company was succeeded by the Farmers Canal Company, and construction began on a crib dam across the Merced River at the present diversion dam site. The Farmers Canal Company also built two major canals still in use today, the Livingston Canal and the Atwater Canal, as well as several branch canals.

In 1883 the Merced Canal and Irrigation Company, with Charles F. Crocker as the principal owner, took over the system, enlarged the original small canal and tunnels, and extended the Main Canal along the western base of the foothills to Lake Yosemite. This lake, with its 16-inch cast iron outlet pipeline which extended to the city of Merced, was originally constructed primarily as regulating reservoir and water supply for the city. Today the Lake remains as a valuable asset to the District's irrigation system as a regulating reservoir, flood control reservoir, as well as a highly utilized and enjoyed recreation site for the public. The "Grand Celebration of Merced" was held at Lake Yosemite on February 1, 1888. Governor Waterman and other state officials attended the dedication of the: "greatest irrigation enterprise in the State of California."

In 1888 the Crocker-Huffman Land and Water Company was incorporated and succeeded to the properties of the Merced Canal and Irrigation Company. In 1894 a new crib dam was constructed across the Merced River, and 16 years later the present concrete diversion dam was built. In 1919 MERCED was organized and soon thereafter bought the Crocker-Huffman system. Exchequer Dam, the largest concrete arch dam in the nation at the time, was subsequently built and completed in 1926 forming Lake McClure and housing two hydroelectric generators.

MERCED's distribution system continued to expand and now consists of about 703 miles of open canals and 89 miles of concrete pipelines, numerous small check dams, siphons and other distribution structures located within the areas stream system. In-house work forces construct, reconstruct and maintain these facilities.

With advancing technology, expanding markets, and increased land taxes, the agricultural need for water continued to increase in the years following MERCED's creation. In addition, several severe water shortages had occurred during the months of July, August and September of certain intermittent years, causing heavy crop losses. Then, conversely, a disastrous flood on the Merced River occurred in 1950. A second purpose for MERCED – flood control – was born of necessity.

In view of these seemingly incongruous events, plans began to evolve for greater control and utilization of the water of the Merced River, which could only be accomplished by regulating and controlling its flow. Studies were begun in 1951 on the feasibility of additional storage on the Merced River and it was soon evident that increased hydroelectric power was the key to the realization of the project. A Revenue Bond Election in 1961 approved, by an overwhelming majority of over 12 to1, the sale of Power Revenue Bonds to finance construction of additional storage facilities on the Merced River.

After lengthy negotiations with the Federal Power Commission, the U.S. Army Corps of Engineers, the State Department of Water Resources, the State Water Rights Board, the State Department of Fish and Game, the County of Mariposa, Pacific Gas and Electric Company, and others, a contract was signed with Tudor Engineering Company of San Francisco for engineering and design on enlarged water storage and power facilities on the Merced River, to be known as the Merced River Development Project. In 1964, the District obtained a license from the Federal Power Commission for the development of enlarged irrigation and power facilities on the Merced River, designated as F.P.C. Project No. 2179. On June 25, 1964 a contract was signed with Pacific Gas and Electric Company which provided for MERCED to sell to PG&E all electric energy produced by the Project, at a price sufficient to pay off the Power Revenue Bonds. On July 24, 1964, a contract was awarded to Dravo Corporation of Pittsburgh, Pennsylvania for construction of the facilities.

The two main elements of the Project are the New Exchequer Dam, powerhouse and spillway, and the McSwain dam, powerhouse and spillway. The New Exchequer Dam was constructed of rockfill and an upstream concrete face. It has a crest elevation of 879 feet and a maximum length of 1400 feet, and had the distinction of being the highest, concrete-faced, rockfill dam in the world at the time of its construction. The old Exchequer Dam became a part of the New Exchequer Dam as an immediate upstream supporting structure, and is inundated by Lake McClure. New Exchequer Powerhouse has a single turbine-generator unit capable of generating 94,500 kilowatts.

McSwain Dam, approximately six miles downstream from New Exchequer Dam, is also constructed of rockfill and has an impervious earthfill core. The dam is 1500 feet in length and has a crest elevation of 425 feet. The McSwain Powerhouse uses the discharge flows of New Exchequer Dam to generate additional electrical energy which is also sold to the Pacific Gas and Electric Company."

Description of Project Facilities

New Exchequer Dam/Lake McClure

New Exchequer Dam, located at river mile (RM) 62, impounds Lake McClure (Figure 1), a large reservoir in excess of 1 million acre-feet and prone to strong thermal stratification. The reservoir experiences long residence time, has great depth, and has modest flow-through volumes during warmer periods of the year. Residence time is on the order of one-year. Figure 2 shows a longitudinal schematic of the dam with relative elevations. Note the location of Old Exchequer Dam in relation to the new dam and the water intake elevation. Unlike some Central Valley dams, New Exchequer Dam draws water from the bottom of the reservoir in the hypolimnion and does not have the facilities for water intake from alternative elevations (depths). Physical characteristics of the dam are provided in Table 1 with additional details in Appendix A. Detailed engineering drawings are maintained by Merced ID in Merced, California.

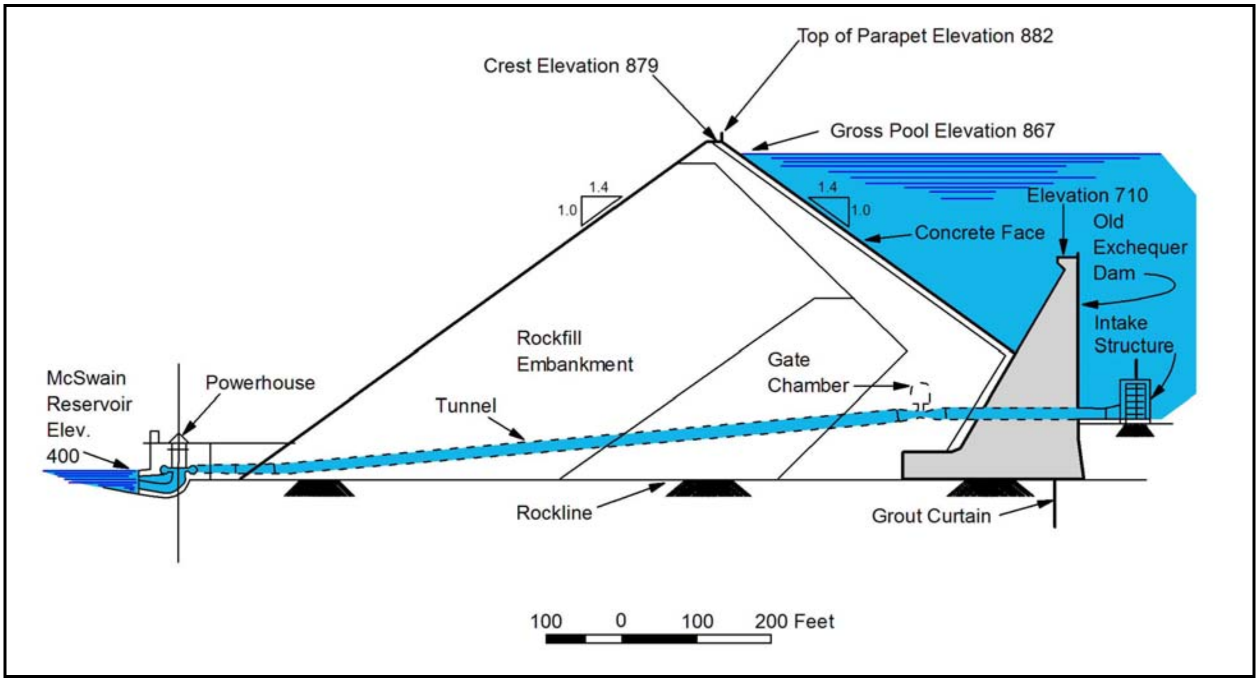

Figure 2. Longitudinal schematic of New Exchequer Dam on the Merced River (source: Merced ID).

McSwain Dam and Reservoir

McSwain Dam, located at RM 56 (Figure 1), and Reservoir re-regulates peaking power releases from New Exchequer Dam. There are no appreciable diversions from this reservoir; however, hydropower production occurs at McSwain Dam. The reservoir is approximately 6 miles long, with a residence time ranging from less than three days to over three weeks during summer periods. This impoundment may exhibit weak to moderate thermal stratification throughout the warmer periods of the year when releases from New Exchequer are modest. There are no existing data on the persistence of thermal stratification. Figure 3 shows a longitudinal schematic of McSwain Dam with relative elevations. Physical characteristics of the dam are provided in Table 1 with additional details in Appendix A. Detailed engineering drawings are maintained by Merced ID.

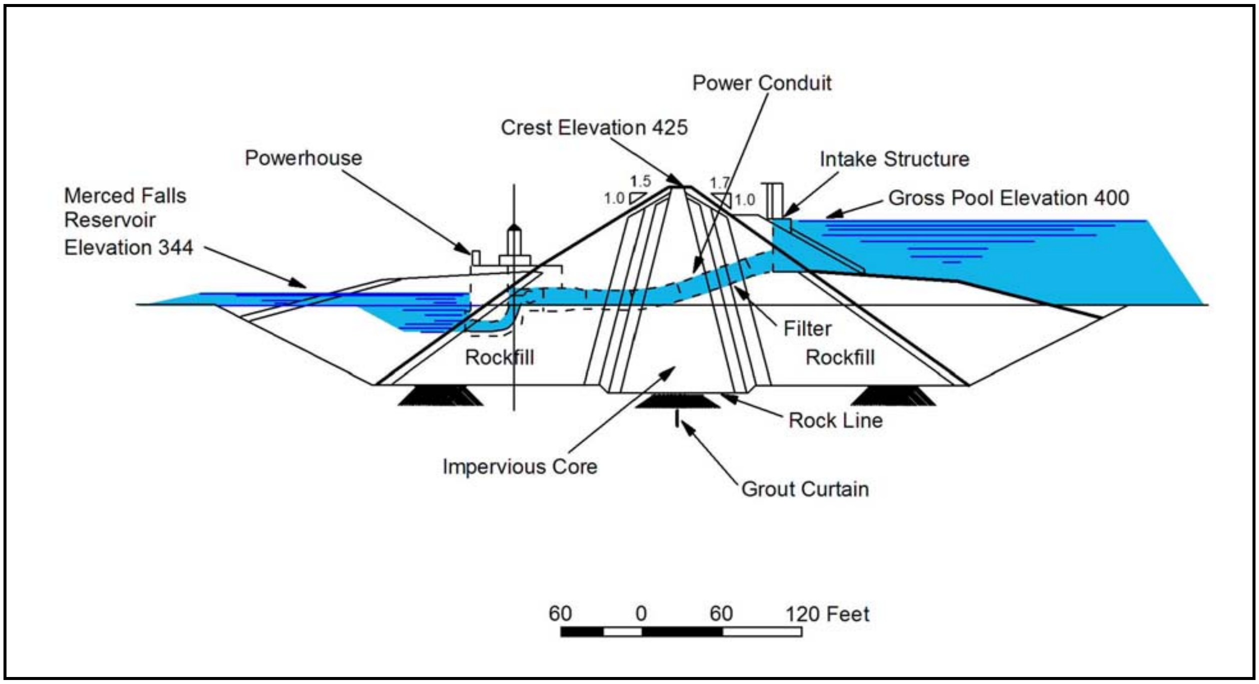

Figure 3. Longitudinal schematic of McSwain Dam on the Merced River (source: Merced ID).

Merced Falls Dam and Forebay

Merced Falls Dam, owned by Pacific Gas & Electric Company, located at RM 55 (Figure 1), and forebay is a diversion point for the Northside Canal. This diversion is relatively small compared to the diversions from Crocker-Huffman Dam (see below). This impoundment is approximately one mile long, with a residence time on the order of hours to a few days depending on flow conditions. No schematics or engineering drawings could be obtained for this dam. Physical characteristics of the dam are provided in Table 1. Pacific Gas and Electric Company maintains engineering drawings for Merced Falls Dam.

Crocker-Huffman Dam and Reservoir

Crocker-Huffman Dam, located at RM 52 (Figure 1), impounds water for diversion into the Main Canal and is a primary diversion point for Merced ID. Crocker-Huffman Dam is the upstream terminus for salmon on the Merced River (i.e., downstream reaches are accessible to anadromous fish). This impoundment is three miles long, relatively shallow, and has a residence time on the order of hours to days depending on the flow conditions. The water supply for CDFG's Merced River Hatchery as well as a privately owned trout farm is drawn from the downstream end of this small reservoir. The intake locations for the existing canals may play a role in the thermal regime of the reservoir as well as affect downstream release temperature. Physical characteristics of the dam are provided in Table 1. No schematics or engineering drawings could be obtained for this dam.

Merced River Hatchery

Merced River Hatchery (MRH) is located immediately downstream of Crocker-Huffman Dam (Figure 1). It is the only hatchery in the San Joaquin River basin that utilizes San Joaquin basin Chinook salmon broodstock (CDFG 1998). The original facility was designed as a Chinook salmon spawning channel to enhance salmon runs in the Merced River. It was completed in the summer of 1970 and went into operation in the fall of 1970. The spawning channel was built by Merced ID using Davis-Grunsky Act funds received for recreation and fish enhancement. The original facility also included an off-channel rearing pond to raise juvenile salmon to a yearling size (Menchen 1971). The facility was converted to a conventional fish hatchery (i.e., artificial spawning and rearing) through gradual facility changes during the 1980s and 1990s. The changes were implemented to increase fish production efficiency (Loudermilk 1998). In 1997, CDFG formally identified the production goals and objectives for the hatchery. The goal of the hatchery is "to effectively supplement natural production of Chinook salmon in the Merced River to help restore and maintain healthy runs that sustain sport and commercial fisheries" with an objective to achieve an annual average egg take of two million eggs and 960,000 smolt production (CDFG 1997).

The water supply for the hatchery is drawn from the reservoir at Crocker-Huffman Dam approximately one-quarter mile downstream of Merced ID's main canal intake off the reservoir. The provision of appropriate water temperatures for spawning and rearing salmon at MRH is critically important to its successful operation.

Table 1. Description of dams on the Merced River (CDWR 1993).

NAME OF DAM	NAME OF OWNER	COUNTY	LATITUDE (DEG. N)	LONGITUDE (DEG. W)	TYPE	STORAGE CAPACITY (AC. FT.)	DRAINAGE AREA (SQ. MI.)	RESERV. AREA (ACRES)	CREST ELEVATION (FT)	CREST LENGTH (FT)	HEIGHT (FT)	CREST WIDTH (FT)	VOLUME OF DAM (CU. YDS.)	YEAR COMPLETED
Crocker-Huffman	MERCED IRRIGATION DISTRICT	MERCED	37.514	120.371	GRAVITY	300	1,045	56	308	725	22	15	6,224	1910
McSwain	MERCED IRRIGATION DISTRICT	MARIPOSA	37.521	120.310	EARTH & ROCK	9,730	1,037	312	425	1,600	97	15	425,000	1966
Merced Falls	PAC GAS AND ELECTRIC CO	MERCED	37.523	120.329	GRAVITY	620	1,040	65	347	815	37	10	5,300	1901
New Exchequer	MERCED IRRIGATION DISTRICT	MARIPOSA	37.586	120.270	ROCK	1,024,600	1,040.1	7,147	882	1,240	479	18	5,169,000	1967

Water Project Operating Strategies, Requirements, and Agreements

There are a variety of requirements and agreements concerning reservoir operations for the Project that can affect flows (and therefore, to varying extents, water temperatures) in the lower Merced River.

U.S. Army Corps of Engineers Flood Control

According to criteria established by the U.S. Army Corps of Engineers (USCOE 1981), the following are flood control storage limits for Lake McClure and New Exchequer Dam (Figure 4) (MBK 2001):

<u>Rain Flood Space</u>

June 16 to August 31:	1,024,600 acre-feet
September 1 to October 31:	Linear reduction from 1,024,600 acre-feet to 674,600 acre-feet
November 1 to March 15:	674,600 acre-feet
March 16 to June 15:	Linear increase from 674,600 acre-feet to 1,024,600 acre-feet

During the months of March through July, depending on the forecasted runoff and demands, the allowable storage may fall anywhere between the defined Rain Flood Space provided above and the following Maximum Conditional Space (Figure 4) (MBK 2001):

<u>Conditional Space (snow melt flood space)</u>

March 1 to March 31:	Linear reduction from 674,600 acre-feet to 624,600 acre-feet
April 1 to May 15:	624,600 acre-feet
May 16 to July 31:	Linear increase from 624,600 acre-feet to 1,024,600 acre-feet

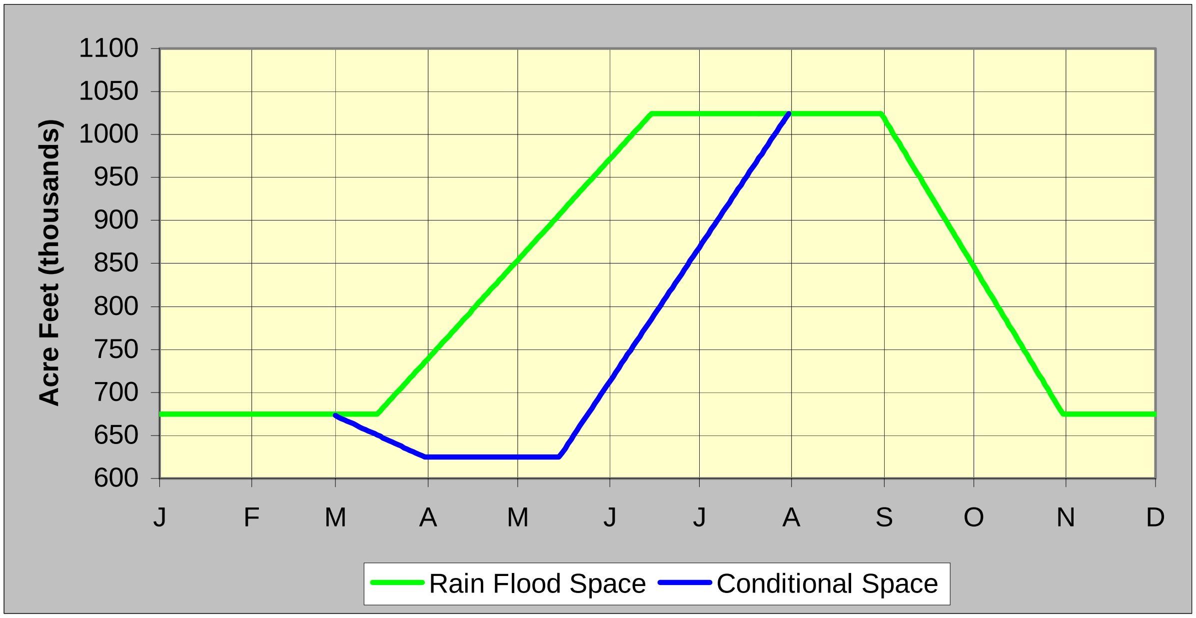

Figure 4. Flood control storage space criteria for Lake McClure/New Exchequer Dam.

Table 2 summarizes the maximum end-of-month flood control storage limits for Lake McClure (MBK 2001):

Table 2. Maximum end-of-month storage (in thousands of acre-feet) in Lake McClure for flood control.

Month	Rain Flood Storage Limit	Maximum Conditional Space Storage Limit
October	674.6	674.6
November	674.6	674.6
December	674.6	674.6
January	674.6	674.6
February	674.6	674.6
March	736.0	624.6
April	850.0	624.6
May	968.0	708.0
June	1024.6	864.0
July	1024.6	1024.6
August	1024.6	1024.6
September	858.0	858.0

Federal Energy Regulatory Commission (FERC)

Merced ID's Federal Energy Regulatory Commission (FERC) license associated with the construction of the New Exchequer Dam calls for Merced ID to provide water for both instream fishery enhancement and to provide up to 15,000 acre feet of water to the Merced National Wildlife Refuge (Selb 1999). Merced ID is required by its FERC power license, issued on April 8, 1964, to release Project water to the Merced River below the Project for fish enhancement (Article 40 & 41, 31 F.P.C. at 901). The FERC fish flow schedule is divided into two (2) categories, a normal year release schedule and a dry year release schedule. A "Dry Year" is defined in the FERC license as a year in which the forecasted April 1 through July 31 unimpaired runoff, as published in the May 1st bulletin of the California Department of Water Resources (CDWR) for the station, "inflow to Exchequer" is less than 450,000 Acre Feet (AF). A "Normal Year" is defined by FERC as a year in which the forecasted April 1 through July 31 unimpaired runoff, as published in the May 1 bulletin of the CDWR for the station "inflow to Exchequer" is more than 450,000 AF. In the "Normal Year" release schedule, 43,734 AF of Project water is released annually to the Merced River downstream of the Project. The "Dry Year" release schedule totals 33,024 AF annually. The monthly flows provided under this FERC license are provided in Table 3 (from CDFG/Merced ID 2002).

Davis-Grunsky Agreement

In October 1967, Merced ID executed a contract with the State of California, known as the Davis-Grunsky ("DG") Contract for State funds in the amount of $8,000,000, to be used for the construction of recreational facilities at the Project, as required by FERC, as well as the construction of fish enhancement facilities operated by CDFG on the Merced River downstream of the Project, in the vicinity of the Crocker-Huffman Diversion Dam. The DG also provides for Merced ID to maintain continuous flow of between 180 and 220 cfs in the Merced River spawning area each year during the period October 31 to March 31. The Merced River spawning area is described as a 20 mile (+/-) reach of the Merced River between the Crocker-Huffman Diversion Dam and Shaffer Bridge (Oakdale Road). Annual DG flows for fish enhancement total from 54,269 to 66,326 AF (from CDFG/Merced ID MOU 2002). The monthly flows are provided in Table 3:

Table 3. Annual FERC flows and Davis-Grunsky flows in the Merced River for fish enhancement.										
Month	FERC (Normal/n)		FERC (Dry/d)		Davis -Grunsky		TOTAL FLOWS (n)		TOTAL FLOWS (d)	
	CFS	AF	CFS	AF	CFS	AF	CFS	AF	CFS	AF
Jan	75	4612	60	3689	180–220	11068–13527	180-220	11068-13527	180-220	11068-13527
Feb	75	4165	60	3332	180–220	9997–12218	180-220	9997-12218	180-220	9997-12218
Mar	75	4612	60	3689	180–220	11068–13527	180-220	11068-13527	180-220	11068-13527
Apr	75	4463	60	3570		0	75	4463	60	3570
May	75	4812	60	3689		0	75	4612	60	3689
Jun	25	1488	15	893		0	25	1488	15	893
Jul	25	1537	15	922		0	25	1537	15	922
Aug	25	1537	15	922		0	25	1537	15	922
Sep	25	1488	15	893		0	25	1488	15	893
Oct 01-15	25	744	15	446		0	25	744	15	446
Oct 16-31	25	2380	60	1904		0	75	2380	60	1904
Nov	100	5951	75	4463	180–220	10711–13091	180-220	10711-13091	180-220	10711-13091
Dec	100	6149	75	4612	180-220	11068–13527	180-220	11068-13527	180-220	11068-13527
Total		**43938**		**33024**		**53912 - 65890**		**72161-84139**		**67151-79129**

In terms of actual Project operations, the higher of the two instream flow requirements is implemented for a given month. DG flows are not linked to water year types. In addition, Merced ID regularly provides for the 220 cfs instream flow target during those months of the DG flow requirement of 180-220 cfs (Ted Selb, Merced ID, personal communication).

Cowell Agreement Diversions

A water rights adjudication determined that Merced ID must provide water downstream of Crocker-Huffman Dam that could then be diverted from the river at private ditches (Cowell Agreement) (MBK 2001). The flows required to meet the Cowell Agreement Entitlement are provided in Table 4. As described by MBK (2001): "In order to satisfy the flow requirements and the Cowell Agreement, Merced ID operates to a target flow below Crocker-Huffman Diversion Dam equal to the Cowell Agreement adjudicated entitlement plus the FERC/Davis-Grunsky flow requirement. The flow below Crocker-Huffman Diversion Dam must equal the greater of the Davis-Grunsky and FERC flows plus the Cowell Agreement Entitlement."

Stevinson Diversions

Flow entitlements to Stevinson Water District, formerly J.J. Stevinson Company, are diverted from the Merced River through Merced ID's Main Canal and rediverted at Merced ID's west boundary to the Stevinson Eastside Canal. Normal year entitlements total 24,000 acre-feet. If in any year the Project does not fill on or before June 15th to the amount of 289,000 acre-feet, then

Stevinson Water District water deliveries are curtailed in the same proportion as Merced ID curtailments (Ted Selb, Merced ID, personal communication).

Table 4. Merced ID minimum flow (cfs) requirements for the Cowell Agreement Entitlement and Stevinson entitlement (does not include FERC and Davis-Grunsky flow requirements).

	Cowell	Stevinson[3]
October 1 – 15	50[1]	0
October 16 – 31	50[1]	0
November	50[1]	0
December	50[1]	0
January	50[1]	0
February	50[1]	0
March	100	0
April	175	30 – 70
May	225	50 - 100
June	250[2]	50 - 100
July	225[2]	50 - 100
August	175[2]	50 - 100
September	150[2]	30 – 70

[1] Entitlement is equal to 50 cfs or the natural flow of the Merced River (inflow to Lake McClure), whichever is less.
[2] If the natural flow of the Merced River falls below 1,200 cfs in the month of June, the entitlement flows are reduced accordingly from that day: 225 cfs flow for next 31 days; 175 cfs flow for next 31 days; 150 cfs for next 30 days; 50 cfs for remainder of September.
[3] Measured at Merced ID westerly boundary

Merced ID Main Canal and Northside Canal Diversions

Merced ID's Main Canal and Northside Canal are the primary water supply conveyance facilities off the Merced River for Merced ID operations. Data on historical diversions are provided in a subsequent section of this report.

Vernalis Adaptive Management Plan and San Joaquin River Agreement

Merced ID is a signatory to the San Joaquin River Agreement (SJRA) dated February 1998 which, among other things, implements the Vernalis Adaptive Management Plan (VAMP). The SJRA was developed as an alternative that provides a level of protection equivalent to the San Joaquin River flow objectives contained in the SWRCB 1995 Water Quality Control Plan for the Delta (URS 2001). Under the VAMP, effects of flow and export from the Sacramento/San Joaquin River Delta upon salmon will be investigated. The first year of full implementation of VAMP occurred in 2000 (SJRA 2000). Specific information on the VAMP flows is described in Appendix B of this report. As part of that agreement, increased flows in the spring and fall will be provided in the Merced, Tuolumne, and Stanislaus Rivers, more than 50 percent of which is to be supplied by Merced ID. Such flows are to be provided during an April/May pulse flow and during October. The SJRA specifies the quantity of water from the Project that will be dedicated to meeting the flow needs for VAMP. The SJRA contains two flow components applicable to the Merced River: 1) It provides for Merced ID to sell 12,500 acre-feet above existing flow releases for Chinook salmon during October of all years, and 2) It provides for Merced ID to meet a portion of the April/May VAMP flow target under a Division Agreement among San Joaquin River Group Authority (SJRGA) members (discussed below). With the participation of the Project in the VAMP to meet ecosystem hydrologic objectives in the Delta and planned flow augmentation in the Merced River to potentially meet the needs of early returning salmon into the Merced River, it will be important to assess if cold water supplies for release to the river and water temperatures are suitable for those fish that spawn early in the season. A Final Environmental Impact Statement/Environmental Impact Report (FEIS/EIR) for "Meeting Flow Objectives for the San Joaquin River Agreement (1999-2010)" was completed on January 28, 1999 (EA 1999). This FEIS/EIR concluded that meeting flow objectives for VAMP through partial use of the Project would result in less-than-significant impacts to anadromous salmonids in the Merced River and will result in beneficial effects.

The reference gage for additional water released downstream of Crocker-Huffman Dam for fishery purposes is the U.S. Geologic Survey/Merced ID gage at Shaffer Bridge. In the event that the annual schedule at any time exceeds 220 cubic feet per second, the CDWR Cressey gage is used. The Shaffer Bridge gage is not accurate beyond approximately 220 cubic feet per second (CDFG/Merced ID 2002).

Division Agreement. Pursuant to the SJRA, the SJRGA members[1] (with the exception of Friant Water Users) have agreed to meet specified Vernalis flow requirements for Delta protection and to complete studies over a 12-year period, which requirements were adopted by the SWRCB in Water Right Decision 1641 revised March 15, 2000, in accordance with Order WR-2000-02. The SJRGA executed a Division Agreement dated June 12, 1998 which assigns to each SJRGA member some responsibility for specified target flows at Vernalis on the San Joaquin River (Table 5). Merced ID's responsibility ranges between 50% and 100% of such flows. These specified target flows will be provided in the Merced River during the 31-day, April/May, pulse flow period in a manner that: (a) facilitates the studies defined in a CDFG/Merced ID MOU Exhibit "A" (described in a subsequent section of this report); and (b) are timed for arrival at Vernalis pursuant to the requirements of the SJRA.

[1] As used in the Division Agreement, the SJRGA is a joint powers authority consisting of Merced ID, Modesto ID, Oakland ID, Turlock ID, South San Joaquin ID, San Joaquin River Exchange Contractors Water Authority, and the Friant Water Users Authority.

Table 5. Water allocation (in acre-feet) specified in the Division Agreement among water district members within the San Joaquin River Group Authority for use in the Vernalis Adaptive Management Plan.					
Priority in Descending Order	First 50,000	Next 23,000	Next 17,000	Next 20,000	Totals
Merced ID	25,000	11,500	8,500	10,000	55,000
Oakdale ID/ South San Joaquin ID	10,000	4,600	3,400	4,000	22,000
Exchange Contractors	5,000	2,300	1,700	2,000	11,000
Modesto ID/Turlock ID	10,000	4,600	3,400	4,000	22,000

From approximately February 10th through April 15th of each year of the VAMP, the Hydrology Group of the San Joaquin River Technical Committee meet to determine the volumes of water required to meet the VAMP flows. This volume of water is then used to specify which SJRGA member provides flows to VAMP and the amount of water provided according to the allocation given in Table 5. The SJRGA can provide up to a maximum of 110,000 acre-feet of water annually and can be paid $4 million dollars annually[2] that can be used for construction of projects to make water available for VAMP, increasing funding for habitat restoration and monitoring, and to administer the Division Agreement (from SJRGA 1998).

Supplemental Water above the 110,000 Acre-Feet. Because of the potential need for up to 47,000 acre-feet of water in addition to the 110,000 acre-feet identified in the SJRA for the VAMP April/May pulse flow period in water years 2001 through 2010, a Final Supplemental Environmental Impact Statement/Environmental Impact Report (FSEIS/EIR) was completed on March 13, 2001 (URS 2001). The additional water may be needed to support flows identified for VAMP by providing flows at Vernalis, and to assist the U.S. Bureau of Reclamation (USBR) in meeting the AFRP, Bay-Delta flow objectives as required by SWRCB Water Right Decision 1641, and the USFWS 1995 Biological Opinion on Delta Smelt (USFWS 1995b) (URS 2001). The FEIS/EIR for the 110,000 acre-feet of water noted: "If achieving the double-step[3] requires more than the 110,000 acre-feet of supplemental water, additional water from willing sellers on the San Joaquin, Stanislaus, Tuolumne, and Merced rivers (approximately 50,000 acre-feet) may be acquired by Reclamation for the pulse flow period, and it would require additional [National Environmental Policy Act/California Environmental Quality Act] NEPA/CEQA analysis". Therefore, the FSEIS/EIR was prepared to provide the required environmental documentation for the acquisition of additional water (URS 2001). As with the FEIS/EIR, the FSEIS/EIR concluded that the supplemental water would result in less-than-significant impacts to Chinook salmon in the Merced River and be beneficial to the species (URS 2001).

[2] As escalated by the provisions of the SJRA.
[3] Described in Appendix B of this report.

Merced River Adaptive Management Plan (MRAMP)

In the event that the SJRA is terminated before its expiration as approved by the SWRCB, Merced ID will continue to provide supplemental interim spring flows at such times and in such quantities as are set forth in the Merced River Adaptive Management Plan (MRAMP) agreement between Merced ID, CDFG, CDWR and USBR. The MRAMP will have no effect unless the SJRA is terminated prior to the SWRCB approved expiration date of the SJRA.

Additional 12,500 Acre-Feet October Flows

As part of the 2002 Memorandum of Understanding between Merced ID and CDFG (CDFG/Merced ID MOU) and pursuant to the SJRA, Merced ID agreed to provide additional flows (12,500 acre-feet) above the existing instream flows described above during October every year. The increased October flow each year continues beyond the expiration of VAMP. The following describes how the timing for that additional flow is determined:

Each year CDFG develops a flow schedule for the augmentation of Merced River flow in the month of October of not less than 12,500 acre feet. That schedule is developed and delivered to Merced ID not later than August 15th each year. If CDFG and Merced ID fail to agree on the flow schedule by September 15th of any year, the schedule for delivery of supplemental water is as follows:

October 1-15	2500 acre feet
October 16-31	5000 acre feet
October 7-31	5000 acre feet

In the event that CDFG and Merced ID fail to agree on a pulse flow schedule, the default is level flow of 2500 acre feet between October 10 and 15 inclusive, and 2500 acre feet between October 16 and 20, inclusive (CDFG/Merced ID 2002).

Miscellaneous Water Withdrawals

Lake Don Pedro Community Services District

The Lake Don Pedro Community Services District, located adjacent to Lake McClure, pumps under 1,000 acre-feet annually, with a maximum of 5,000 acre-feet of raw water annually from Lake McClure for both domestic and irrigation purposes (Selb 1999).

Mariposa County Public Utilities District

The Mariposa County Public Utilities District has the capacity to pump up to a maximum of 5,000 acre-feet annually from the Merced River upstream of Lake McClure (Selb 1999).

Merced ID Campground Facilities

The Merced ID pumps and treats water from both Lake McClure and Lake McSwain for domestic purposes associated with the operation of the District's campground facilities (Selb 1999).

Accretions/Depletions

Accretions and depletions from the Merced River between stream gages are indirectly estimated by the Merced River Simulation Model (described in a subsequent section of this report) though computations of gains or losses between stream gages within specific river reaches. Data on Lake McClure evaporation losses are available through the California Data Exchange Center: (http://cdec.water.ca.gov/cgi-progs/queryMonthly?MCR)

Merced Water Supply Plan

Merced ID recently completed an update of a 1995 study known as the Merced Water Supply Plan (MWSP), a cooperative regional conjunctive use water master plan which was being jointly conducted with the City of Merced and the University of California, Merced. The goal of this study is to identify all sources of water within the study area (the area generally includes all of Merced County east of the San Joaquin River channel not otherwise contained in another water agency), to identify and meet water needs of the same area through the year 2040, which includes balancing the groundwater at 1999 levels. The study contemplates additional water for instream uses, as well as additional uses of applied water. CDFG participated in the early phases of the study as a Technical Committee member. The MWSP has, in addition to conservation and operational improvements, identified the potential diversion of above normal Merced River flows for off stream groundwater storage as a part of a conjunctive use program, as a means to achieve a balanced regional water budget while at the same time providing a larger more predictable flow for instream use over time. (from CDFG/Merced ID MOU 2002).

The current conjunctive use project for Merced ID consists of several programs and projects, including groundwater management, surface water conservation, system flow capacity enhancement, and system automation, all collectively referred to as the Surface-Groundwater Optimization Program. A pilot project for groundwater recharge was suspended with the completion of one test recharge basin on City of Merced property near Farhen's Park. Recently, Merced ID has purchased 20 acres of land for a regulating basin that could be enlarged to function as a secondary groundwater recharge site. Hydrogeologic studies will soon be underway to determine whether the site will be a good candidate for a recharge basin; if the tests indicate the site is good, Merced ID may expand the current site or purchase adjacent land. Most of the recharge of the Merced Groundwater Basin occurs from irrigation water diverted from the Merced River. Implementation of recharge facilities will replenish depleted groundwater supplies from ongoing activities as well as the direct and indirect impacts from the proposed project. Also, canal seepage contributes to recharging the basin's aquifers. (from FEIS/EIR 2001)

For the conjunctive use project, a groundwater aquifer will be selected to act as a reservoir. In dry years, groundwater will be used to make up for the shortfall in surface water deliveries, and the aquifer will be replenished during wet years with surface water from the Merced River. Exploratory studies for highly improved areas upslope of the Merced ID were undertaken, but were suspended early in 2000 pending the outcome of the 2001 water plan update. (from FEIS/EIR 2001)

To further reduce reliance on groundwater, Merced ID has implemented three programs to encourage groundwater pumpers to convert their systems to surface water: 1) In-Canal Surface Water Incentive Program, 2) On-Farm Low-Volume Incentive Program, and 3) the Highlands Pilot Project (an agricultural water treatment plant). The Highlands Pilot Project has been completed, and a new 1,200-acre high-ground study is under way on lands adjacent to the Highlands Pilot Project to provide surface water to lands which have relied exclusively on groundwater in the past. Phase One (of three phases) of this new project has been completed. Expansion of these programs will also contribute to reductions in groundwater usage. (from FEIS/EIR 2001)

Historical Water Year Classifications

Water year classification in the San Joaquin basin affects how many of the San Joaquin reservoirs are operated. The following is a description of the classification system and how water year types are determined in the San Joaquin basin (from the California Department of Water Resources web site: http://watersupplyconditions.water.ca.gov/hydrologic.cfm)

"Water year classification systems provide a means to assess the amount of water originating in a basin. Because water year classification systems are useful in water planning and management, they have been developed for several hydrologic basins in California. The Sacramento Valley 40-30-30 Index and the San Joaquin Valley 60-20-20 Index were developed by SWRCB for the Sacramento and San Joaquin River hydrologic basins as part of SWRCB's Bay-Delta regulatory activities. Both systems define one "wet" classification, two "normal" classifications (above and below normal), and two "dry" classifications (dry and critical), for a total of five water year types.

The San Joaquin Valley 60-20-20 Index is computed as a weighted average of the current water year's April-July unimpaired runoff forecast (60 percent), the current water year's October-March unimpaired runoff forecast (20 percent), and the previous water year's index (20 percent). A cap of 4.5 maf is placed on the previous year's index to account for required flood control reservoir releases during wet years. San Joaquin Valley unimpaired runoff is defined as the sum of inflows to New Melones Reservoir (from the Stanislaus River), Don Pedro Reservoir (from the

Tuolumne River), New Exchequer Reservoir (from the Merced River), and Millerton Lake (from the San Joaquin River). A water year with a 60-20-20 index equal to or greater than 3.8 maf is classified as "wet." A water year with an index equal to or less than 2.1 maf is classified as "critical."”

Figure 5 shows historical classifications for the San Joaquin basin. Data are provided in Appendix C.

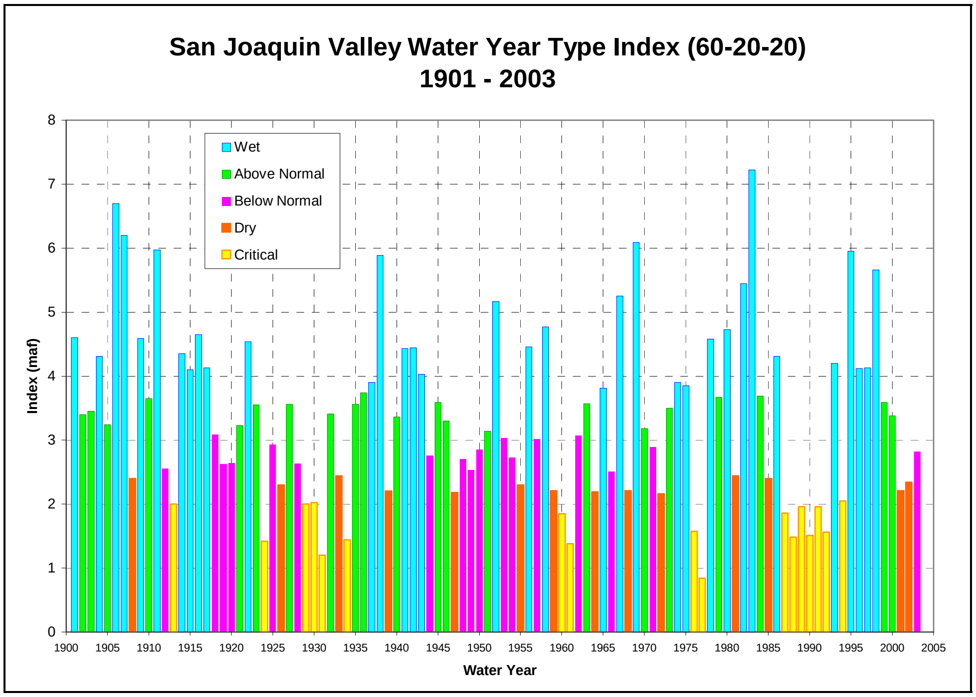

Figure 5. Classification of water year types for the San Joaquin River basin (from Mike Archer, MBK Engineers).

Recent Historical Operations of the Merced River Development Project

For purposes of this report, recent historical operations of the Project are compiled after completion of New Exchequer Dam. Because New Exchequer Dam altered the flow regime of the Merced River (Figure 6), prior years are not relevant for this report. The best representation of the Merced ID’s historical operations since construction of New Exchequer Dam is characterized with a water project operations model called “Merced River Simulation Model” (MRSIM) developed by MBK Engineers (MBK) for Merced ID.

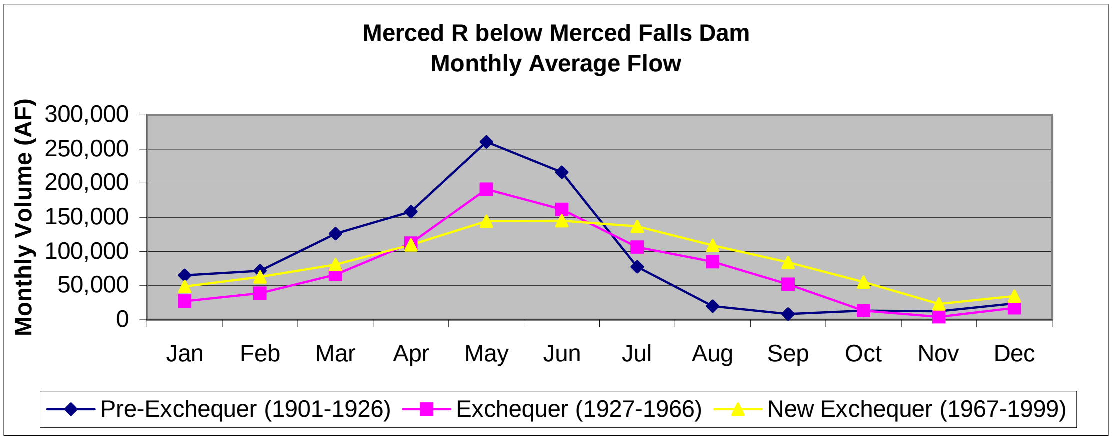

Figure 6. Historical monthly average flow (acre-feet) downstream of Merced Falls Dam prior to the construction of Exchequer Dam, during Exchequer Dam operations, and after construction of New Exchequer Dam.

Merced River Simulation Model (MRSIM)

The following is extracted from MBK (2001). The Merced River Simulation Model (MRSIM) is a computer simulation model of the Merced River encompassing Lake McClure downstream to Cressey. MRSIM does not address reregulation of the Merced River above Lake McClure or operations downstream from Cressey. Figure 7 shows the area and model nodes represented by the model. Although there are three regulatory reservoirs downstream from Lake McClure, they are not operated by MRSIM; their storage is assumed to remain constant throughout the simulation.

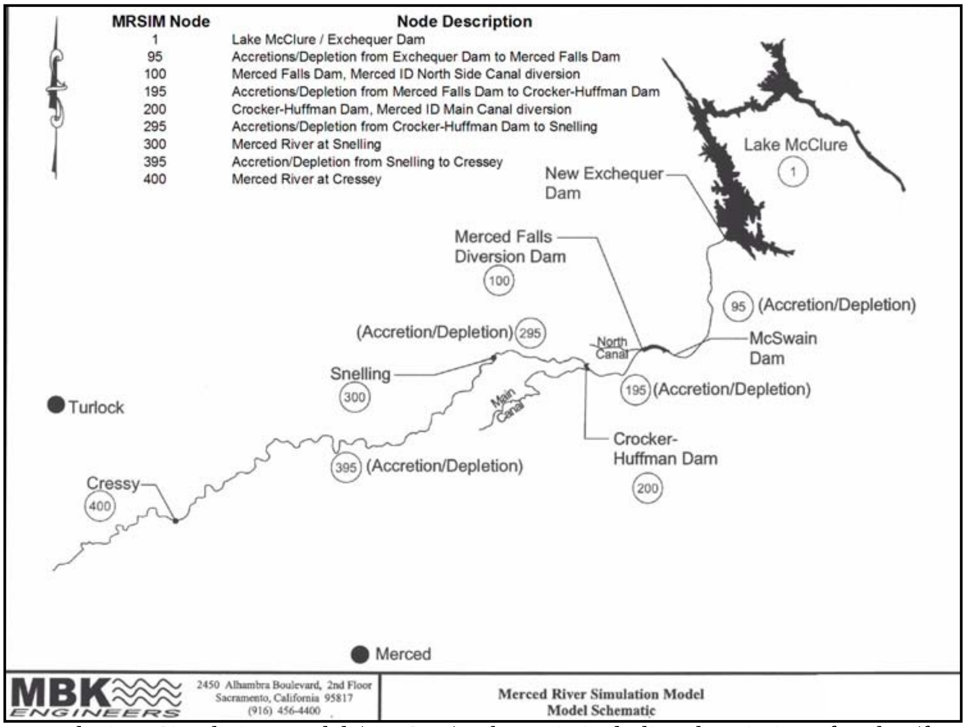

Figure 7. Merced River Simulation Model (MRSIM) schematic including description of nodes (from MBK 2001).

MRSIM is a mass balance sequential simulation model that operates Lake McClure on a monthly time step to satisfy irrigation demands and instream flow requirements on the Merced River from Exchequer Dam to Cressey. MRSIM is written in FORTRAN and is specifically designed to simulate Lake McClure and the Merced River down to Cressey. Operational rules that are specific to this river system are incorporated into the FORTRAN code to reflect actual operational constraints. (MBK 2001)

MRSIM begins each month by operating Lake McClure for flood control and required releases from Exchequer Dam. After necessary releases have been made from Lake McClure, MRSIM sequentially steps through each downstream node satisfying demands and instream flow requirements and accounting for river accretions and depletions. (MBK 2001)

When storage in Lake McClure falls below 115,000 acre-feet storage, releases can only be used for instream flows and Merced ID is not allowed to make diversions from the Merced River. During periods of low storage, MRSIM determines how much water Merced ID can divert each month while storage remains above 115,000 acre-feet. In addition to simply curtailing diversions by Merced ID when storage in Lake McClure falls below 115,000 acre-feet, MRSIM make a water supply forecast at the beginning of March each year to determine if the water supply available for that year is greater than or less than the diversion demands. If the available water supply is less than the diversion demand, the MRSIM shortens the irrigation season by setting the March and October diversion demands to zero. If the available water supply is insufficient, the remaining deficit is distributed proportional over the April through September period. (MBK 2001)

Details on the model's documentation are described by MBK (2001).

Main Canal Diversions

Appendix C provides data for the historical monthly diversions into Merced ID's Main Canal. Figure 8 shows the average monthly diversions into the Main Canal for the period 1970 through 1999.

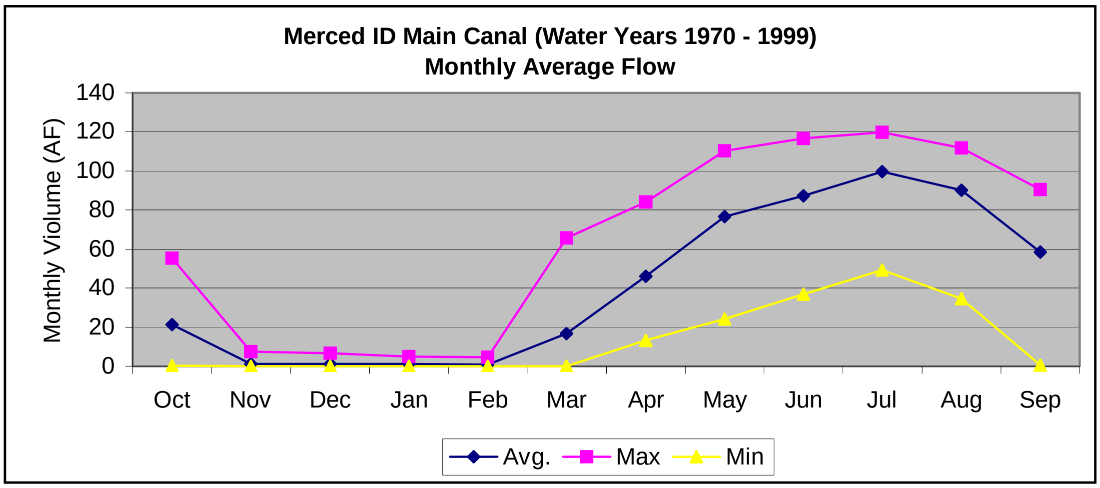

Figure 8. Historical water diversions (acre-feet) into Merced ID's main canal.

Northside Canal Diversions

Appendix C provides data for the historical monthly diversions into Merced ID's Northside Canal. Figure 9 shows the average monthly diversions into the Northside Canal for the period 1970 through 1999.

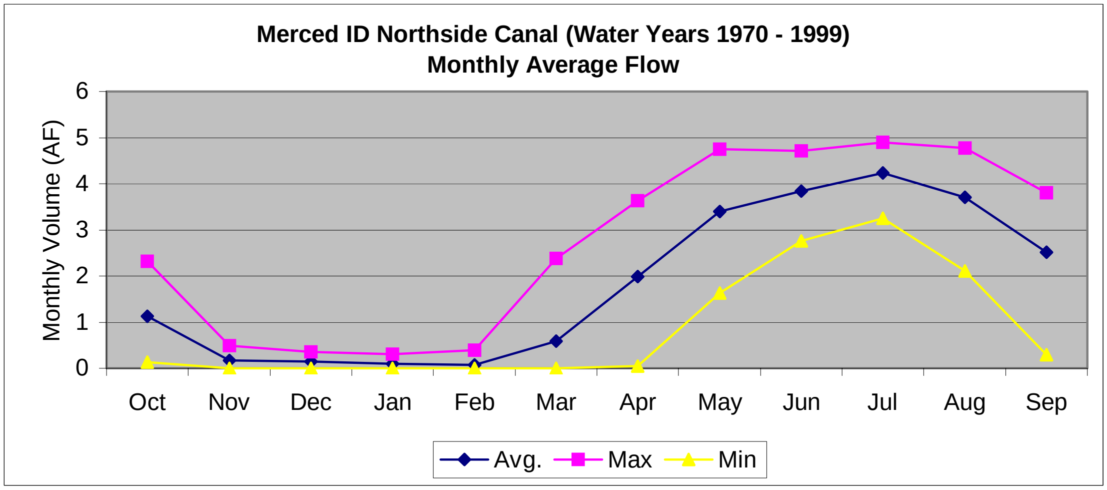

Figure 9. Historical water diversions (acre-feet) into Merced ID's Northside Canal for the period 1970 through 1999.

Stream Flow, Reservoir, and Weather Records

Stream flow, reservoir, and weather data for the Merced River watershed were not compiled within this report because those data are readily available through the Internet. Stream flow and reservoir data are available through the California Data Exchange Center (CDEC) at http://cdec.water.ca.gov and weather data are available through the California Irrigation Management Information System at: http://www.cimis.water.ca.gov (station no. 148) and the Western Regional Climate Center at: www.wrcc.dri.edu/summary/climsmnca.html. Specific CDEC sites are tabulated in Table 6. A meteorological station was recently installed by Merced ID at New Exchequer Dam. Prior to installation of the weather station, Merced ID staff recorded daily observations (e.g., air temperature, cloud cover, precipitation). Those records are maintained at the Merced ID powerhouse office at New Exchequer Dam (Bobby Mooneyham, Merced ID, personal communication). Tables 6 and 7 provide pertinent information for those stations throughout the watershed available from the Internet. Figure 10 shows locations of past and existing stream gaging stations and Figure 11 shows locations of weather stations in the nearby vicinity of the Merced River.

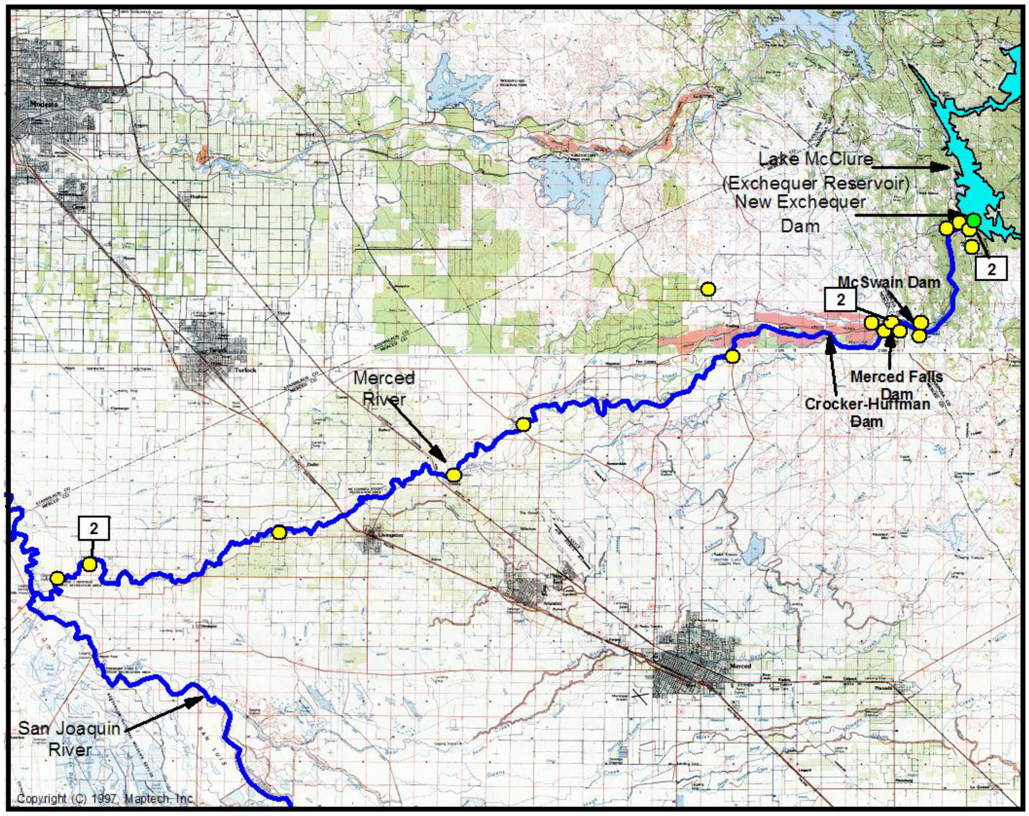

Figure 10. Location of stations in the Merced River watershed downstream of New Exchequer Dam.

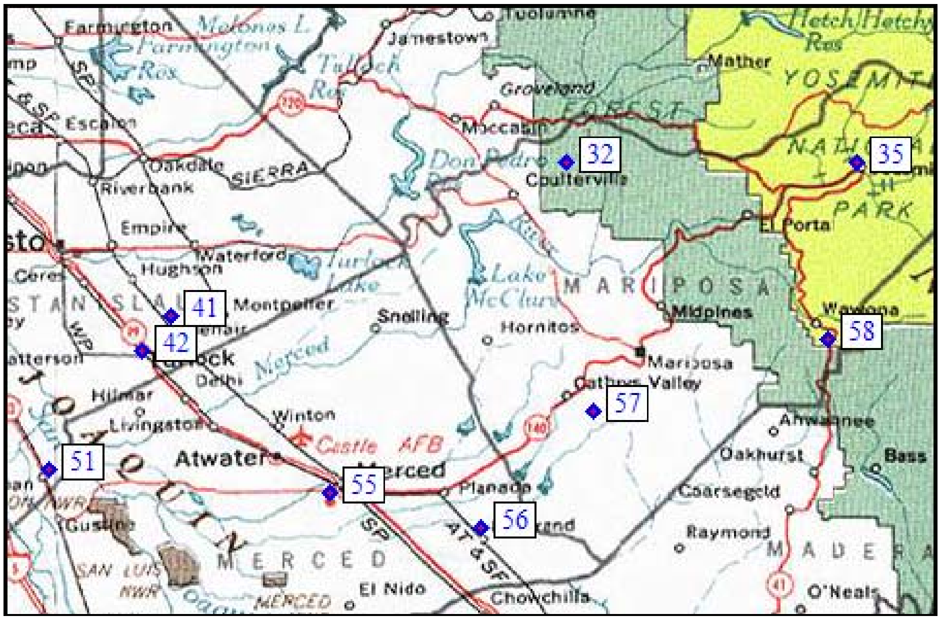

Figure 11. Weather data stations located near the Merced River watershed. Weather statistics from the Western Region Climate Center archives. These and other northern California climate summaries can be found at the following URL address: www.wrcc.dri.edu/summary/climsmnca.html

Table 6. Stream flow and related records for the Merced River, its tributaries, and reservoirs.

Agency	Station Name	Station ID	Station Location (WGS84 datum)		Elev (feet)	URL address	Station Data Format	Data Type and Link	Period of Record
			Latitude (deg N)	Longitude (deg W)					
USGS	MERCED R AT HAPPY ISLES BR NR YOSEMITE CA (HIB)	CDEC (HIB)	37.7320	119.5580	4017	http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=HIB	**FLOW, RIVER DISCHARGE**, cfs	(event)	From 03/24/1997 to present
							FLOW, RIVER DISCHARGE, cfs	(hourly)	From 04/09/1997 to present
							RIVER STAGE, feet	(event)	From 03/24/1997 to present.
							RIVER STAGE, feet	(hourly)	From 04/09/1997 to present.
		USGS (11264500)				http://nwis.waterdata.usgs.gov/ca/nwis/inventory/?site_no=11264500	**FLOW, RIVER DISCHARGE**, cfs	Real-time	Current Conditions
							RIVER STAGE, feet	Real-time	Current Conditions
							FLOW, RIVER DISCHARGE, cfs	Peak streamflow	From 06/07/1916 to 05/31/2002
							FLOW, RIVER DISCHARGE, cfs	Daily streamflow	From 10/01/1915 to 09/30/2002
USGS	MERCED R AT YOSEMITE CA	USGS (11265500)	37.7438	119.5902	4050	http://nwis.waterdata.usgs.gov/ca/nwis/inventory/?site_no=11265500	**FLOW, RIVER DISCHARGE**, cfs	Peak streamflow	From 06/02/1912 to 06/09/1917
							FLOW, RIVER DISCHARGE, cfs	Daily streamflow	From 04/01/1912 to 03/30/1917
USGS	YOSEMITE C AT YOSEMITE CA	USGS (11266000)	37.7455	119.5954	3963	http://nwis.waterdata.usgs.gov/ca/nwis/inventory/?site_no=11266000	**FLOW, RIVER DISCHARGE**, cfs	Peak streamflow	From 06/02/1912 to 06/12/1918
							FLOW, RIVER DISCHARGE, cfs	Daily streamflow	From 04/01/1912 to 09/30/1918

Table 6. Stream flow and related records for the Merced River, its tributaries, and reservoirs.

Agency	Station Name	Station ID	Station Location (WGS84 datum)		Elev (feet)	URL address	Station Data Format	Data Type and Link	Period of Record
			Latitude (deg N)	Longitude (deg W)					
USGS	SF MERCED R AT WAWONA CA	USGS (11267300	37.5388	119.6621	3968	http://nwis.waterdata.usgs.gov/ca/nwis/inventory/?site_no=11267300	**FLOW, RIVER DISCHARGE**, cfs	Peak streamflow	From 12/23/1955 to 06/02/1975
							FLOW, RIVER DISCHARGE, cfs	Daily streamflow	From 10/01/1958 to 09/30/1968
USGS	SF MERCED R NR WAWONA CA	USGS (11267500)	37.5416	119.6732	3960	http://nwis.waterdata.usgs.gov/ca/nwis/inventory/?site_no=11267500	**FLOW, RIVER DISCHARGE**, cfs	Peak streamflow	From 06/03/1912 to 05/13/1921
							FLOW, RIVER DISCHARGE, cfs	Daily streamflow	From 10/01/1911 to 09/30/1921
USGS	SF MERCED R NR EL PORTAL CA	USGS (11268000)	37.6513	119.8855	4053	http://nwis.waterdata.usgs.gov/ca/nwis/inventory/?site_no=11268000	**FLOW, RIVER DISCHARGE**, cfs	Peak streamflow	From 11/19/1950 to 06/01/1975
							FLOW, RIVER DISCHARGE, cfs	Daily streamflow	From 04/01/1951 to 10/07/1975
USGS	MERCED R AT POHONO BR NR YOSEMITE CA	USGS (11266500)	37.7169	119.6663	3862	http://nwis.waterdata.usgs.gov/ca/nwis/inventory/?site_no=11266500	**FLOW, RIVER DISCHARGE**, cfs	Real-time	Current Conditions
							RIVER STAGE, feet	Real-time	Current Conditions
							FLOW, RIVER DISCHARGE, cfs	Peak streamflow	From 06/10/1917 to 05/18/2002
							FLOW, RIVER DISCHARGE, cfs	Daily streamflow	From 10/01/1916 to 09/30/2002
USGS	MERCED R AT POHONO BR NR YOSEMITE	CDEC (POH)	37.7170	119.6650	3862	http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=poh	**FLOW, MEAN DAILY**, cfs	(daily)	From 10/01/2001 to present.
							FLOW, RIVER DISCHARGE, cfs	(hourly)	From 03/25/1997 to 08/01/2001.

Table 6. Stream flow and related records for the Merced River, its tributaries, and reservoirs.

Agency	Station Name	Station ID	Station Location (WGS84 datum)		Elev (feet)	URL address	Station Data Format	Data Type and Link	Period of Record
			Latitude (deg N)	Longitude (deg W)					
None Specified	MERCED AT POHONO BRIDGE	CDEC (MDP)	37.7170	119.6650	3862	http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=mdp	**FLOW, FULL NATURAL**, af	(monthly)	From 10/01/1900 to 09/01/1995.
							FLOW, MONTHLY VOLUME, af	(monthly)	From 10/01/1916 to 09/01/1987.
USGS	MERCED R NR BRICEBURG CA	USGS (11268200)	37.6358	119.9332	3868	http://nwis.waterdata.usgs.gov/ca/nwis/inventory/?site_no=11268200	**FLOW, RIVER DISCHARGE**, cfs	Peak streamflow	From 05/07/1966 to 05/28/1974.
							FLOW, RIVER DISCHARGE, cfs	Daily streamflow	From 10/01/1965 to 10/08/1974.
MID	MERCED RIVER NEAR BRICEBURG CA	CDEC (MBB)	37.5990	119.9780	1150	http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=mbb	**FLOW, RIVER DISCHARGE**, cfs	(hourly)	From 06/09/1999 to present.
							RIVER STAGE, feet	(hourly)	From 06/07/1999 to present.
USGS	MERCED R AT BAGBY CA	USGS (11268500)	37.6110	120.1316	780	http://nwis.waterdata.usgs.gov/ca/nwis/inventory/?site_no=11268500	**FLOW, RIVER DISCHARGE**, cfs	Peak streamflow	From 04/06/1923 to 11/24/1965.
							FLOW, RIVER DISCHARGE, cfs	Daily streamflow	From 10/01/1922 to 09/30/1966.
USGS	MAXWELL C AT COULTERVILLE CA	USGS (11269300)	37.7160	120.1899	886	http://nwis.waterdata.usgs.gov/ca/nwis/inventory/?site_no=11269300	**FLOW, RIVER DISCHARGE**, cfs	Peak streamflow	From 02/08/1960 to 01/13/1980.
							FLOW, RIVER DISCHARGE, cfs	Daily streamflow	From 10/01/1959 to 09/30/1980.
USGS	EXCHEQUER POWERHOUSE AT EXCHEQUER CA	USGS (11269700)	37.5835	120.2757	181	http://nwis.waterdata.usgs.gov/ca/nwis/inventory/?site_no=11269700	**FLOW, RIVER DISCHARGE**, cfs	Daily streamflow	From 10/01/1973 to 09/30/2002.

Table 6. Stream flow and related records for the Merced River, its tributaries, and reservoirs.									
Agency	**Station Name**	**Station ID**	**Station Location (WGS84 datum)**		**Elev (feet)**	**URL address**	**Station Data Format**	**Data Type and Link**	**Period of Record**
			Latitude (deg N)	**Longitude (deg W)**					
USGS	MERCED R AT EXCHEQUER CA	USGS (11270000)	37.5819	120.2802	400	http://nwis.waterdata.usgs.gov/ca/nwis/inventory/?site_no=11270000	**FLOW, RIVER DISCHARGE**, cfs	Peak streamflow	From 04/07/1902 to 08/20/1964.
							FLOW, RIVER DISCHARGE, cfs	Daily streamflow	From 04/01/1901 to 09/30/1964.
MERCED CO.	NEW EXCHEQUER - LAKE MCCLURE	CDEC (EXC)	37.5850	120.2700	879	http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=exc	**RESERVOIR ELEVATION**, feet	(daily)	From 01/01/1985 to present.
							RESERVOIR INFLOW, cfs	(daily)	From 01/02/1994 to present.
							RESERVOIR OUTFLOW, cfs	(daily)	From 10/03/1993 to present.
							RESERVOIR STORAGE, af	(daily)	From 01/01/1985 to present.
							RESERVOIR, STORAGE CHANGE, af	(daily)	From 10/04/1993 to present.
							RESERVOIR, TOP CONSERV STORAGE, af	(daily)	From 10/20/2000 to present.
							RESERVOIR ELEVATION, feet	(hourly)	From 01/01/1997 to present.
							RESERVOIR INFLOW, cfs	(hourly)	From 01/15/1997 to present.
							RESERVOIR OUTFLOW, cfs	(hourly)	From 01/01/1997 to present.

Table 6. Stream flow and related records for the Merced River, its tributaries, and reservoirs.

Agency	Station Name	Station ID	Station Location (WGS84 datum)		Elev (feet)	URL address	Station Data Format	Data Type and Link	Period of Record
			Latitude (deg N)	Longitude (deg W)					
							RESERVOIR STORAGE, af	(hourly)	From 01/01/1997 to present.
MERCED CO.	LAKE MCCLURE	CDEC (MCR)	37.5840	120.2670	867	http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=mcr	**EVAPORATION, LAKE COMPUTED**, af	(monthly)	From 03/01/1995 to present.
							RESERVOIR STORAGE, af	(monthly)	From 10/01/1965 to present.
MERCED CO.	LAKE MCSWAIN	CDEC (MCS)	37.5200	120.3090	425	http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=mcs	**RESERVOIR, SCHEDULED RELEASE**, cfs	(event)	From 10/01/1995 to present.
							RESERVOIR ELEVATION, feet	(hourly)	From 05/13/1997 to present.
							RESERVOIR STORAGE, af	(hourly)	From 06/18/1998 to present.
							RESERVOIR STORAGE, af	(monthly)	From 07/01/1966 to present.
USGS	MCSWAIN POWERHOUSE NR SNELLING CA	USGS (11270610)	37.5213	120.3099	4436	http://nwis.waterdata.usgs.gov/ca/nwis/inventory/?site_no=11270610	**FLOW, RIVER DISCHARGE**, cfs	Daily streamflow	From 10/01/1973 to 09/30/2002.
USGS	NORTHSIDE CANAL AT MERCED FALLS CA	USGS (11270800)	37.5227	120.3344	394	http://nwis.waterdata.usgs.gov/ca/nwis/inventory/?site_no=11270800	**FLOW, RIVER DISCHARGE**, cfs	Daily streamflow	From 10/01/1986 to 09/30/1994.
CDWR	MERCED RIVER AT CRESSEY	CDEC (CRS)	37.4250	120.6630	165	http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=crs	**FLOW, MEAN DAILY**, cfs	(daily)	From 03/30/1999 to present.
							TEMPERATURE, WATER, deg f	(daily)	From 10/25/2000 to present.

Table 6. Stream flow and related records for the Merced River, its tributaries, and reservoirs.

Agency	Station Name	Station ID	Station Location (WGS84 datum)		Elev (feet)	URL address	Station Data Format	Data Type and Link	Period of Record
			Latitude (deg N)	Longitude (deg W)					
							FLOW, RIVER DISCHARGE, cfs	(hourly)	From 03/20/1997 to present.
							RIVER STAGE, feet	(hourly)	From 03/20/1997 to present.
							TEMPERATURE, WATER, deg f	(hourly)	From 10/23/2000 to present.
MID	MERCED RIVER - NORTHSIDE CANAL	CDEC (MDS)				http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=mds	**FLOW, CANAL DIVERSION (AF)**, af	(monthly)	From 10/01/1985 to present.
MERCED CO.	MERCED RIVER BELOW MERCED FALLS	CDEC (MMF)	37.5220	120.3310	310	http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=mmf	**FLOW, RIVER DISCHARGE**, cfs	(hourly)	From 06/18/1998 to present.
							RIVER STAGE, feet	(hourly)	From 05/13/1997 to present.
CDWR	MERCED RIVER NEAR SNELLING	CDEC (MSN)	37.5020	120.4510	260	http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=msn	**FLOW, MEAN DAILY**, cfs	(daily)	From 03/30/1999 to present.
							FLOW, RIVER DISCHARGE, cfs	(hourly)	From 04/22/1998 to present.
							RIVER STAGE, feet	(hourly)	From 04/22/1998 to present.
MERCED CO.	MERCED FALLS FOREBAY	CDEC (MFF)	37.5230	120.3290	345	http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=mff	**RESERVOIR ELEVATION**, feet	(hourly)	From 05/28/1997 to present.
							RESERVOIR STORAGE, af	(hourly)	From 06/18/1998 to present.

Table 6. Stream flow and related records for the Merced River, its tributaries, and reservoirs.

Agency	Station Name	Station ID	Station Location (WGS84 datum) Latitude (deg N)	Station Location (WGS84 datum) Longitude (deg W)	Elev (feet)	URL address	Station Data Format	Data Type and Link	Period of Record
MID	MERCED MAIN CANAL	CDEC (MMC)	37.5700	120.2700		http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=mmc	**FLOW, CANAL DIVERSION (AF)**, af	(monthly)	From 05/01/1993 to 09/01/1995.
USGS	MERCED R NR MERCED FALLS	CDEC (MRC)	37.5220	120.3310	311	http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=mrc	**FULL NATURAL FLOW**, cfs	(daily)	From 01/01/1988 to present.
							FLOW, FULL NATURAL, af	(monthly)	From 10/01/1900 to present.
							FLOW, MONTHLY VOLUME, af	(monthly)	From 10/01/1964 to present.
USGS	MERCED R BELOW MERCED FALLS DAM NR SNELLING CA	USGS (11270900)	37.5216	120.3324	341	http://nwis.waterdata.usgs.gov/ca/nwis/inventory/?site_no=11270900	**FLOW, RIVER DISCHARGE**, cfs	Peak streamflow	From 01/31/1911 to 05/07/2002.
							FLOW, RIVER DISCHARGE, cfs	Daily streamflow	From 04/01/1901 to 09/30/2002.
USGS	DRY C NEAR SNELLING CA	USGS (11271320)	37.5549	120.4632	322	http://nwis.waterdata.usgs.gov/ca/nwis/inventory/?site_no=11271320	**FLOW, RIVER DISCHARGE**, cfs	Peak streamflow	From 04/21/1967 to 02/15/1992.
							FLOW, RIVER DISCHARGE, cfs	Daily streamflow	From 10/01/1966 to 09/30/1992.
USGS	MERCED R AT SHAFFER BRIDGE NR CRESSEY CA	USGS (11271290)	37.4541	120.6088	341	http://nwis.waterdata.usgs.gov/ca/nwis/inventory/?site_no=11271290	**FLOW, RIVER DISCHARGE**, cfs	Daily streamflow	From 10/01/1965 to 09/30/2002.
USGS	MERCED R NR LIVINGSTON CA	USGS (11271500)	37.3913	120.7871	82	http://nwis.waterdata.usgs.gov/ca/nwis/inventory/?site_no=11271500	**FLOW, RIVER DISCHARGE**, cfs	Peak streamflow	From 06/05/1922 to 02/23/1944.
							FLOW, RIVER DISCHARGE, cfs	Daily streamflow	From 04/01/1922 to 02/29/1944

Table 6. Stream flow and related records for the Merced River, its tributaries, and reservoirs.										
Agency	**Station Name**	**Station ID**	**Station Location (WGS84 datum)**		**Elev (feet)**	**URL address**	**Station Data Format**	**Data Type and Link**	**Period of Record**
			Latitude (deg N)	**Longitude (deg W)**					
USGS	MERCED R NR STEVINSON CA	USGS (11272500)	37.3708	120.9305	73	http://nwis.waterdata.usgs.gov/ca/nwis/inventory/?site_no=11272500	**FLOW, RIVER DISCHARGE**, cfs	Peak streamflow	From 05/03/1924 to 12/30/2001
							FLOW, RIVER DISCHARGE, cfs	Daily streamflow	From 10/01/1940 to 09/30/2002.
CDWR	MERCED RIVER NEAR STEVINSON	CDEC (MST)	37.3710	120.9310	82	http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=mst	**FLOW, MEAN DAILY**, cfs	(daily)	From 03/30/1999 to present.
							TEMPERATURE, WATER, deg f	(daily)	From 07/01/2000 to present.
							FLOW, RIVER DISCHARGE, cfs	(hourly)	From 05/27/1997 to present.
							RIVER STAGE, feet	(hourly)	From 05/13/1997 to present.
							TEMPERATURE, WATER, deg f	(hourly)	From 07/01/2000 to present.
USGS	MERCED R SLOUGH NR NEWMAN CA	USGS (11273000)	37.3599	120.9616	59	http://nwis.waterdata.usgs.gov/ca/nwis/inventory/?site_no=11273000	**FLOW, RIVER DISCHARGE**, cfs	Peak streamflow	From 12/05/1950 to 00/00/1972
							FLOW, RIVER DISCHARGE, cfs	Daily streamflow	From 10/01 /1941 to 09/30/1972.

Table 7. Weather-related records for the Merced River, its tributaries, and reservoirs.									
Agency	**Station Name**	**Station ID**	**Station Location (WGS84 datum)**		**Elev (feet)**	**URL address**	**Station Data Format**	**Data Type and Link**	**Period of Record**
			Latitude (deg N)	**Longitude (deg W)**					
CDWR	TENAYA LAKE	CDEC (TNY)	37.8380	119.4480	8150	http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=tny	**SNOW, WATER CONTENT(REVISED)**, inches	(daily)	From 11/01/1998 to present.
							RELATIVE HUMIDITY, %	(hourly)	From 09/11/2002 to present.
							SNOW DEPTH, inches	(hourly)	From 09/11/2002 to present.
							SNOW, WATER CONTENT, inches	(hourly)	From 10/28/1998 to present.
							TEMPERATURE, AIR, deg f	(hourly)	From 10/28/1998 to present.
							SNOW DEPTH, inches	(monthly)	From 02/01/1930 to present.
							SNOW, WATER CONTENT(REVISED), inches	(monthly)	From 02/01/1930 to present.
MID	YOSEMITE AT YOSEMITE VALLEY	CDEC (YYV)	37.7400	119.5890	4200	http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=yyv	**PRECIPITATION, INCREMENTAL**, inches	(daily)	From 10/01/2002 to present.
							PRECIPITATION, TIPPING BUCKET, inches	(event)	From 11/30/1998 to present.
							PRECIPITATION, TIPPING BUCKET, inches	(hourly)	From 12/10/1998 to present.
							TEMPERATURE, AIR, deg f	(hourly)	From 12/10/1998 to present.

Table 7. Weather-related records for the Merced River, its tributaries, and reservoirs.									
Agency	**Station Name**	**Station ID**	**Station Location (WGS84 datum)**		**Elev (feet)**	**URL address**	**Station Data Format**	**Data Type and Link**	**Period of Record**
			Latitude (deg N)	**Longitude (deg W)**					
							PRECIPITATION, ACCUMULATED, inches	(monthly)	From 10/01/2002 to present.
NPS	YOSEMITE HEADQUARTERS	CDEC (YSV)	37.7400	119.5830	3966	http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=ysv	**PRECIPITATION, INCREMENTAL**, inches	(daily)	From 12/01/1992 to present.
							PRECIPITATION, ACCUMULATED, inches	(monthly)	From 01/01/1905 to present.
MID	YOSEMITE NEAR WAWONA	CDEC (YOW)	37.5080	119.6320	4957	http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=yow	**PRECIPITATION, INCREMENTAL**, inches	(daily)	From 10/01/2002 to present.
							PRECIPITATION, TIPPING BUCKET, inches	(event)	From 11/30/1998 to present.
							PRECIPITATION, TIPPING BUCKET, inches	(hourly)	From 12/11/1998 to present.
							TEMPERATURE, AIR, deg f	(hourly)	From 12/11/1998 to present.
							PRECIPITATION, ACCUMULATED, inches	(monthly)	From 10/01/2002 to present.
MID	MERCED RIVER NEAR BRICEBURG CA	CDEC (MBB)	37.5990	119.9780	1150	http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=mbb	**PRECIPITATION, TIPPING BUCKET**, inches	(event)	From 03/05/1999 to present.
							PRECIPITATION, TIPPING BUCKET, inches	(hourly)	From 06/07/1999 to present.
							TEMPERATURE, AIR, deg f	(hourly)	From 06/07/1999 to present.

Table 7. Weather-related records for the Merced River, its tributaries, and reservoirs.

Agency	Station Name	Station ID	Station Location (WGS84 datum)		Elev (feet)	URL address	Station Data Format	Data Type and Link	Period of Record
			Latitude (deg N)	Longitude (deg W)					
CDWR	DRY CREEK NEAR COULTERVILLE	CDEC (DCC)	37.6540	120.3120	728	http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=dcc	**PRECIPITATION, TIPPING BUCKET**, inches	(event)	From 04/20/1998 to present.
							PRECIPITATION, TIPPING BUCKET, inches	(hourly)	From 04/28/1998 to present.
MID	DUDLEY RANCH BELOW COULTERVILLE	CDEC (DUC)	37.7410	120.1330	3654	http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=duc	**PRECIPITATION, TIPPING BUCKET**, inches	(hourly)	From 11/30/1998 to present.
							TEMPERATURE, AIR, deg f	(hourly)	From 11/30/1998 to present.
USFS	CRANE FLAT LOOKOUT	CDEC (CFL)	37.7500	119.8000	5957	http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=cfl	**PRECIPITATION, ACCUMULATED**, inches	(hourly)	From 11/01/1992 to present.
							TEMPERATURE, AIR, deg f	(hourly)	From 11/01/1992 to present.
NPS	SNOW FLAT	CDEC (SNF)	37.8270	119.4970	8700	http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=snf	**SNOW DEPTH**, inches	(monthly)	From 02/01/1930 to present.
							SNOW, WATER CONTENT(REVISED), inches	(monthly)	From 02/01/1930 to present.
MERCED CO.	NEW EXCHEQUER - LAKE MCCLURE	CDEC (EXC)	37.5850	120.2700	879	http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=exc	**PRECIPITATION, INCREMENTAL**, inches	(daily)	From 01/09/1989 to present.
							PRECIPITATION, TIPPING BUCKET, inches	(hourly)	From 04/08/1998 to present.
							TEMPERATURE, AIR, deg f	(hourly)	From 07/22/1998 to present.

Table 7. Weather-related records for the Merced River, its tributaries, and reservoirs.									
Agency	**Station Name**	**Station ID**	**Station Location (WGS84 datum)**		**Elev (feet)**	**URL address**	**Station Data Format**	**Data Type and Link**	**Period of Record**
			Latitude (deg N)	**Longitude (deg W)**					
							PRECIPITATION, ACCUMULATED, inches	(monthly)	From 10/01/1935 to present.
USFS	JERSEYDALE	CDEC (JSD)	37.5420	119.8400	3900	http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=jsd	**PRECIPITATION, ACCUMULATED**, inches	(hourly)	From 08/01/2002 to present.
							RELATIVE HUMIDITY, %	(hourly)	From 08/01/2002 to present.
							TEMPERATURE, AIR, deg f	(hourly)	From 08/01/2002 to present.
CDWR	GIN FLAT	CDEC (GIN)	37.7670	119.7730	7050	http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=gin	**PRECIPITATION, ACCUMULATED**, inches	(daily)	From 10/01/2002 to present.
							PRECIPITATION, INCREMENTAL, inches	(daily)	From 01/03/1987 to present.
							SNOW, WATER CONTENT(REVISED), inches	(daily)	From 10/28/1981 to present.
							PRECIPITATION, ACCUMULATED, inches	(hourly)	From 10/01/1985 to present.
							SNOW DEPTH, inches	(hourly)	From 08/21/2000 to present.
							SNOW, WATER CONTENT, inches	(hourly)	From 10/01/1985 to present.
							TEMPERATURE, AIR, deg f	(hourly)	From 10/01/1985 to present.

Table 7. Weather-related records for the Merced River, its tributaries, and reservoirs.									
Agency	**Station Name**	**Station ID**	**Station Location (WGS84 datum)**		**Elev (feet)**	**URL address**	**Station Data Format**	**Data Type and Link**	**Period of Record**
			Latitude (deg N)	**Longitude (deg W)**					
NPS	GIN FLAT (COURSE)	CDEC (GFL)	37.7650	119.7730	7000	http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=gfl	**SNOW DEPTH**, inches	(monthly)	From 02/01/1930 to present.
							SNOW, WATER CONTENT(REVISED), inches	(monthly)	From 02/01/1930 to present.
CDF	MARIPOSA GROVE	CDEC (MPG)	37.5000	119.6000	6400	http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=mpg	**PRECIPITATION, ACCUMULATED**, inches	(hourly)	From 11/01/1992 to present.
							RELATIVE HUMIDITY, %	(hourly)	From 01/01/1995 to present.
							TEMPERATURE, AIR, deg f	(hourly)	From 11/01/1992 to present.
CDF	MARIPOSA RANGER STATION	CDEC (MRP)	37.5010	120.0660	2250	http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=mrp	**PRECIPITATION, INCREMENTAL**, inches	(daily)	From 01/01/1995 to present.
							PRECIPITATION, ACCUMULATED, inches	(hourly)	From 09/01/1987 to present.
							RELATIVE HUMIDITY, %	(hourly)	From 01/01/1995 to present.
							TEMPERATURE, AIR, deg f	(hourly)	From 09/01/1993 to present.
							PRECIPITATION, ACCUMULATED, inches	(monthly)	From 10/01/1957 to present.
USBLM	MERCED RIVER (BLM)	CDEC (MRV)	37.6500	120.0830	2600	http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=mrv	**PRECIPITATION, ACCUMULATED**, inches	(hourly)	From 11/01/1992 to 11/07/2000.

Table 7. Weather-related records for the Merced River, its tributaries, and reservoirs.									
Agency	**Station Name**	**Station ID**	**Station Location (WGS84 datum)**		**Elev (feet)**	**URL address**	**Station Data Format**	**Data Type and Link**	**Period of Record**
			Latitude (deg N)	**Longitude (deg W)**					
							RELATIVE HUMIDITY, %	(hourly)	From 01/01/1995 to 11/07/2000.
							TEMPERATURE, AIR, deg f	(hourly)	From 11/01/1992 to 11/07/2000.
NPS	PEREGOY MEADOWS	CDEC (PGM)	37.6670	119.6250	7000	http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=pgm	**SNOW DEPTH**, inches	(monthly)	From 02/01/1931 to present.
							SNOW, WATER CONTENT(REVISED), inches	(monthly)	From 02/01/1931 to present.
NWS	SOUTH ENTRANCE YOSEMITE	CDEC (SEY)	37.5000	119.6330	5120	http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=sey	**PRECIPITATION, INCREMENTAL**, inches	(daily)	From 01/11/1993 to present.
							PRECIPITATION, ACCUMULATED, inches	(monthly)	From 10/01/1984 to present.
CDWR	OSTRANDER LAKE	CDEC (STR)	37.6370	119.5500	8200	http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=str	**SNOW, WATER CONTENT(REVISED)**, inches	(daily)	From 12/01/1988 to present.
							BATTERY VOLTAGE, volts	(hourly)	From 01/01/1995 to present.
							SNOW, WATER CONTENT, inches	(hourly)	From 10/14/1988 to present.
							TEMPERATURE, AIR, deg f	(hourly)	From 10/14/1988 to present.
							SNOW DEPTH, inches	(monthly)	From 04/01/1938 to present.

Table 7. Weather-related records for the Merced River, its tributaries, and reservoirs.									
Agency	**Station Name**	**Station ID**	**Station Location (WGS84 datum)**		**Elev (feet)**	**URL address**	**Station Data Format**	**Data Type and Link**	**Period of Record**
			Latitude (deg N)	**Longitude (deg W)**					
							SNOW, WATER CONTENT(REVISED), inches	(monthly)	From 04/01/1938 to present.
None Specified	JOHNSON LAKE	CDEC (JHN)	37.5680	119.5170	8500	http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=jhn	**SNOW DEPTH**, inches	(monthly)	From 02/01/1931 to 12/31/1941.
							SNOW, WATER CONTENT(REVISED), inches	(monthly)	From 02/01/1931 to 12/31/1941.

Lower Merced River Chinook Salmon Phenology and Monitoring

Chinook Salmon Phenology

The life history timing of fall-run salmon in the Merced River is characteristic of that for the San Joaquin River basin (Figure 12) (CDFG 1993). Elevated water temperatures in the lower Merced River may result in delayed salmon spawning, decreased egg survival, and increased juvenile mortality. Stream temperatures in some portions of the spawning reach and at Merced River Hatchery can exceed widely recognized temperature tolerances for salmon spawning and egg incubation in October and early November. Elevated water temperature can affect spawning migration rates, alter the incidence of disease, and delay or accelerate spawning to the detriment of reproductive performance (Marine 1993). In recent drought years, salmon have not spawned until after the first week in November, when water temperatures have cooled, through the effect of reduced day length and concomitant decreased insolation, as well as declining ambient air temperatures, to suitable levels for egg incubation. In more-recent wet years, spawning occurred in October. In late April and May, water temperature often exceeds recognized stressful levels for emigrating smolts. Elevated springtime temperatures are a more frequent and significant problem on the lower Merced River than other Chinook salmon streams, even in the San Joaquin River basin, because of its most southerly latitude in the range of Chinook salmon and consequent higher air temperatures. In these circumstances, salmon have to spawn later and leave the system earlier to be successful. This “compresses” their life cycle into a shorter period. This is likely to reduce the level of success fish have in reproducing, as well as reduce diversity in the overall population to only those fish that are successful in following that pattern. To ensure a more robust population it would be valuable to sustain an environment that provided a longer “window” to spawn, incubate, rear, and leave the system, particularly during drought years.

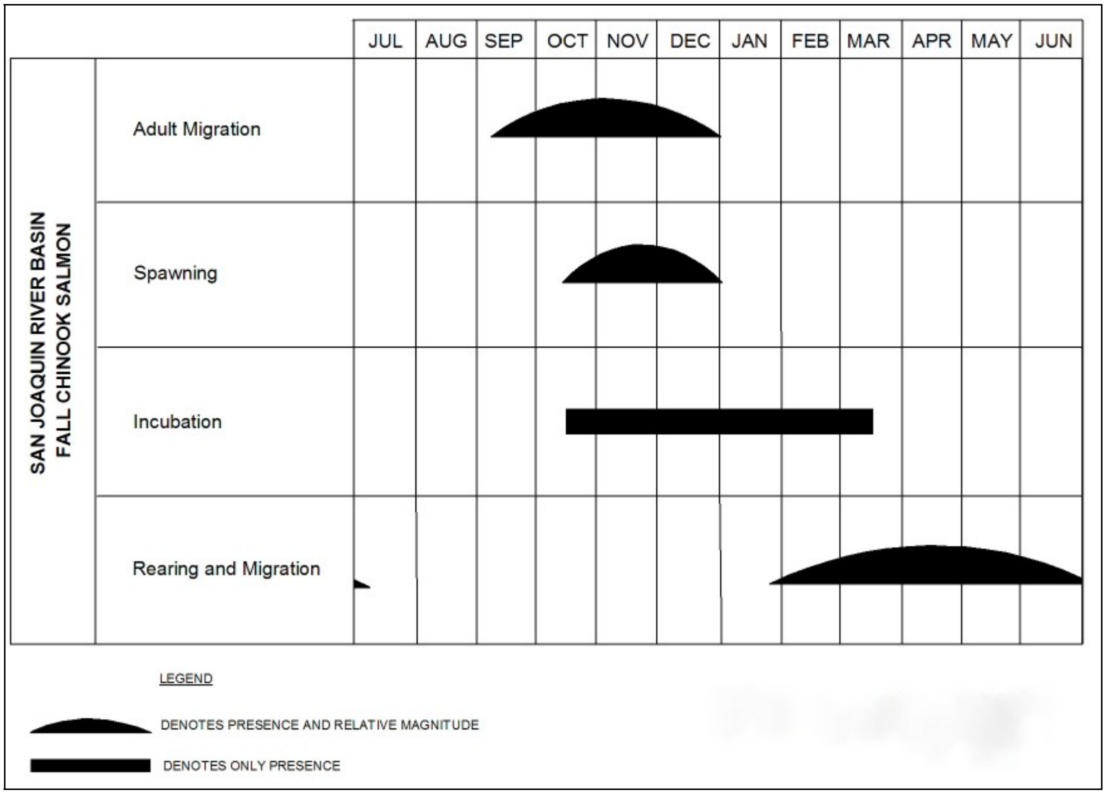

Figure 12. Freshwater life history periodicity for San Joaquin River basin fall-run Chinook salmon.

Warm water temperatures create conditions in the natural and hatchery environment that are conducive to many salmon pathogens resulting in many types of diseases or infections that reduce fitness or cause mortality (Piper et al. 1982, Marine 1993, Fagerlund et al. 1995, NMFS 1998). This is most evident in hatchery populations but can occur in the Merced River as well (Bill Loudermilk, CDFG, personal communication). In many years, salmon production at Merced River Hatchery is impaired by warm water temperatures in the fall, late spring and summer months (Mike Cozart, CDFG, personal communication).

Salmon Monitoring

CDFG Annual Spawning Ground Surveys

CDFG has performed annual spawning ground surveys for fall-run Chinook salmon in the lower Merced River. These surveys generally begin in October and are conducted weekly through December every year. CDFG has conducted the surveys since 1953 to estimate the annual spawning escapement to the river. This information has been invaluable in monitoring trends in salmon abundance. Recently, CDFG expanded the scope of the surveys by collecting additional biological data on the annual runs. These data include: fish size, fish scale and otolith collection (to determine age), distribution of spawners within three river reaches, seasonal timing of the run, spawning on each riffle, and recovery of coded-wire tags from salmon carcasses.

CDFG/Merced ID Memorandum of Understanding Biological Studies

Merced ID and CDFG have jointly developed and agreed upon a 10-year study program to determine the potential factors that may limit salmon production in the Merced River. This program is designed to evaluate the habitats necessary for increased salmon production by assessing the needs for each freshwater salmon life stage (i.e., upstream migration, spawning, egg incubation, fry and juvenile rearing, and outmigration). The joint study program defines the objectives, basic experimental design, and the responsibilities for study implementation. The studies and instream flow scheduling are coordinated with other studies throughout the San Joaquin basin and the Delta. Components of this program are presently underway. The completion of the 10-year program is intended to identify the long-term instream flow and other needs of salmon in the Merced River. To facilitate the studies, CDFG and Merced ID have established the Merced Management and Technical Advisory Committees (TAC); the latter committee establishes and coordinates study protocols, study amendments, funding issues, and information sharing and exchange. USFWS and NOAA Fisheries staffs also participate in the TAC meetings. This committee has endorsed the Merced River Water Temperature Management Feasibility Study. Water temperature management in the Merced River watershed was also identified as a high priority issue in the CALFED San Joaquin Regional Meeting.

Table 8 provides the study elements, study purposes, and duration for each study element within the CDFG and Merced ID 10-year program.

Table 8. Summarization of the biological studies in the Merced ID/CDFG 10-year MOU.		
ADULT CHINOOK SALMON LIFE PHASE (MIGRATION)		
ELEMENT TITLE	**ELEMENT PURPOSE**	**DURATION**
Chinook Salmon Attraction into the Merced River	Evaluate potential benefits of attraction of adult Chinook salmon into the Merced River by flow augmentation.	10 years
ADULT CHINOOK SALMON LIFE PHASE (SPAWNING)		
ELEMENT TITLE	**ELEMENT PURPOSE**	**DURATION**
Annual Salmon Spawning Ground Surveys	To estimate annual abundance and assess biological characteristics of fall Chinook salmon spawning in the Merced River.	10 years
Empirical Validation of DFG's Instream Flow Recommendations for Salmon Spawning	To determine if salmon spawning utilization in the Merced River corresponds to the instream flows recommended by DFG to improve spawning habitat.	3 years
CHINOOK SALMON EGG INCUBATION LIFE PHASE		
ELEMENT TITLE	**ELEMENT PURPOSE**	**DURATION**
Monitoring of Water Temperatures During Salmon Egg Incubation	To monitor and evaluate water temperatures at sites and times when Chinook salmon eggs are incubating in the Merced River and at Merced River Hatchery.	10 years
Evaluation of Chinook Salmon Spawning Substrate	To quantify the characteristics of spawning substrate conditions in the Merced River as related to salmon survival.	2 years
CHINOOK SALMON FRY AND JUVENILE REARING LIFE PHASE		
ELEMENT TITLE	**ELEMENT PURPOSE**	**DURATION**
Evaluation of the Contribution of Merced River Hatchery to Catch and Escapement	To quantify the contribution of Merced River Hatchery Chinook salmon production to sport and commercial harvest and spawning escapement.	10 years
CHINOOK SALMON REARING LIFE PHASE		
ELEMENT TITLE	**ELEMENT PURPOSE**	**DURATION**
Effects of past gravel mining activities and predation of Chinook salmon fry.	To assess the effects of past gravel mining in the Merced River and the resultant creation of predatory fish habitat on juvenile salmon.	10 years
Empirical Validation of DFG's Instream Flow Recommendations for Juvenile Salmon Rearing	To determine if juvenile salmon rearing utilization in the Merced River corresponds to the instream flows recommended by DFG to improve rearing habitat.	3 years
Rearing Habitat Structure Evaluation	To determine if rearing habitat structures placed in the Merced River are beneficial to juvenile salmonids.	4 years
Abundance of Natural Salmon Production in the Merced River	To quantify and evaluate the numbers of outmigrant Chinook salmon leaving the Merced River on a daily basis.	10 years

Table 8. Summarization of the biological studies in the Merced ID/CDFG 10-year MOU. (continued)		
CHINOOK SALMON DOWNSTREAM MIGRATION LIFE PHASE		
ELEMENT TITLE	**ELEMENT PURPOSE**	**DURATION**
Determination of Optimal Time and Size at Release for Merced River Hatchery Salmon	To evaluate alternative measures of smoltification for determining appropriate size and time to release hatchery salmon.	5 years
Transport Timing of Downstream Migrant Salmon During Pulse Flow Events	To evaluate potential changes in outmigration timing of young salmon during pulse flow events.	6 years
Survival of Salmon Migrating Out of the Merced River	To estimate the survival of outmigrant Chinook salmon leaving the Merced River.	10 years
WATER TEMPERATURE MANAGEMENT		
ELEMENT TITLE	**ELEMENT PURPOSE**	**DURATION**
Temperature Management Reconnaissance Study	Compile and summarize pertinent physical project specifications, operating strategies and requirements, related agreements, and existing thermal and flow information and biological monitoring activities.	1 year
Merced River and Reservoir Water Temperature Models	To develop water temperature models for the Merced River and reservoirs to facilitate adaptive management of Merced River water supplies for anadromous fish and other beneficial uses.	1 year
Temperature Management Feasibility Study	Develop potential alternatives and recommend one to three alternatives that may improve temperature management for Chinook salmon (a) in the Merced River and (b) at Merced River Hatchery.	2 years
Lower Merced River Temperature Management Proposal	Develop a joint MID/Fish and Game proposal, seek and secure funds to design, permit, construct and operate the preferred temperature management alternative (s).	2 years
STEELHEAD ASSESSMENT		
ELEMENT TITLE	**ELEMENT PURPOSE**	**DURATION**
Compilation of Existing Information on Potential Steelhead Presence in the Merced River	To compile all existing information on steelhead in the Merced River to help guide the MTAC in their decision making.	1 year
Determine Presence of Adult Steelhead in the Merced River	To determine the presence or absence of adult steelhead in the Merced River.	3 years
WATERSHED ASSESSMENT		
ELEMENT TITLE	**ELEMENT PURPOSE**	**DURATION**
Watershed Assessment of the Lower Merced River	To perform an assessment of the Merced River watershed prior to large-scale major river channel alterations.	3 years

Juvenile Salmon Outmigration

CDFG and Merced ID have been monitoring the downstream migration of juvenile Chinook salmon and other species in the Merced River since 1999. The monitoring is conducted using two eight-foot diameter rotary fish traps at RM 38 and one eight-foot diameter rotary fish trap RM 13. The fish traps are operated and checked daily during the sampling period of January through May each year. Merced ID is responsible for monitoring at RM 38 and CDFG at RM 13. The fish trapping operations are also used to support other short-term studies such as recent fish survival investigations associated with stream channel restoration projects by CDFG and CDWR.

Merced River Corridor Restoration Plan

With funding from the USFWS AFRP and the CALFED Bay-Delta Program, the Merced County Planning and Community Development Department, with cooperation from Merced ID, have embarked on a collaborative effort to develop a restoration strategy for the Merced River corridor. This program sought input from community stakeholders with a scientifically-based understanding of current river conditions and processes to identify a feasible corridor restoration strategy. Public involvement played a key role in the restoration planning process, and public coordination will continue through the life of the project. To establish this role, the County, with Merced ID's assistance, convened a Merced River Stakeholder Group. The Stakeholder Group represented a broad array of public and private interests, including local business and property owners; state, local, and federal agencies; fish and environmental groups; and other groups or individuals. The Final Merced River Corridor Plan was completed in 2002 by Stillwater Sciences (Stillwater Sciences 2002). The report provides information and data on channel morphology and the riparian corridor that would be useful for development of a water temperature model for the Merced River from Crocker-Huffman Dam to the confluence with the San Joaquin River.

USFWS AFRP Projects

Since 1997, the USFWS Anadromous Fish Restoration Program has funded ecosystem-related projects in the Merced River watershed (including this report). These projects are listed in Table 9. Details on each project are available at: **http://www.delta.dfg.ca.gov/afrp/projects.asp**

Table 9. List of USFWS Anadromous Fish Restoration Program (AFRP) Projects in the Merced River Watershed (from http://www.delta.dfg.ca.gov/afrp/projects.asp)	
Year	**Project Title**
1997	In stream flow studies in the Sacramento River, American River and Merced River.
1998	Assist development of locally led restoration planning efforts on the Merced River
1999	Assist development of locally-led restoration planning efforts on the Merced River
1999	Enhance salmon habitat at the Western Stone segment of the Robinson/Ratzlaff Reach on the Merced River.
1999	Restore in-channel habitat at the Ratzlaff Reach on the Merced River.
1999	Support programs to provide educational outreach and local involvement in restoration for teachers and students in the Lodi, Modesto and Merced unified school districts.
1999	Update and Validate the Spawning Riffle Atlas for the San Joaquin Tributaries
2000	Analyze Archived San Joaquin Basin Chinook Salmon Scale Samples and Develop a Comprehensive Database Accessible to Interested Parties (multi-year)
2000	Develop an adaptive management forum for large-scale restoration projects.
2000	Enhance salmon habitat at the Western Stone segment of the Robinson/Ratzlaff Reach on the Merced River.
2000	Evaluate use of PHABSIM/2D modeling of spawning and rearing habitat to assess benefits of channel restoration on the Merced River.
2000	Merced River Wing-Dam Gravel Monitoring
2000	Study the feasibility of developing a long-term aggregate source for San Joaquin tributary channel restoration projects.
2001	Merced River Water Temperature Management Feasibility Study.
2002	A Feasibility Investigation of Reintroduction of Anadromous Salmonids Above Crocker-Huffman Dam on the Merced River
2003	Evaluating the success of spawning habitat enhancement on the Merced River, Robinson reach

Water Temperature Monitoring

As part of the joint studies between Merced ID and CDFG, a comprehensive water temperature monitoring program in the Merced River was initiated in 1997. Continuously recording water temperature thermographs were placed at strategic locations within the watershed to develop a database for monitoring temperatures and provide for future water temperature model development and calibration. Locations of those sites are shown in Figure 13. Datasets from this monitoring network constitute the most comprehensive information on water temperatures in the Merced River. The following is a summary of the data collected at each site comparing data within and between years and between sites from the upstream-most thermograph site to the downstream-most site. Graphical summaries of those datasets are shown in the following Figures 14 - 40. The complete datasets (Appendix D) including hourly data are provided in the attached CD to this report.

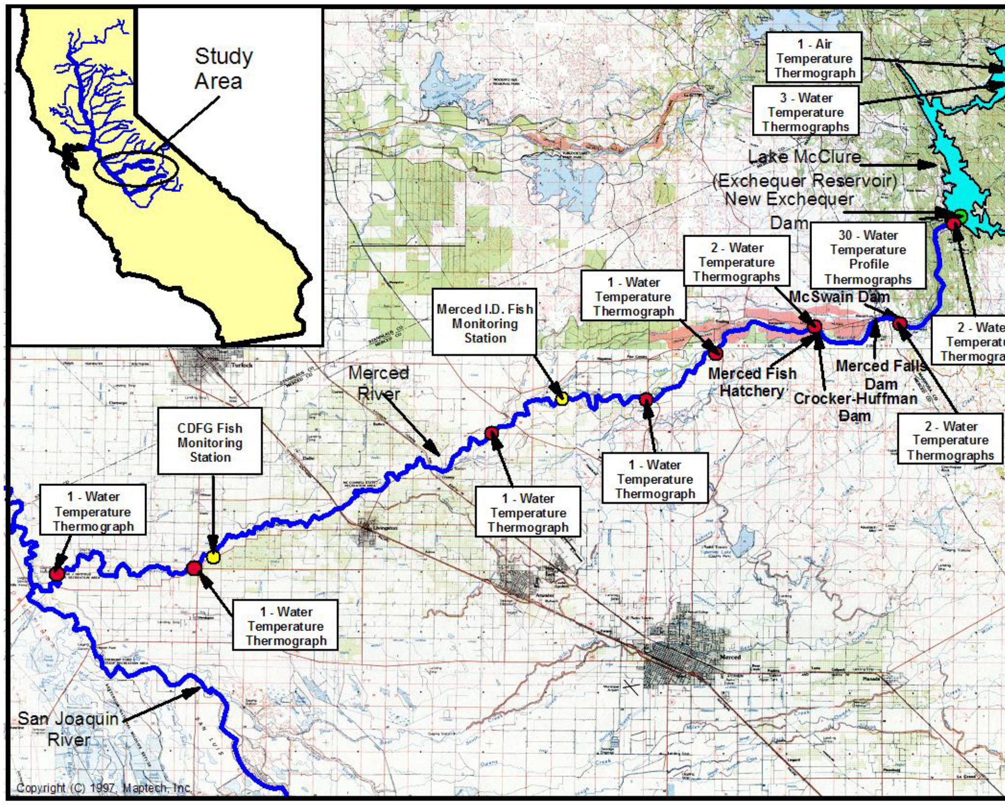

Figure 13. Locations of water temperature thermographs recording hourly water temperatures in the Merced River and reservoirs.

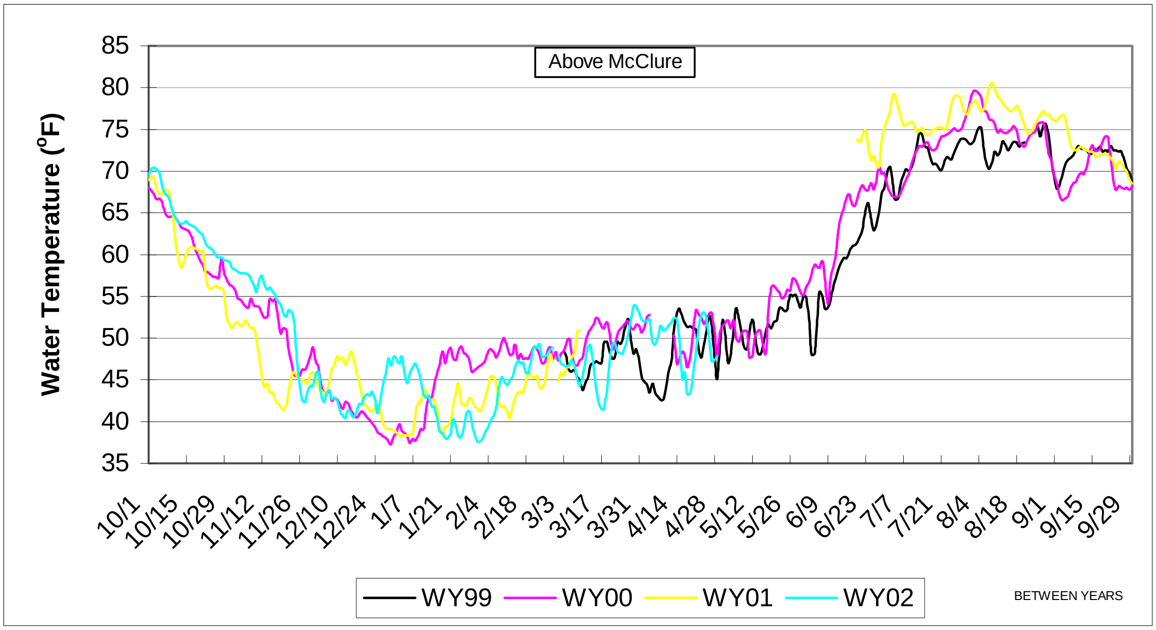

Figure 14. Average daily water temperatures (^{o}F) measured in the Merced River upstream of Lake McClure (water years 1999 – 2002).

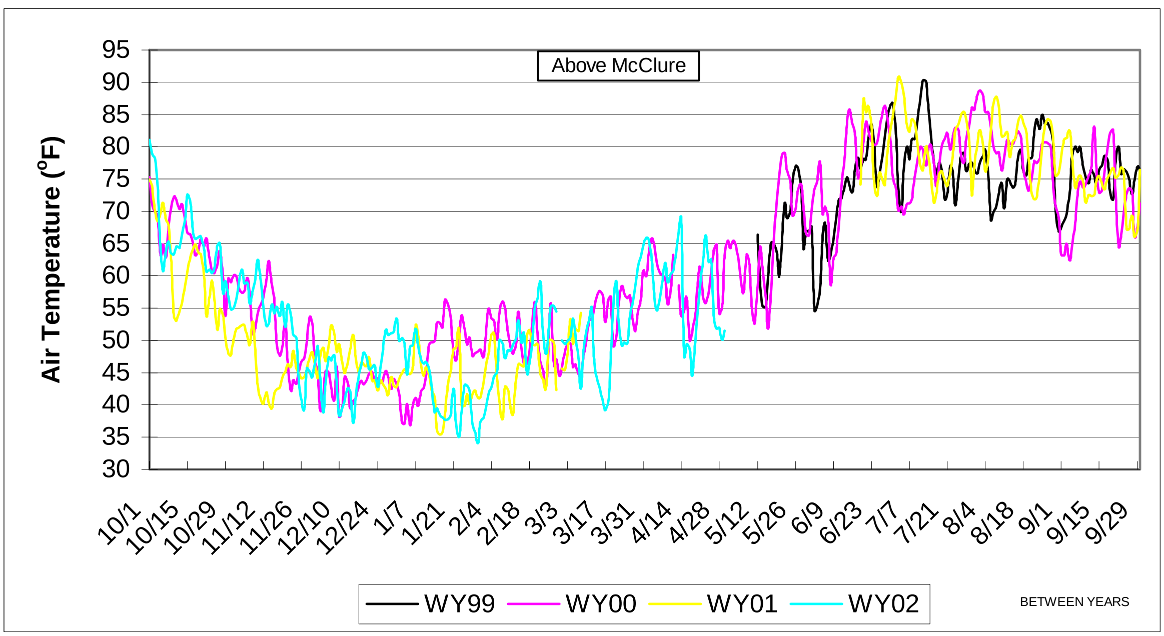

Figure 15. Average daily air temperatures (^{o}F) measured near the Merced River upstream of Lake McClure (water years 1999 – 2002).

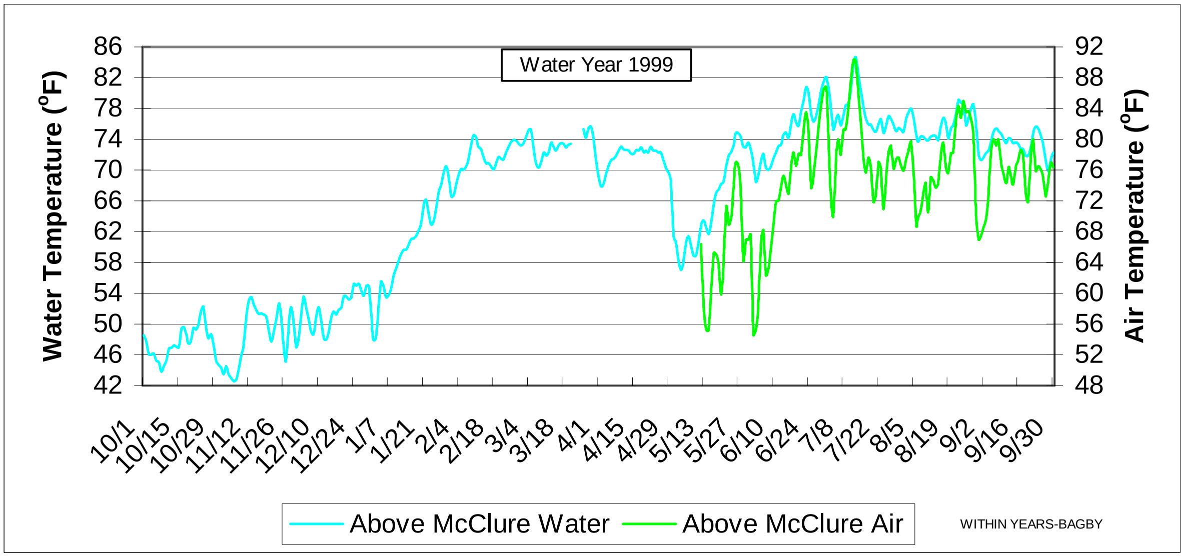

Figure 16. Average daily water and air temperatures (°F) measured in the Merced River upstream of Lake McClure for water year 1999.

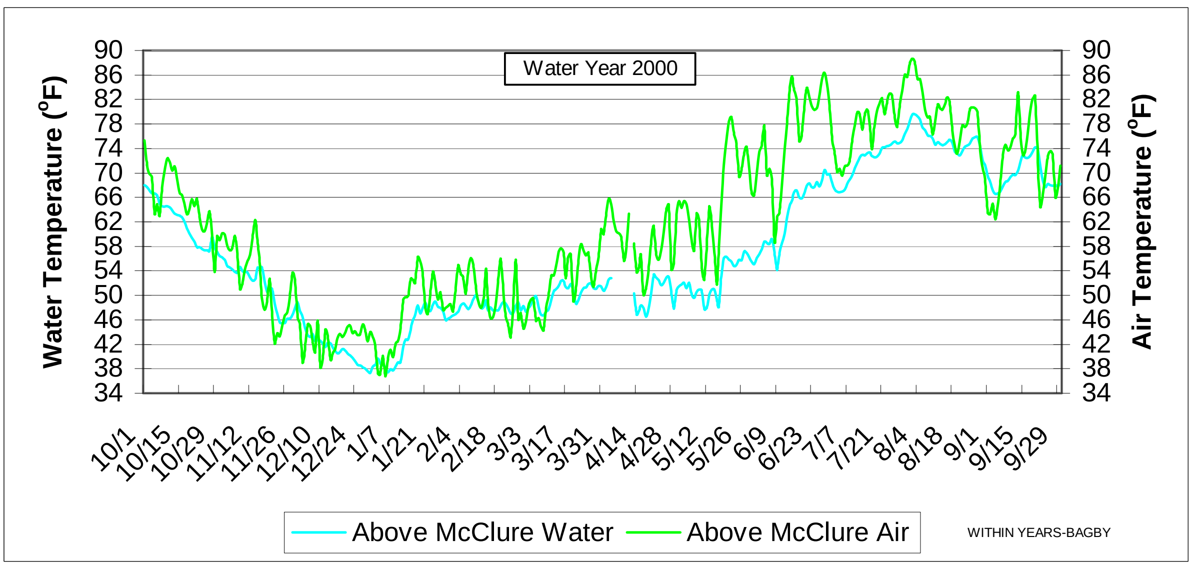

Figure 17. Average daily water and air temperatures (°F) measured in the Merced River upstream of Lake McClure for water year 2000.

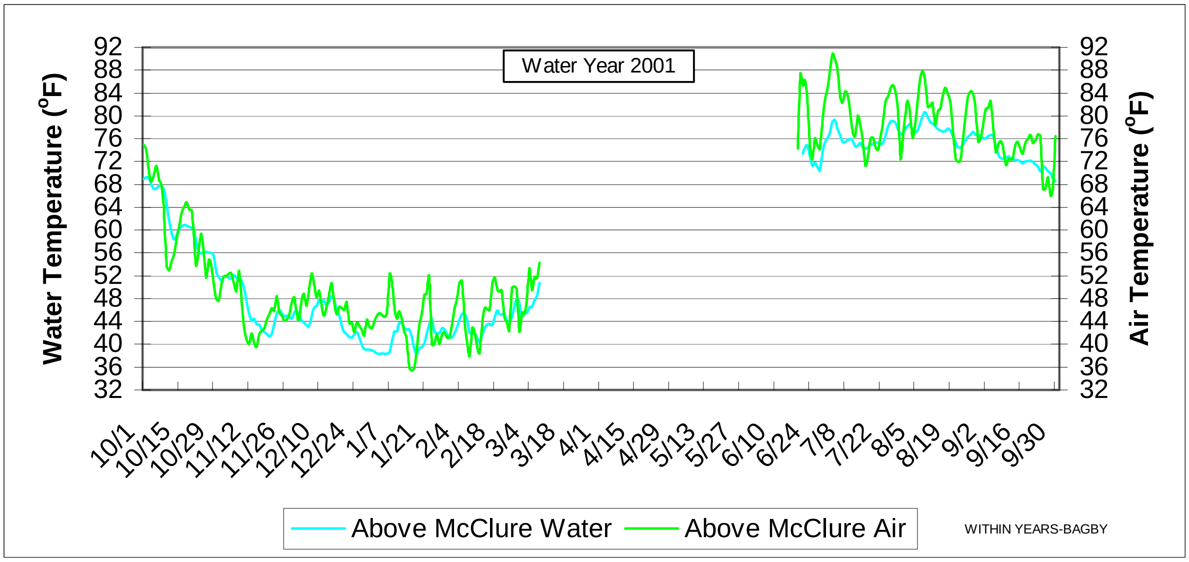

Figure 18. Average daily water and air temperatures (°F) measured in the Merced River upstream of Lake McClure for water year 2001.

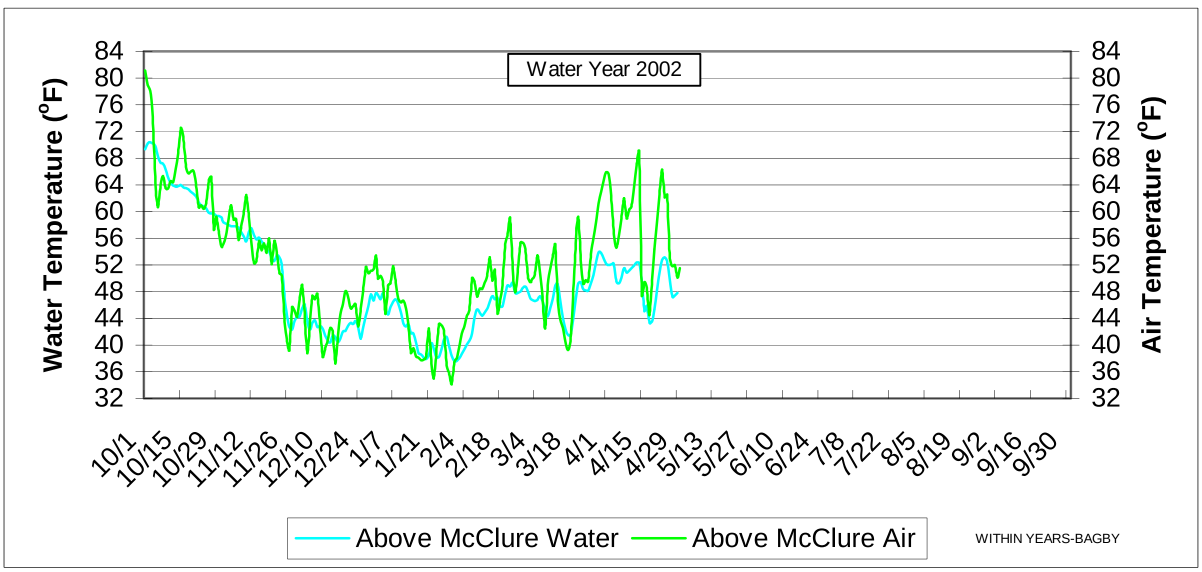

Figure 19. Average daily water and air temperatures (°F) measured in the Merced River upstream of Lake McClure for water year 2002.

Water Temperature Profiles Upstream of New Exchequer Dam.

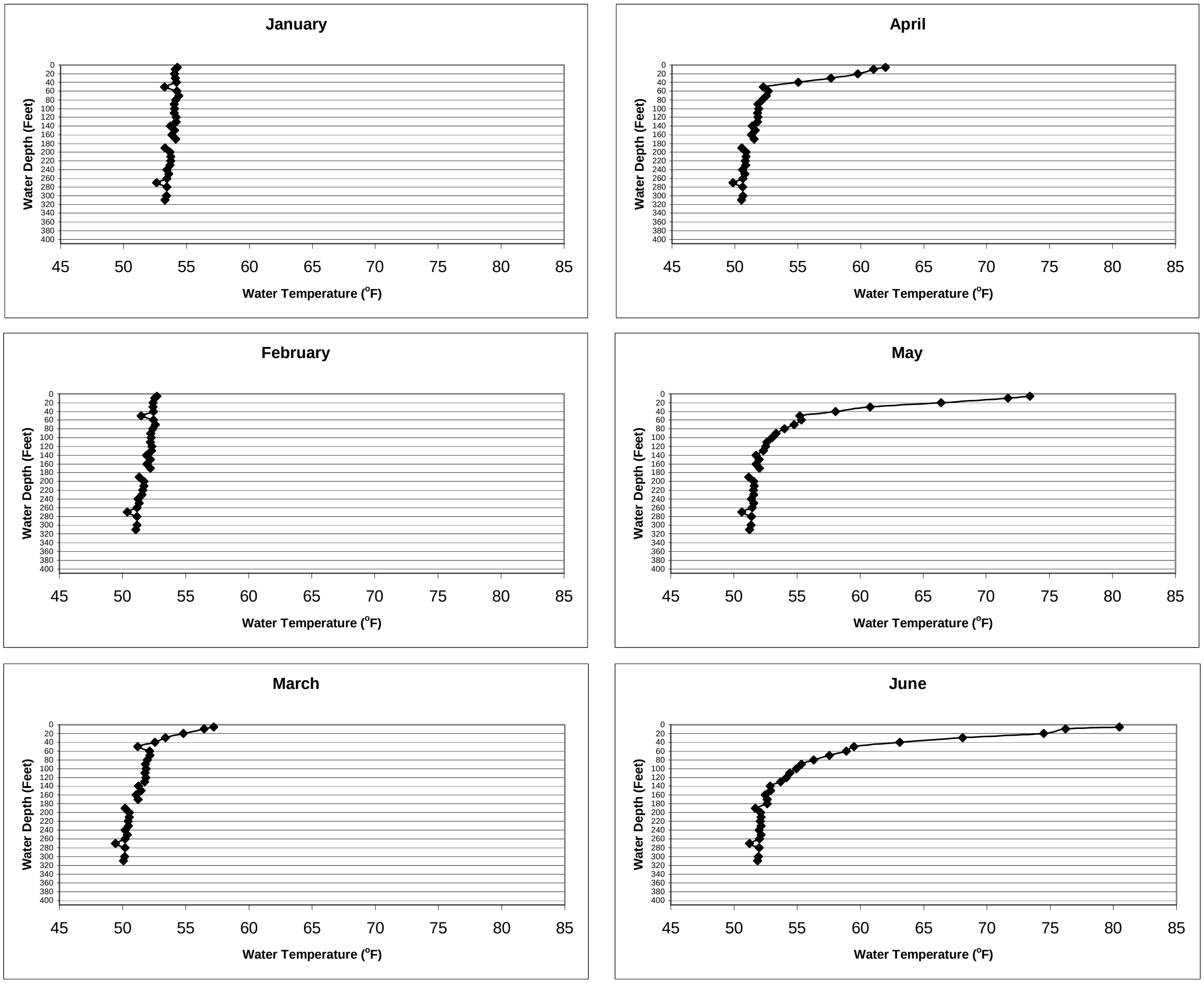

Figure 20a. Average monthly water temperatures (°F) and corresponding depths measured upstream of New Exchequer Dam (Water Year 2001).

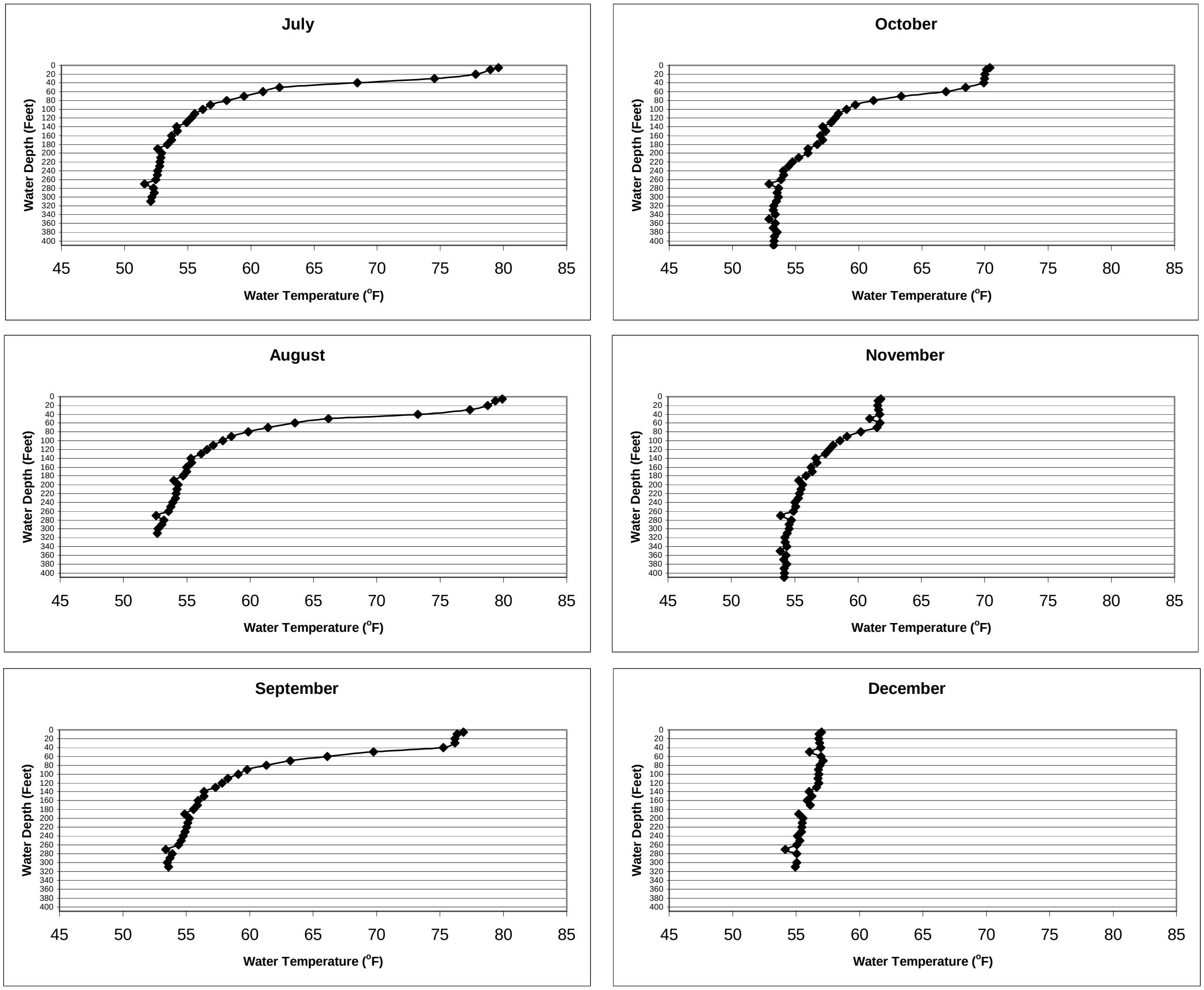

Figure 20b. Average monthly water temperatures (^{o}F) and corresponding depths measured upstream of New Exchequer Dam (Water Year 2001).

Merced River Downstream of New Exchequer, McSwain, and Crocker-Huffman Dams.

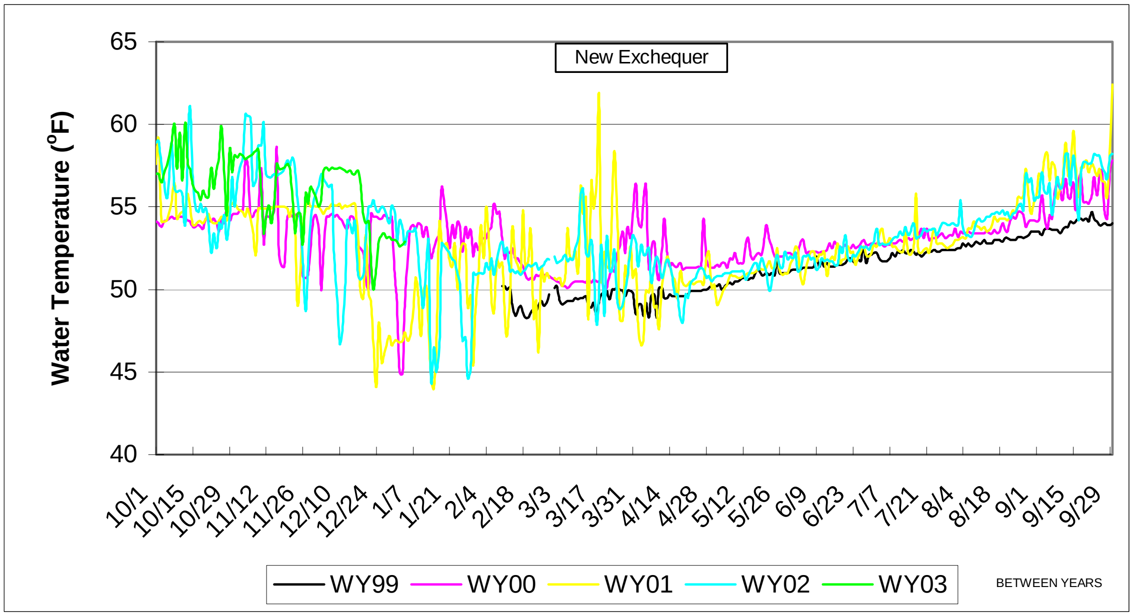

Figure 21. Average daily water temperatures (°F) measured in the Merced River downstream of New Exchequer Dam (water years 1999 – 2003).

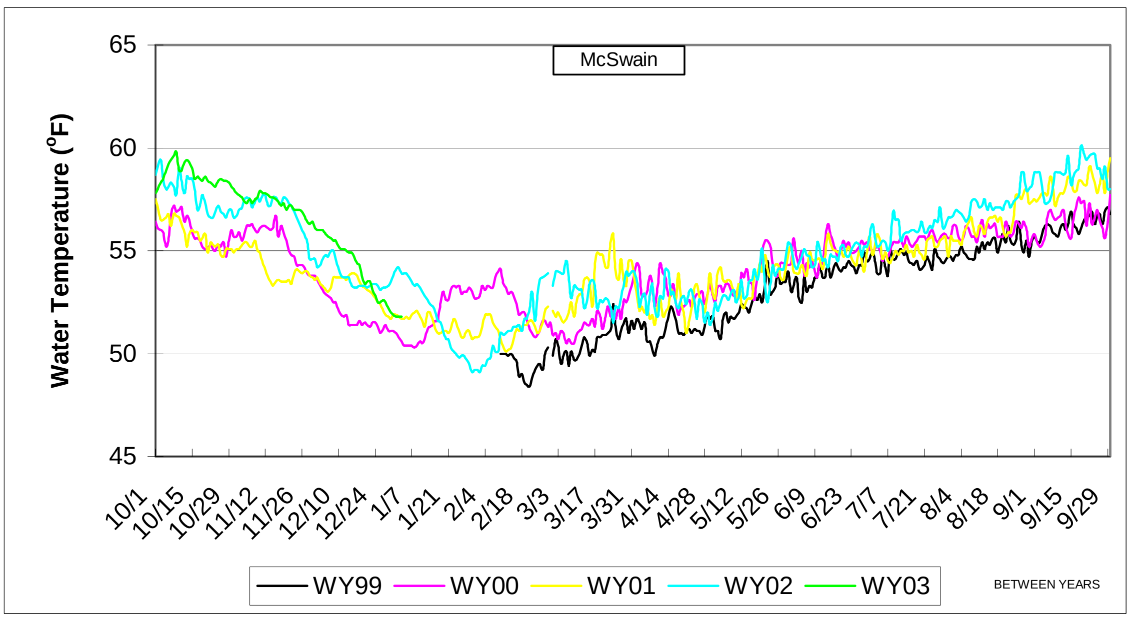

Figure 22. Average daily water temperatures (°F) measured in the Merced River downstream of McSwain Dam (water years 1999 – 2003).

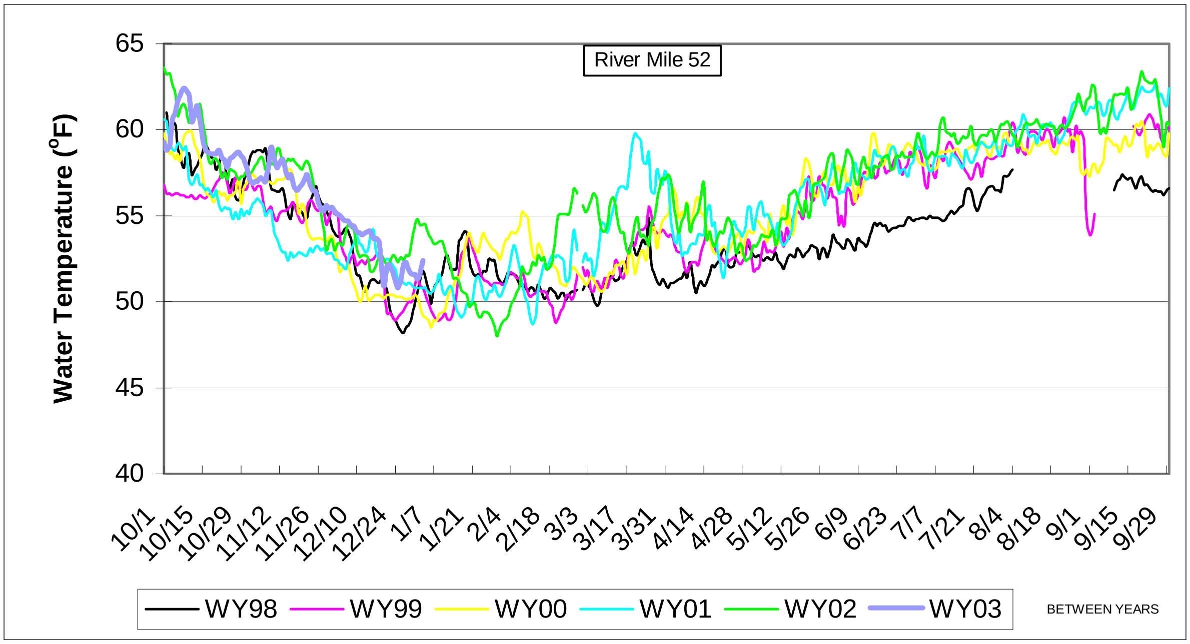

Figure 23. Average daily water temperatures (°F) measured in the Merced River downstream of Crocker-Huffman Dam (water years 1998 – 2003).

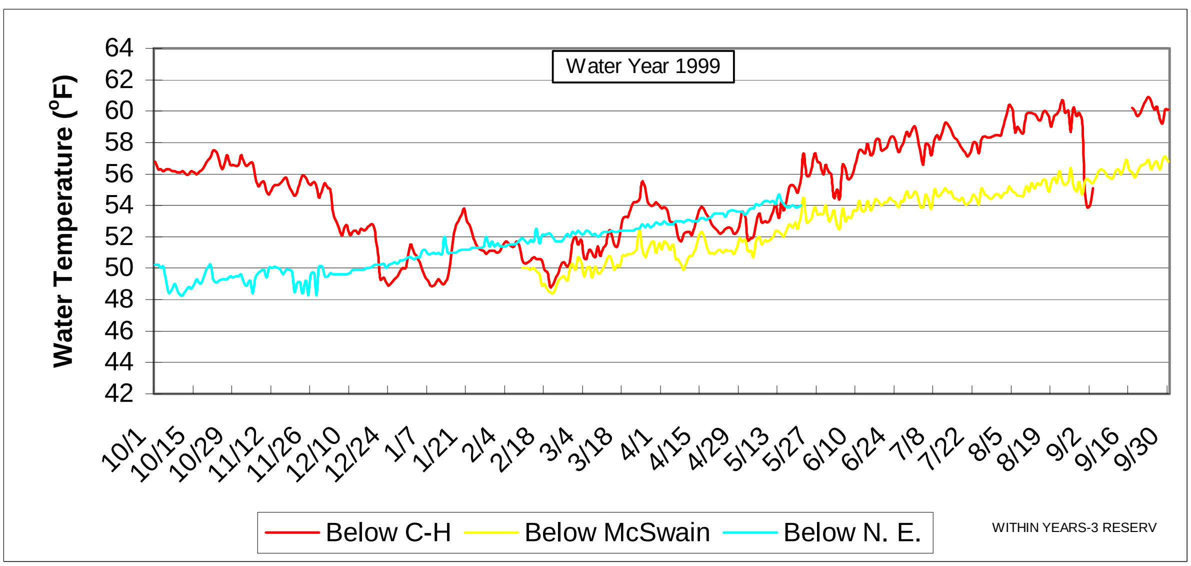

Figure 24. Average daily water temperatures (°F) measured in the Merced River downstream of New Exchequer, McSwain, and Crocker-Huffman Dams for water year 1999.

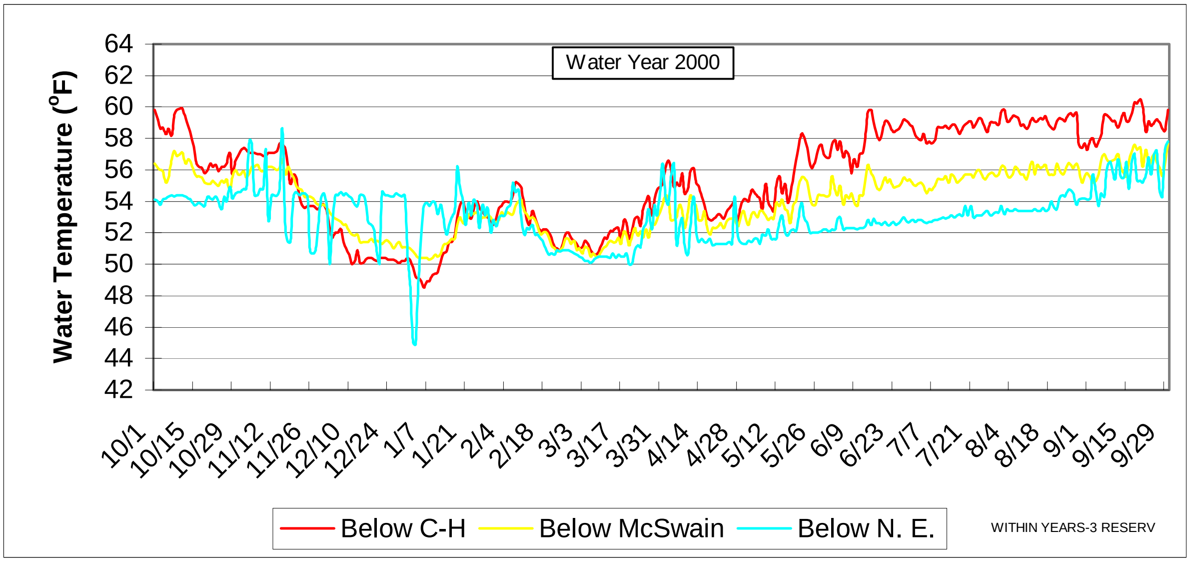

Figure 25. Average daily water temperatures (°F) measured in the Merced River downstream of New Exchequer, McSwain, and Crocker-Huffman Dams for water year 2000.

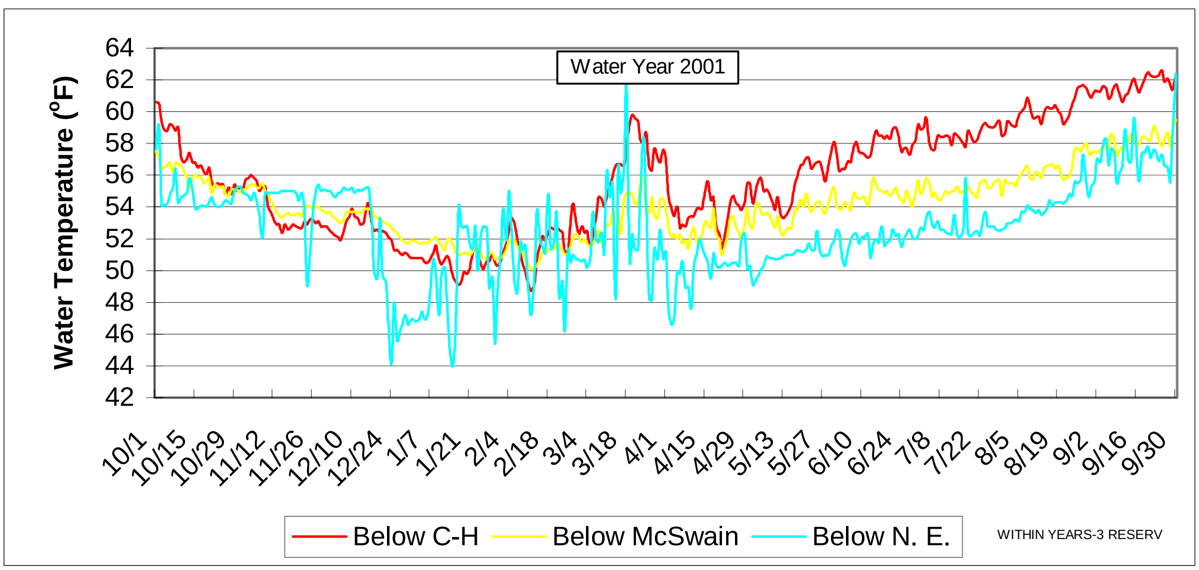

Figure 26. Average daily water temperatures (°F) measured in the Merced River downstream of New Exchequer, McSwain, and Crocker-Huffman Dams for water year 2001.

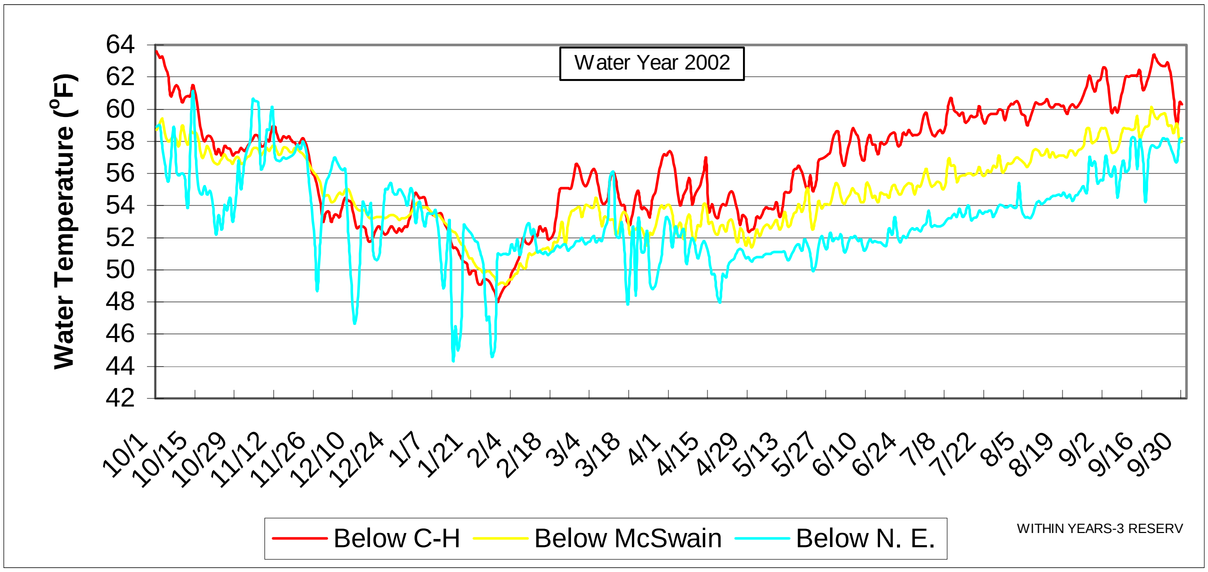

Figure 27. Average daily water temperatures (°F) measured in the Merced River downstream of New Exchequer, McSwain, and Crocker-Huffman Dams for water year 2002.

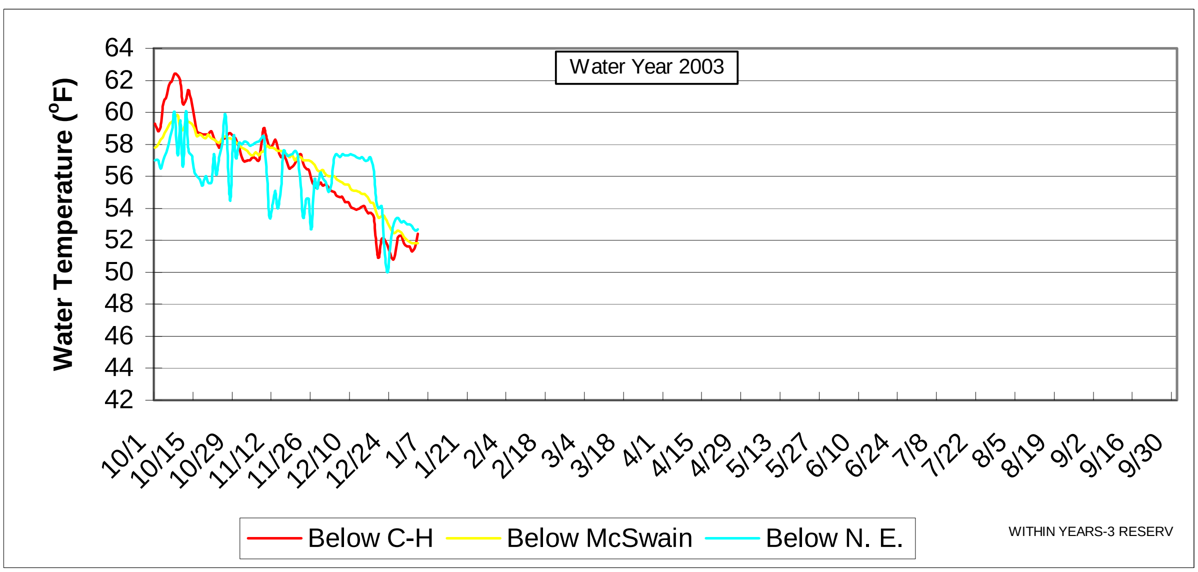

Figure 28. Average daily water temperatures (°F) measured in the Merced River downstream of New Exchequer, McSwain, and Crocker-Huffman Dams for water year 2003.

Lower Merced River Downstream of Crocker-Huffman Dam.

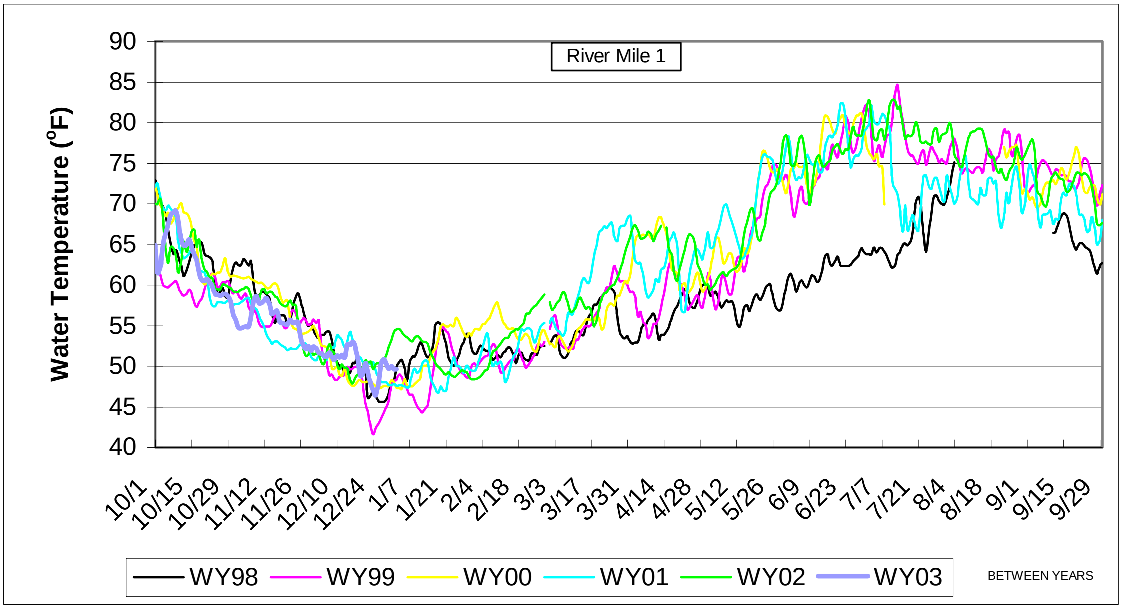

Figure 29. Average daily water temperatures (°F) measured at river mile 1 in the lower Merced River downstream of Crocker-Huffman Dam (water years 1998 – 2003).

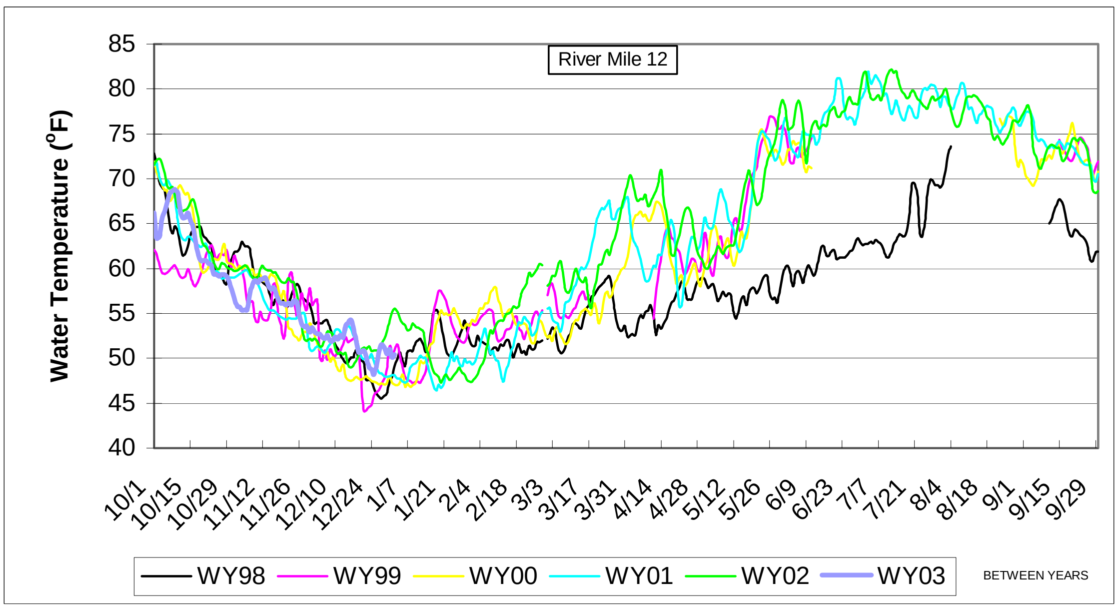

Figure 30. Average daily water temperatures (°F) measured at river mile 12 in the lower Merced River downstream of Crocker-Huffman Dam (water years 1998 – 2003).

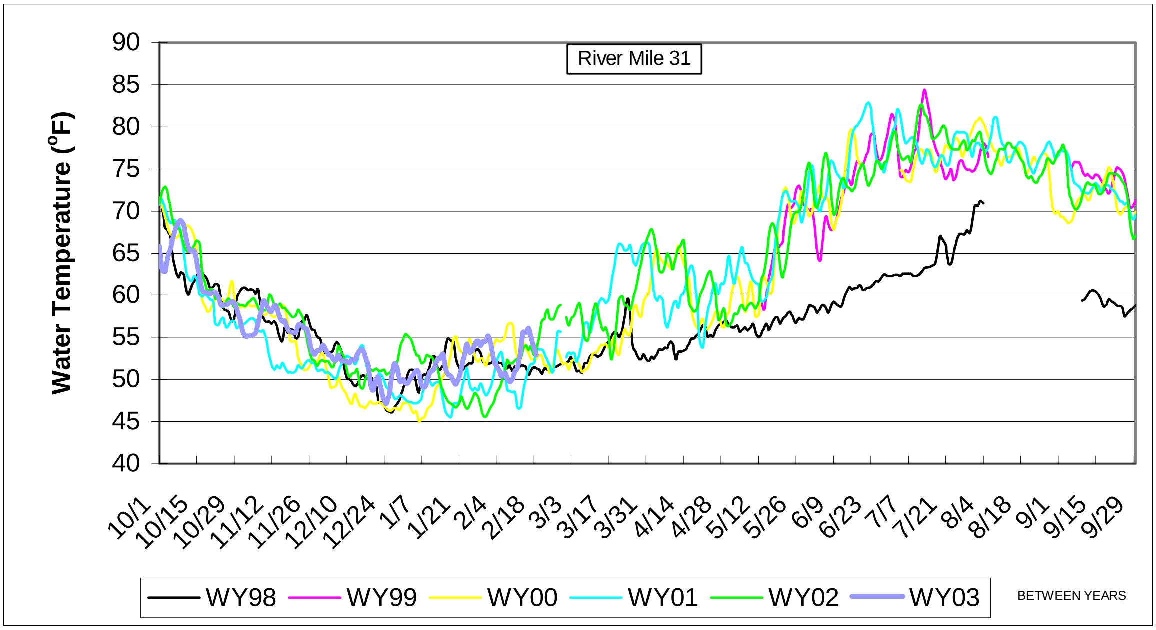

Figure 31. Average daily water temperatures (°F) measured at river mile 31 in the lower Merced River downstream of Crocker-Huffman Dam (water years 1998 – 2003).

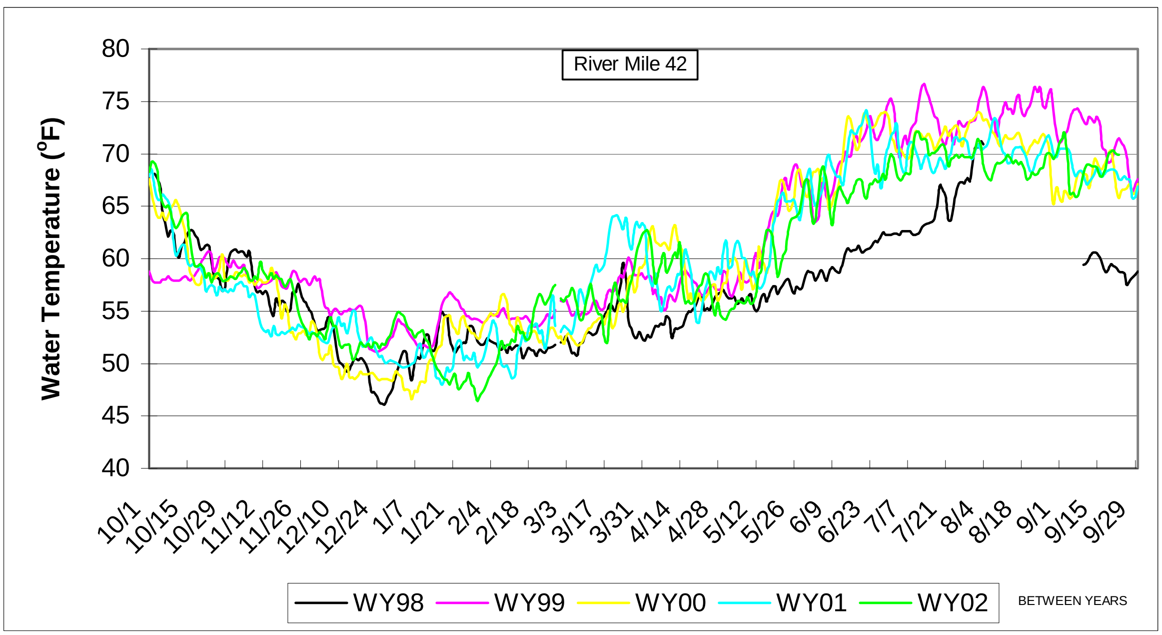

Figure 32. Average daily water temperatures (°F) measured at river mile 42 in the lower Merced River downstream of Crocker-Huffman Dam (water years 1998 – 2002).

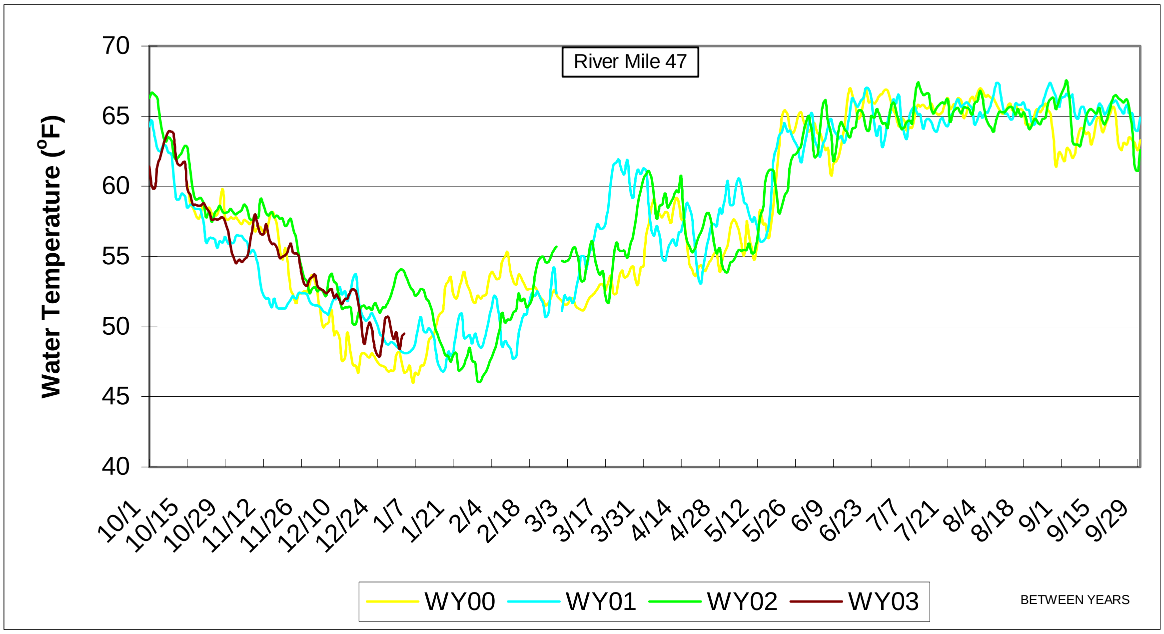

Figure 33. Average daily water temperatures (°F) measured at river mile 47 in the lower Merced River downstream of Crocker-Huffman Dam (water years 2000 – 2003).

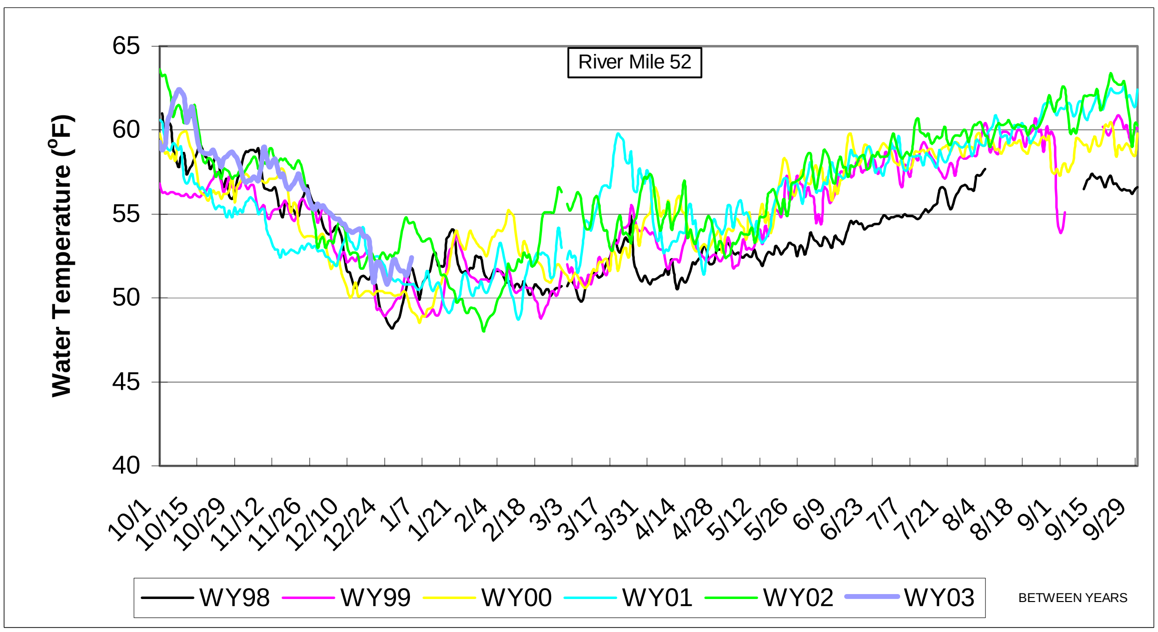

Figure 34. Average daily water temperatures (°F) measured at river mile 52 in the lower Merced River downstream of Crocker-Huffman Dam (water years 1998 – 2003).

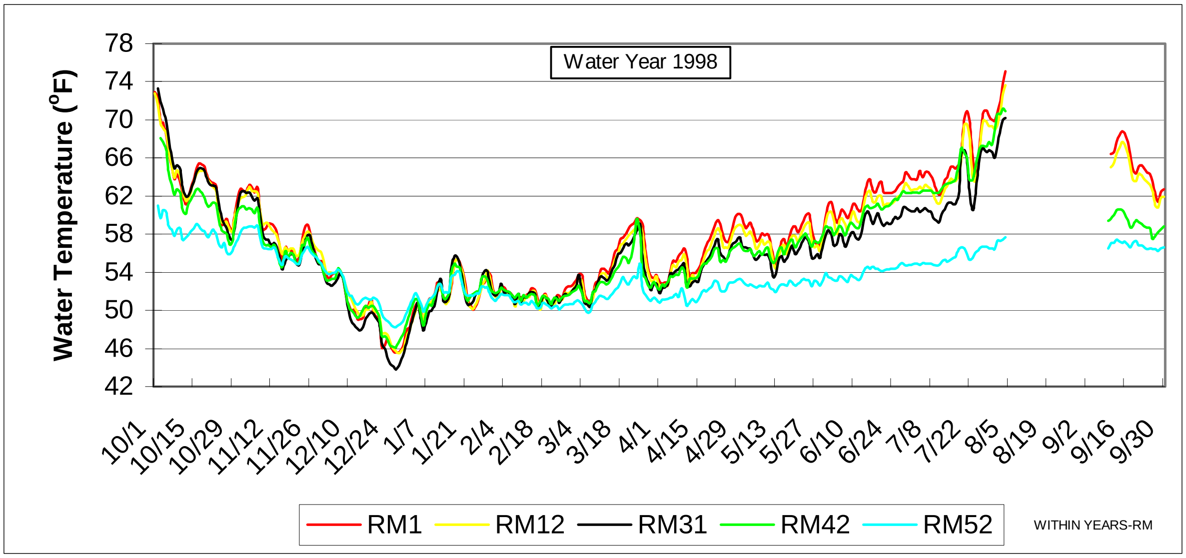

Figure 35. Average daily water temperatures (°F) measured in the lower Merced River downstream of Crocker-Huffman Dam for water year 1998.

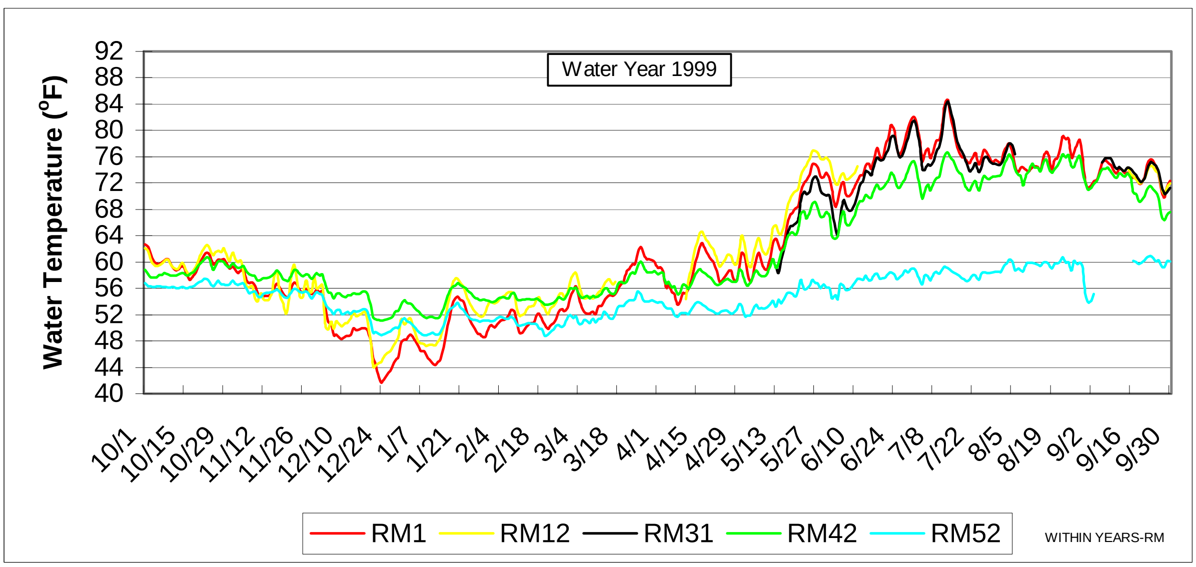

Figure 36. Average daily water temperatures (°F) measured in the lower Merced River downstream of Crocker-Huffman Dam for water year 1999.

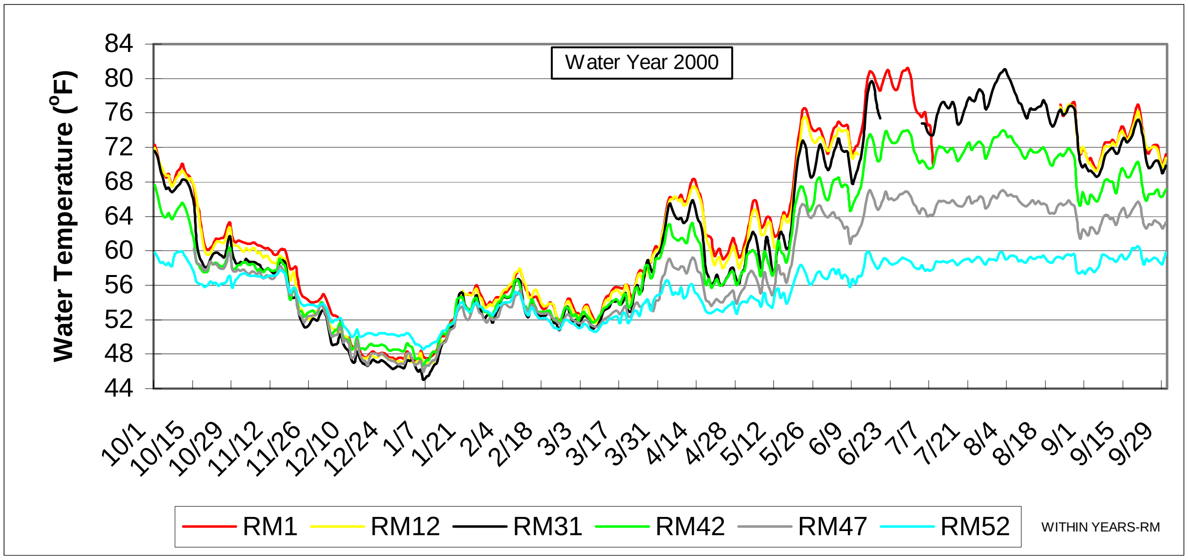

Figure 37. Average daily water temperatures (°F) measured in the lower Merced River downstream of Crocker-Huffman Dam for water year 2000.

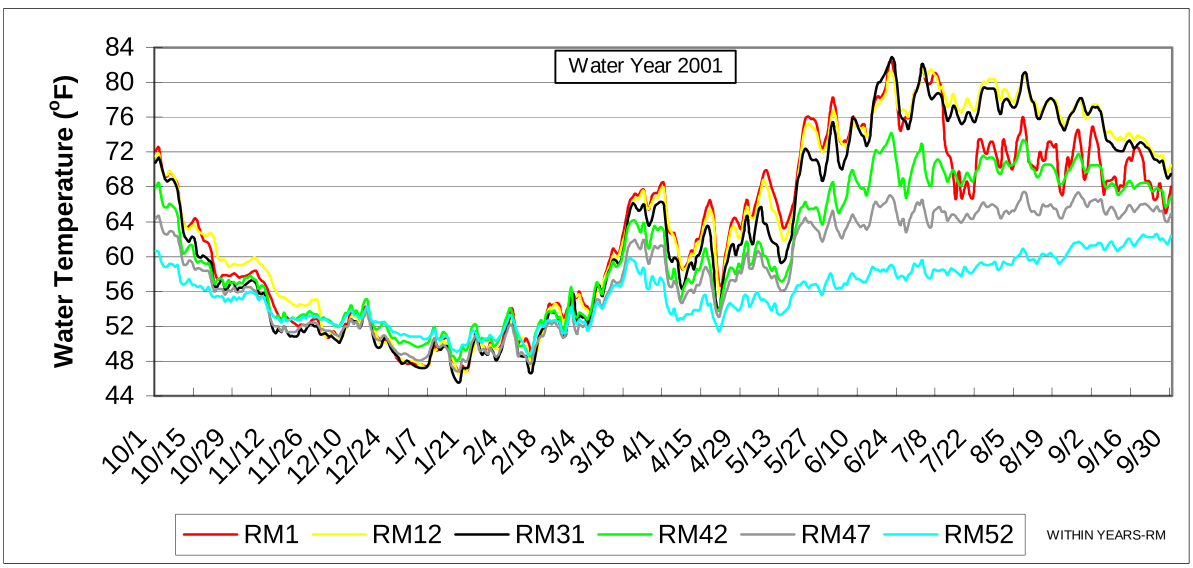

Figure 38. Average daily water temperatures (°F) measured in the lower Merced River downstream of Crocker-Huffman Dam for water year 2001.

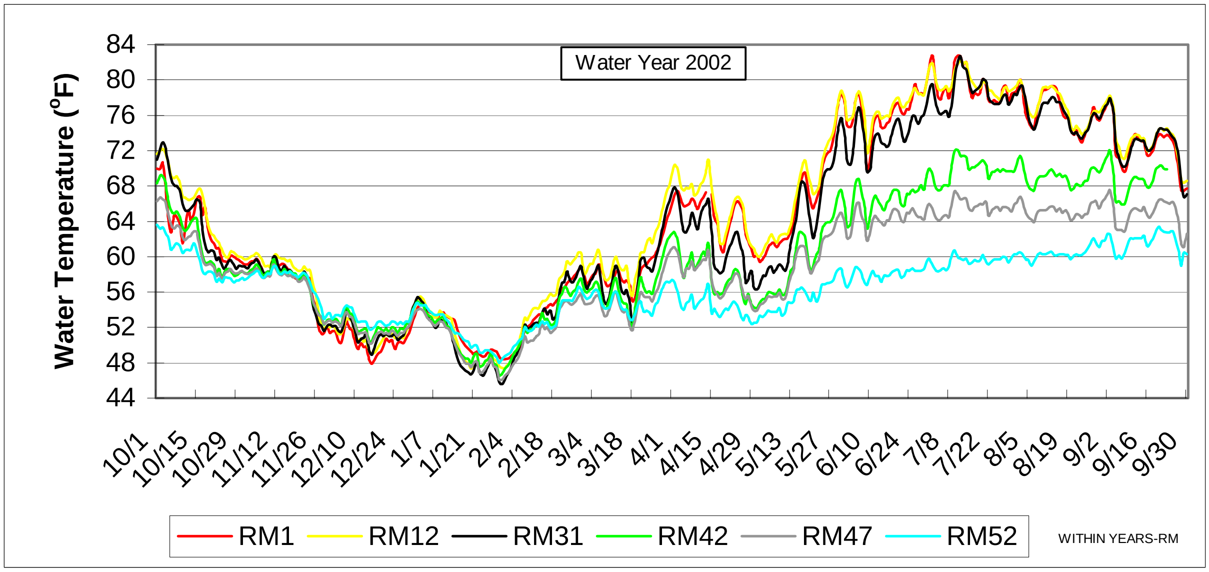

Figure 39. Average daily water temperatures (^{o}F) measured in the lower Merced River downstream of Crocker-Huffman Dam for water year 2002.

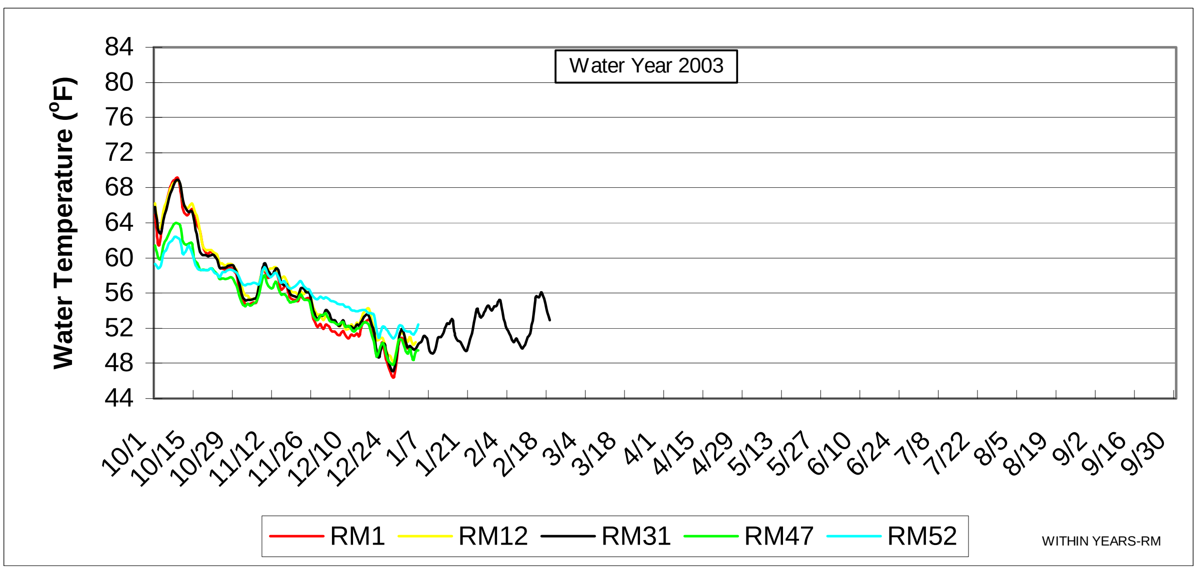

Figure 40. Average daily water temperatures (^{o}F) measured in the lower Merced River downstream of Crocker-Huffman Dam for water year 2003.

Water Temperature Models

Merced River and Lake McClure Water Temperature Model

A temperature model for the Merced River and Lake McClure was developed by Jones and Stokes Associates (JSA) in 1995 (JSA 1995) as part of CDFG's Merced River investigations. The following is a summary of the models and limitations based on a technical review of the 1995 report and a briefing on the topic on April 25, 1995 (extracted from Marine 1995).

Lake McClure Temperature Model

"The Lake McClure temperature model is a Box Exchange Transport Temperature and Ecology of Reservoirs (BETTER) model developed by Dr. Brown for applications to reservoirs while he worked for the Tennessee Valley Authority in the 1980's. This model divides the reservoir longitudinally into 10 segments each with up to 15 vertical layers. These segments and layers essentially define two-dimensional cells, or boxes, through which the model routes water movement and computes temperature dynamics based on physical geometry of the reservoir and hydrological and meteorological measurements (or estimated inputs).

The performance of this model was checked against a limited number of water temperature profiles and other grab sample temperature measurements made during the contrasting water years of 1992 and 1993. It generally tended to overestimate the hypolimnetic water temperatures measured near New Exchequer Dam in both 1992 and 1993. However, the input variables to this model likely limited its ability to accurately simulate the reservoir temperature profiles. No measurements of actual inflow or outflow temperatures were available to JSA which they had to estimate. And, the meteorological data were obtained from the CIMIS meteorological station near Modesto, California which may not accurately reflect the climatological conditions at Lake McClure. With improvements in these particular input factors (*i.e.*, actual measurements), JSA encouraged the use of this model in combination with an operations model for Lake McClure and downstream diversion dams for assessing effects of different operational scenarios on Merced River temperature conditions for fishery management.

This model incorporates several features that when properly parameterized likely generates a reasonable representation of the release temperatures from Lake McClure. However, due to the limitations briefly listed in this letter and described in the JSA report, the accuracy of its output is questionable. It was not relied upon for producing New Exchequer Dam release temperatures for input into the river temperature model for JSA's current assessment. And, it would not be recommended for use in a comprehensive assessment of operational scenarios at this time.

Improvements in estimates of seasonal reservoir inflow temperatures, or better yet actual measurements, as well as improvements in local meteorological data inputs would be highly recommended before proceeding with application of this model to the Merced River."

Merced River Temperature Model

"The river temperature model was described as an hourly model that operates over the course of a monthly interval. It incorporates mass balance and thermal energy balance calculations as water flows downstream. However, the temperature model is not a hydraulic routing model. It uses heat transfer and transport equations similar to those used in the widely accepted U.S. Fish and Wildlife Service's SNTEMP model. The model divides the river into 22 approximately 3 mile long segments from New Exchequer Dam to the confluence with the San Joaquin River. The model uses channel geometry, hydrology, inflow temperatures, and meteorological data inputs to simulate thermal dynamics of the river as it flows downstream.

Data inputs to the model utilized existing USGS gaging stations for river flows, six CDFG thermographs located along the river from the Merced River Fish Facility to George Hatfield State Park, CIMIS meteorological data for Modesto, and channel geometry data from CDFG instream flow datasets for lower flow regimes (200-350cfs) and USGS floodflow channel capacity data for high flow regimes (4000-8000cfs). JSA also assumed an average streamside shading factor of about 20% for the entire study reach and that all accretions were at equilibrium temperature with the air upon entering the river.

The model appears to do a reasonable job, in most cases, of simulating the amplitude of daily fluctuation in water temperatures measured at most of the monitoring stations. And, the model simulates average daily temperatures fairly well. However, model results seem to fairly consistently overestimate the daily maximum temperatures during warm periods and underestimate daily temperatures during cooling periods, at least at the downstream-most station (Hatfield). I believe this is likely related to the numerous assumptions and estimated input parameters related in particular to channel geometry, local channel shading, and potential discrepancies resulting from using Modesto CIMIS meteorological data. JSA recognized these limitations, both in their presentation and in the report, and recommends that the model be improved by gathering additional information on streamside shading, channel geometry, accretions and depletions, and local accretion temperatures. However, they also stated that the model is adequate, based on their calibrations with 1992 and 1993 data, for conducting evaluations of water temperature management along the lower Merced River.

Based on JSA's presentation and the results in their report, I feel that the stream temperature model, as currently parameterized, may only be useful for the most general cursory, or exploratory-level, evaluations of providing temperature management by using different flow regimens on the Merced River. Assumptions and estimations used for average channel width/depth ratios and the broad and unverified application of these relationships to several stream segments, as well as the broad application of an assumed shading factor of about 20% to all stream segments, precludes use of the model for examining specific management alternatives affecting these factors in individual stream reaches. For instance, the model would not allow evaluation of potential alternative methods of providing temperature management, such as changing channel configurations in certain reaches or improving shading by revegetating the river bank, or augmenting riparian vegetation. Nor would the model provide the means to identify river reaches that may benefit from such management prescriptions.

Another critical assumption of the model which limits its use in evaluating different water temperature management alternatives is the assumption that accretions throughout the study reach are at equilibrium temperature with the air. This may, or may not, be the case but it has important biological relevance. Inflows and groundwater seeps in streams have been identified to provide thermal refugia and critical microhabitats for many species of fish including salmonids. Accretion temperatures different from the air could also contribute to discrepancies between model simulations and actual measured temperatures depending on the relative seasonal contributions of accretions to total flow in various stream reaches. Identification and specification of the actual reach-by-reach accretions and accretion temperatures would provide important seasonal habitat information as well as improving the temperature model for use in evaluating a broader range of water temperature management alternatives."

Alternative Flow Analyses

"The alternative flow analyses conducted by JSA assume a 15.5°C (60°F) upper optimal temperature threshold for most of the analyses. This threshold has been demonstrated to be most critical for the reproductive period including spawning, incubation, and early fry rearing life stages. A higher upper optimal temperature threshold of around 17°-18°C (62.6°F-64.4°F) has been demonstrated for juvenile and subadult Chinook salmon, which JSA acknowledges in their report. JSA's evaluation shows that a considerable amount of water released down the Merced River would be required to achieve the 15.5°C objective especially in May and June of most years (more required during dry, low reservoir carry over storage years). Less water would be required to meet the 17°C-18°C objective. Meeting the temperature objective (15.5°C) during the fall season would require additional releases during some years in October. However, during the fall of warm, low reservoir carry over years meeting this objective may not be possible and releasing more water would be detrimental since the cool hypolimnic storage can be depleted by the fall months in such years.

Maintaining protective water temperatures should include analyses of effects on food production, salmon growth, and ecological interactions. If river temperatures are too warm, salmon growth and smoltification as well as vulnerability to predation may be negatively effected. However, constraining temperatures too much or cooling long reaches of the river may restrict growth or limit access to relatively warmer conditions for older more tolerant juvenile salmon. Since the size of outmigrant salmon smolts has been implicated in survival and seawater tolerance, any temperature management scenarios for the Merced River should include analyses of balancing protection of early life stages and providing suitable conditions for juvenile salmon growth. Suitable growth conditions and optimal age of outmigrating fall Chinook salmon will be dependent on year-to-year differences in hydrologic and delta estuary conditions in order to optimize survival of outmigrating smolts.

In order to optimize water management on the Merced River, JSA recommends that this temperature model be used as part of an adaptive management effort. Such an effort would utilize permanent temperature monitoring stations along with the model to adjust stream flows to achieve temperature objectives. Fish migration monitoring would be used to identify time periods of annual migrations to refine the time frame when temperature control releases would be needed. While the temperature model shows some promise as an evaluation tool, I believe that it should be refined and re-evaluated, as briefly described in this letter, before it is considered for adoption as part of a comprehensive stream temperature management program for the Merced River." (Marine 1995)

Because of these limitations, CDFG and Merced ID have requested that new, more expansive reservoir and river temperature models be developed (Bill Loudermilk, CDFG Regional Manager, personal communication).

Proposed Expanded Merced River and Reservoirs Water Temperature Models

Because of the need for more-comprehensive water temperature models for the four Merced River reservoirs and the lower river, a proposal for model development was submitted[4] to CALFED in 2001 to fund such a project. That project was not funded largely because this report (Phase I) had not yet been completed. The following is a summary of information provided in the CALFED funding request describing the approach and additional data and analyses necessary to develop the models.

The objective for the proposed project is to develop and calibrate system-wide reservoir-and-river linked water flow and temperature models for screening and evaluating the value and feasibility of alternative temperature management measures for the Merced River. Similar modeling efforts for the Sacramento, Trinity, and Klamath river basins have provided the means to systematically assess the relative contributions and value of reservoir management and

[4] The proposal was submitted by Natural Resource Scientists, Inc. with substantial technical input by Dr. Michael Deas, Watercourse Engineering, Inc.

riparian and channel restoration measures for improving water temperatures in anadromous fish habitats (Deas et al. 1997, Deas and Orlob 1998, 1999, USFWS and Hoopa Valley Tribe 1999). The proposed project will support the ongoing efforts of stakeholders and resource managers to identify and implement the most effective, cost-efficient temperature management measures for the lower Merced River.

The primary hypothesis to be evaluated by the proposed research project is that water temperatures in the lower Merced River can be effectively managed to benefit Chinook salmon through operational and/or structural measures at the four mainstem Merced River reservoirs and dams, as well as potential restoration measures in downstream river reaches. As a modeling/simulation study, it is anticipated that the relative temperature improvements that may be achieved through manipulation of operational, structural and/or restoration components of our conceptual model can be determined. The model will serve to reduce scientific uncertainty associated with identification of effective temperature management alternatives prior to selecting and initiating actions. To a certain extent, the project will rely on recent experience involved with development of temperature control for Shasta Dam (USBR 1992). The results of these analyses are expected to provide the necessary 'feedback' to a conceptual model in order to identify the most efficient and effective suite of actions for temperature management on the lower Merced River. A combination of the identified suite of actions will be pursued for implementation after completion of this proposed project.

In order to optimize water management on the Merced River water temperature models will be developed and used as part of an adaptive management effort. Such an effort would utilize temperature monitoring stations along with the models to adjust stream flows and guide restoration efforts to achieve temperature objectives while balancing water supply needs. Fish migration monitoring would be used to identify periods of critical life phases to refine the time frame when temperature management may be needed.

The project will result in the development of water temperature computer models for the Merced River and its reservoirs from Lake McClure to the confluence with the San Joaquin River. The models will incorporate the necessary field data to represent reservoir storage and outlet configuration, river hydrodynamics, channel geometry, inflow temperatures, meteorological data, and water management operation inputs to simulate thermal dynamics of the reservoirs and river reaches. This project will rely heavily on data inputs and results from the initial Reconnaissance Investigation funded by the CVPIA AFRP (this report).

Development of the models will allow evaluation of potential alternative methods of providing temperature management, such as water operations, changing channel configurations in certain reaches or improving shading by revegetating the river bank, or augmenting riparian vegetation. The models will also provide the means to identify river reaches that may benefit from such management prescriptions. The models will be incorporated as a part of a comprehensive stream temperature management program for the Merced River and be used to evaluate a broader range of water temperature management alternatives. The proposed approach for simulation modeling of system reservoirs and river reaches is outlined below.

The project would be composed of three principal tasks:

Task 1. This first task will include data acquisition and processing for the four Merced reservoirs and associated river reaches. However, there are additional data requirements for completing temperature modeling in the Merced River system beyond that provided in this initial reconnaissance report. These data on the Merced River would be collected for Task 1 to provide information to develop the water temperature models (e.g., detailed bathymetry of the reservoirs, meteorological data at Lake McClure). Task 1 will include acquisition and processing of meteorological data, flow data, water project operations data, water temperature data, riparian shading information, and geometric representation of the four reservoirs. Additionally, there is a need to quantify diversion and return flow in the lower Merced River and assess intake and diversion impacts on the thermal regime.

Task 2. Task 2 is the model development, calibration, validation, system-wide interface, and application. The following provides details on this task.

Modeling Approach

The four reservoirs on the Merced River dramatically vary in size and purpose, from the large storage impoundment of Lake McClure, to the small Crocker-Huffman diversion dam. River reaches likewise illustrate a wide range of characteristics as operations and diversions and return flows vary widely in space and time. Modeling the thermal regime of this system requires characterizing each of these reservoir and river reach components individually, identifying the appropriate representation for each component and selecting and implementing a suitable model. These individual models are then used in concert to simulate system response for variable hydrology, meteorology, operations, and system conditions. The approach to modeling each reservoir and Merced River reaches are outlined below. A range of potential models is presented based primarily on preliminary system characterization of the thermal regime of each system in light of the overall project objective.

Modeling time step will potentially range from sub-daily (e.g., hourly) for the smaller impoundments up to one-day for Lake McClure.

River Reaches

River reaches between reservoirs and downstream of Crocker-Huffman dam will be modeled with a one-dimensional longitudinal river model. Approximately fifty-two miles of river will be represented from Crocker-Huffman Dam to the confluence with the San Joaquin River. There are several challenges in representing this river reach, including low flow conditions, variable stream geometry, and diversions and return flows. Further, it has been identified that restoration of channel form and riparian communities is desirable, thus the selected model must be able to accommodate these processes.

It is critical to note that successful representation of the thermal regime of the lower Merced River requires effective representation of both flow and temperature. To address the broadest possible range of alternatives, a hydrodynamic model will be applied to represent the flow regime in the river. Output from the flow model will be passed to the temperature model to determine transport and fate of heat energy.

There are several one-dimensional river models public domain or "open[5]" models available that address both flow and temperature, including WQRRS, HEC5-Q (flow modeled with flood routing), and CE QUAL-RIV1 from the U.S. Army Corps of Engineers; the Tennessee Valley Authority flow and temperature models ADYN and RQUAL, respectively, as well as others. Review of field data and monitoring results, as well as identifying potential management actions (e.g., re-operation, channel and riparian revegetation restoration, etc.) will assist in final model selection. All river modeling will be at sub-daily time steps, e.g., one-hour.

Model Integration
Because there is the potential that different models (sub-models) will be used for different components of the system, there is the need for model integration. The models will be run in series, starting with the most upstream component (Lake McClure) and proceeding downstream to the confluence with the San Joaquin. A simple interface will be developed to aid the construction of input files, application of the various sub-models, and interpretation and presentation of output.

Task 3. Task 3 will encompass Project Management, including all written quarterly and final reports and project coordination.

Thermal loading, through heat exchange at the air-water interface, as well as thermal energy imparted on a water body via inflows is well understood and has been modeled for several decades. From this body of knowledge it is well known that reservoir operations, river flows, channel and riparian vegetation maintenance and restoration can affect thermal conditions within a river basin. The numerical models identified above have been widely applied to a broad range of reservoir and river systems to assess such issues, including several in the Central Valley. The reservoir models WQRRS has been applied to Shasta and Trinity Reservoir, HEC-5Q has been

[5] "Open" models refer to computer codes that are available for a fee, but unlike proprietary codes where only an executable program is supplied, their source code is provided and readily available for peer review.

applied to New Melones reservoir as well as Tulloch Reservoir, and CEQUAL-R1 has been applied at New Bullards Bar on the Yuba River. The aforementioned river models have also been widely applied in temperature studies. Advances in computational ability and improvements in software have reduced the simulation times and allowed management of large data sets to the degree that long simulations at short time steps are now feasible, e.g., 6 month simulations at 1-hour time steps are feasible. The advances in software also allow the analyst to select the best model for each individual reservoir or river reach, adding an integrating interface to simulate entire reservoir-river systems seamlessly. Thus, rather than being tied to a single model that simulates reservoirs and rivers, multiple models of different representations, time steps, parameters, etc. can be coupled for simulation.

This project aims to provide three principal products, (1) a description of the existing thermal regime of the system and inventory/database of available data, (2) a comprehensive modeling framework and associated data set and parameters, and (3) assessment of alternative operations and flow-temperature relationships for the river below the dams, as well as a suite of potential temperature prescriptions for the various alternatives.

Item (1) may be termed a description of baseline conditions. For this project the processes of seasonal thermal loading, thermal processes in the basin, impacts of water resources development (reservoirs, diversions), operations, and short- and long-term temperature response due to meteorological conditions. This is a necessary first stage to clearly identify existing conditions and how controllable and uncontrollable processes affect the thermal regime of the reservoir-river system.

Item (2) is designed to promote the level of scientific analysis within the Merced River basin and provide comprehensive documentation of the model implementation and application, including all data sets, model parameter selection (and motive), calibration and validation results and methods of quantifying uncertainty. Beyond basic information required for this project, comprehensive documentation and discussion will ensure that this work lays a foundation for from which future studies can be made.

Item (3) includes specific analyses completed using the models developed under this project. A final project report will explicitly identify the thermal impacts of alternatives formulated by stakeholders. Alternatives may range from exploring a range of hydrologic and meteorological conditions, re-operation of existing facilities, capital improvements that may include modifying outlet structures (e.g. selective withdrawal, modifying existing dams).

Development of the reservoir and river water temperature models will provide the essential information for subsequent (next phase) engineering analyses and designs to proceed. This proposed modeling and systems evaluation project will use the information and data resulting from the first phase of the Merced River Water Temperature Management Feasibility Study funded by the AFRP (this report). The proposed model's outputs are expected to be useful to the Merced County's Merced River Corridor Restoration Project that was funded by CALFED during 1998-2001. Integration of the shaded riparian habitat and channel maintenance benefits expected from stream corridor restoration projects with options for improved stream temperature management that emerge from our project's assessments will be ultimately important for achieving a coordinated temperature management solution for the lower Merced River. The results will also directly benefit both CDWR's and CDFG's CALFED funded Merced River salmon habitat enhancement projects. The proposal serves to support these ecosystem objectives and future Merced River and San Joaquin Basin restoration/management actions through comprehensive evaluation of options to assure compatible, balanced management of improved flow and water temperature regimes on the Merced River to benefit native aquatic and at-risk species.

Acknowledgements

This project was funded by the USFWS Anadromous Fish Restoration Program. Appreciation is extended to Jeff McLain (USFWS) for his very capable management of the project. Thanks are due to Merced Irrigation District, the District staff, and MBK Engineers for providing valuable data for the reconnaissance study. In particular, Ted Selb (Merced ID) and Mike Archer (MBK Engineers) provided essential information for project completion. The technical input provided by Dr. Michael Deas, Watercourse Engineering, Inc. for a CALFED proposal used in this report was invaluable. Gratitude is also expressed to Ted Selb and Jeff McLain for reviewing a draft of this report.

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APPENDIX A
California Energy Commission Questionnaires for New Exchequer Dam and McSwain Dam

Project & Powerhouse General Information

Please provide the following information for the powerhouse.

FERC project number: 2179	FERC license type: X *Major* □ *Minor* □ *Exemption*
Commercial operation date: January 1967	
FERC license expiration date: 2014	Energy Information Agency (EIA) ID: 409
River/stream name: Merced River	Please provide the GPS coordinates for the powerhouse (UTM coordinates or longitude/latitude): Long. – 120.2667, Lat. – 37.5833

Power Services – Ancillary Services, Reliability Must-Run, and Dispatchability

Please answer the following questions about ancillary services provided by the powerhouse, its California Independent System Operator (Cal-ISO) rating, and its dispatchability.

Does the powerhouse provide any of the following ancillary services? (Check all that apply) X *Voltage Support* X *Spinning Reserve* □ *Black Start* X *Non-Spinning Reserve* X *Regulation Up/Down and/or AGC* □ *Replacement Reserve*			
Has the generating unit been designated Reliability-Must-Run (RMR)?	X *Yes*	□ *No*	□ *N/A*
Is the generating unit dispatchable? (e.g., capable of utilizing water from storage)	X *Yes*	□ *No*	□ *N/A*
Estimated annual peaking energy as a percent of total energy (%): N/A			

Hydroelectric Facility Purpose and Functions

Please rate the relative importance of the following functions in relation to the hydroelectric facility's purpose. Please rate as either: None, Low, Medium, or High. Also please rate the relative priority of current facility purpose on a scale of 1 to 8 (in the right-hand column).

Relative Importance of Facility Functions					**Priority Rating (1-8)**
Flood control:	□ *None*	□ *Low*	□ *Medium*	X *High*	1
Interbasin water diversion and storage:	□ *None*	□ *Low*	□ *Medium*	X *High*	3
Recreation:	□ *None*	□ *Low*	X *Medium*	□ *High*	6
Energy:	□ *None*	□ *Low*	□ *Medium*	X *High*	2
Consumptive water supply:	□ *None*	X *Low*	□ *Medium*	□ *High*	7
Navigation (including rafting):	□ *None*	X *Low*	□ *Medium*	□ *High*	8
Fisheries:	□ *None*	□ *Low*	X *Medium*	□ *High*	4
Other environmental concerns:	□ *None*	□ *Low*	X *Medium*	□ *High*	5

Operations Relative to Inflows and Instream Flow Releases

Please provide the following information for the powerhouse.
Please indicate (N/A) if any of the questions are not applicable to the powerhouse.

Total average annual inflow to project (AF/yr): 1,159,809	Average annual flow through powerhouse (AF/yr): 1,130,744
Are power operations controlled by flow release requirements through the unit? X *Yes* ☐ *No*	Are minimum instream flows required for a bypass reach of river? ☐ *Yes* ☐ *No* X *N/A*
Average annual flow released in bypass reach of river (AF/yr):	Peak streamflow prior to project development (cfs):
Peak streamflow below dam since project development (cfs):	Operator's stream gage station name or number:
Corresponding USGS number for stream gage:	Is unimpaired flow data available? If so, please specify for what period and location: ☐ *Yes* ☐ *No*

Reservoir Storage

Please provide the following information for the powerhouse. Please indicate (N/A) if any of the questions are not applicable to the powerhouse.

Maximum storage capacity of reservoir (total volume of impoundment): 1,024,599	Usable storage capacity of reservoir (usable capacity of impoundment): 851,099

Sedimentation

If there is a reservoir or forebay associated with the powerhouse, please answer the following questions about existing or potential sedimentation problems.

Is reservoir sedimentation a problem now or expected to be within 20 years?	☐ *Yes* ☐ *No* X *N/A*
Are you allowed to sluice the reservoir?	☐ *Yes* ☐ *No* X *N/A*
Is reservoir sluicing effective in passing the majority of sediment inflow downstream?	☐ *Yes* ☐ *No* X *N/A*

Fisheries

Please answer the following questions about fish passage, fish habitat, and fisheries management as they relate to the powerhouse. Please indicate (N/A) if any of the questions are not applicable to the powerhouse. Attach additional sheets as needed.

Is the dam a barrier to anadromous fish (e.g., salmon, steelhead) passage? **X** *Yes* ☐ *No*	Is the dam within a formerly accessible habitat reach of river for anadromous fish? **X** *Yes* ☐ *No*
How many stream miles of formerly accessible anadromous fish habitat are located above the dam (that either presently or under pre-project conditions would have been accessible)? 24.4 miles (distance to main stem falls at North Fork)	Please list the key aquatic species being managed by state and federal agencies: Fall-run Chinook salmon (*Oncorhynchus tshawytscha*)
Have fish hatcheries been built in association with operation of the dam? **X** *Yes* ☐ *No*	
Are any fish screens present at the dam or intake to the power plant? ☐ *Yes* **X** *No*	

Environmental Monitoring

Please describe any environmental monitoring being performed within the project, including any monitoring being conducted to satisfy license conditions. Attached additional sheets as needed.

List any parameters being monitored as an indicator of environmental health (e.g., minimum flow releases, water temperature, dissolved oxygen, etc.): Water temperature: Electronic water temperature thermographs monitor water temperatures in a vertical array in the reservoir just upstream of the powerhouse, the river immediately downstream of the powerhouse, immediately downstream of McSwain powerhouse, and in the anadromous salmon reach beginning 8 river miles downstream of the powerhouse. Minimum flow releases: Minimum daily river flow in the anadromous salmonid river reach downstream of Crocker-Huffman dam is monitored to ensure compliance with minimum flow agreements.	Are adaptive management measures being applied to project operations? **X** *Yes* ☐*No* If so, please list the parameters being monitored and the range that operations can be modified. To a limited extent, water supply in New Exchequer Reservoir is used during a 31-day period (mid-April to mid-May) in a 12-year Program (1999-2010) called the Vernalis Adaptive Management Plan (VAMP). Parameters monitored are related to juvenile salmon survival in the Sacramento-San Joaquin Delta. Details are provided at: http://www.sjrg.org/agreement.htm http://www.sjrg.org/app_a.pdf http://www.sjrg.org/app_b.pdf

Project & Powerhouse General Information

Please provide the following information for the powerhouse.

FERC project number: 2179	FERC license type: X *Major* □ *Minor* □ *Exemption*
Commercial operation date: July, 1967	
FERC license expiration date: 2013	Energy Information Agency (EIA) ID: 410
River/stream name: Merced River	Please provide the GPS coordinates for the powerhouse (UTM coordinates or longitude/latitude): Long – 120.2833, Lat – 37.5167

Power Services – Ancillary Services, Reliability Must-Run, and Dispatchability

Please answer the following questions about ancillary services provided by the powerhouse, its California Independent System Operator (Cal-ISO) rating, and its dispatchability.

Does the powerhouse provide any of the following ancillary services? (Check all that apply) □ *Voltage Support* □ *Spinning Reserve* X *Black Start* □ *Non-Spinning Reserve* □ *Regulation Up/Down and/or AGC* □ *Replacement Reserve*			
Has the generating unit been designated Reliability-Must-Run (RMR)?	X *Yes*	□ *No*	□ *N/A*
Is the generating unit dispatchable? (e.g., capable of utilizing water from storage)	X *Yes*	□ *No*	□ *N/A*
Estimated annual peaking energy as a percent of total energy (%): N/A			

Hydroelectric Facility Purpose and Functions

Please rate the relative importance of the following functions in relation to the hydroelectric facility's purpose. Please rate as either: None, Low, Medium, or High. Also please rate the relative priority of current facility purpose on a scale of 1 to 8 (in the right-hand column).

Relative Importance of Facility Functions					**Priority Rating (1-8)**
Flood control:	□ *None*	□ *Low*	□ *Medium*	X *High*	1
Interbasin water diversion and storage:	□ *None*	□ *Low*	□ *Medium*	X *High*	2
Recreation:	□ *None*	□ *Low*	X *Medium*	□ *High*	4
Energy:	□ *None*	□ *Low*	□ *Medium*	X *High*	3
Consumptive water supply:	□ *None*	X *Low*	□ *Medium*	□ *High*	7
Navigation (including rafting):	□ *None*	X *Low*	□ *Medium*	□ *High*	8
Fisheries:	□ *None*	□ *Low*	X *Medium*	□ *High*	5
Other environmental concerns:	□ *None*	□ *Low*	X *Medium*	□ *High*	6

Operations Relative to Inflows and Instream Flow Releases

Please provide the following information for the powerhouse.
Please indicate (N/A) if any of the questions are not applicable to the powerhouse.

Total average annual inflow to project (AF/yr): 1,159,809	Average annual flow through powerhouse (AF/yr): 1,130,485
Are power operations controlled by flow release requirements through the unit? ☐ *Yes* ☐ *No*	Are minimum instream flows required for a bypass reach of river? ☐ *Yes* ☐ *No* X *N/A*
Average annual flow released in bypass reach of river (AF/yr):	Peak streamflow prior to project development (cfs):
Peak streamflow below dam since project development (cfs):	Operator's stream gage station name or number: Crocker-Huffman
Corresponding USGS number for stream gage:	Is unimpaired flow data available? If so, please specify for what period and location: ☐ *Yes* ☐ *No*

Reservoir Storage

Please provide the following information for the powerhouse. Please indicate (N/A) if any of the questions are not applicable to the powerhouse.

Maximum storage capacity of reservoir (total volume of impoundment): 9730	Usable storage capacity of reservoir (usable capacity of impoundment): 3092

Sedimentation

If there is a reservoir or forebay associated with the powerhouse, please answer the following questions about existing or potential sedimentation problems.

Is reservoir sedimentation a problem now or expected to be within 20 years?	☐ *Yes* ☐ *No* X *N/A*
Are you allowed to sluice the reservoir?	☐ *Yes* ☐ *No* X *N/A*
Is reservoir sluicing effective in passing the majority of sediment inflow downstream?	☐ *Yes* ☐ *No* X *N/A*

Fisheries

Please answer the following questions about fish passage, fish habitat, and fisheries management as they relate to the powerhouse. Please indicate (N/A) if any of the questions are not applicable to the powerhouse. Attach additional sheets as needed.

Is the dam a barrier to anadromous fish (e.g., salmon, steelhead) passage? **X** *Yes* ☐ *No*	Is the dam within a formerly accessible habitat reach of river for anadromous fish? **X** *Yes* ☐ *No*
How many stream miles of formerly accessible anadromous fish habitat are located above the dam (that either presently or under pre-project conditions would have been accessible)? 4.2 miles (distance to New Exchequer Dam)	Please list the key aquatic species being managed by state and federal agencies: Fall-run Chinook salmon (*Oncorhynchus tshawytscha*)
Have fish hatcheries been built in association with operation of the dam? **X** *Yes* ☐ *No*	
Are any fish screens present at the dam or intake to the power plant? ☐ *Yes* **X** *No*	

Environmental Monitoring

Please describe any environmental monitoring being performed within the project, including any monitoring being conducted to satisfy license conditions. Attached additional sheets as needed.

List any parameters being monitored as an indicator of environmental health (e.g., minimum flow releases, water temperature, dissolved oxygen, etc.): Water temperature: Electronic water temperature thermographs monitor water temperatures immediately downstream of McSwain powerhouse, and in the anadromous salmon reach beginning 4 river miles downstream of the powerhouse. Minimum flow releases: Minimum daily river flow in the anadromous salmonid river reach downstream of Crocker-Huffman dam is monitored to ensure compliance with minimum flow agreements.	Are adaptive management measures being applied to project operations? ☐ *Yes* **X** *No* If so, please list the parameters being monitored and the range that operations can be modified.

APPENDIX B
Vernalis Adaptive Management Plan (VAMP) Flows
(as described in the FEIS/EIR)

VAMP flows are guaranteed water supplies for the April-May pulse flow from the Authority of up to 110,000 acre-feet per year to support VAMP. The Authority proposes to cause to flow in the San Joaquin River at Vernalis during each April and May, a 31-day pulse flow period, the amount of water needed to achieve the Target Flow (described below) or up to 110,000 acre-feet, whichever is less. Additional water (in excess of the required water, possibly up to a total of 160,000 acre-feet) necessary to achieve VAMP Test Target Flow may be available on a "willing seller basis."[6]

- X The Pulse Flow Period is defined as a period of 31 continuous days during the months of April and May. This is anticipated to be the period that most of the juvenile anadromous fish migrate out of the tributaries, through the Delta, and into the Pacific Ocean in order to complete their life cycle. It is expected to occur most often between mid-April and mid-May. The timing of the pulse flow is to coincide with the peak period of time when naturally spawned smolts are migrating out of the San Joaquin River Basin.

- X The Target Flow is a specific flow regime between 2,000 and 7,000 cubic feet per second (cfs) for the Pulse Flow Period. It consists of the existing flow, plus either a single-step incremental increase in flow (over existing flow) or a double-step increase, depending on hydrologic conditions.

The 31-day out-migration Target Flow would be established as follows:

Single-Step Target Flow. Unless modified by the subsequently listed criteria, the annual 31-day out-migration Target Flow equals:

[6] The need for "up to" 160,000 acre-feet derives from the mathematics of the double-step target flows and the 110,000 acre-feet cap as described in Appendix A, Hydrologic Analysis. In the maximum exposure case where the "existing flow" is 4,450 cfs and the double-step increment requires a target flow of 7,000 cfs, the required flow would amount to approximately 2,550 cfs to get to 7,000 cfs. This amounts to approximately 156,800 acre-feet for the 31-day period. The SJRA identifies that willing sellers could provide the 50,000 acre-feet over and above the 110,000 acre-feet cap when it is available. Additional NEPA/CEQA analysis would be required, as who would provide the water and on which river is not known at this time.

Existing Flow (cfs)	Target Flow (cfs)
0–1,999	2,000
2,000–3,199	3,200
3,200–4,449	4,450
4,450–5,699	5,700
5,700–6,999	7,000
7,000 or greater	Existing flow

When the existing flow exceeds 7,000 cfs, the Authority would use its best efforts to maintain a constant or stable flow rate during the Pulse Flow Period to the extent reasonably possible through cooperating in development of an operations plan and coordination of operations during the Spring Pulse Flow. During high flow events such as those occurring in Spring 1998 (20,000 cfs), it may not be possible to maintain a constant flow rate at Vernalis during the 31-day pulse flow period.

Double-Step Target Flow. In any year when the sum of the current year's 60-20-20 Indicator and previous year's 60-20-20 Indicator is seven or greater, an annual 31-day out-migration flow target will be the Target Flow one level higher than that established by the single-step Target Flow. The 60-20-20 Indicator is the numeric adjunct to the State Water Resource Control Board's (SWRCB's) San Joaquin Valley Water Year Hydrologic Classification that is used to establish Target Flows and certain responsibilities of the parties to the Agreement. The San Joaquin Valley Water Year Hydrologic Classification was developed as an index of wetness and water supply availability within the San Joaquin River basin. The index is mathematically derived as the summation of 0.6 times the current year's April–July San Joaquin Valley unimpaired runoff, plus 0.2 times the current year's October–March unimpaired runoff, plus 0.2 times the lesser of 4.5 or the previous year's index (thus the "60-20-20" reference). The streams used in the index are the Stanislaus, Tuolumne, Merced and the San Joaquin. The index defines five different year types: wet, above normal, below normal, dry and critical. Each of these year types has been designated a numeric indicator by the Agreement.

The 60-20-20 Indicator for VAMP is as follows:

SJR Basin 60-20-20 Classification	60-20-20 Indicator
Wet	5
Above Normal	4
Below Normal	3
Dry	2
Critical	1

For example, assuming a dry year followed by a wet year results in the sum of 7 (i.e., 2 + 5 = 7). Assuming the single-step Target Flow is 5,700 cfs, one step higher would be 7,000 cfs.

If achieving the double-step requires more than the 110,000 acre-feet of supplemental water, additional water from willing sellers on the San Joaquin, Stanislaus, Tuolumne, and Merced rivers (approximately 50,000 acre-feet) may be acquired by the Bureau of Reclamation (Reclamation) for the Pulse Flow Period, and it would require additional NEPA/CEQA analysis.

Sequential Dry Year Relaxation. During years when the sum of the current year's 60-20-20 indicator and the previous two years' 60-20-20 Indicator is four (4) or less, the Authority's members will not be required to make water available above existing flow, except as may be provided by Merced and Oakdale Irrigation Districts or any of the districts under the willing sellers provision of the SJRA. Reclamation has continuing obligations to meet San Joaquin River flows pursuant to the March 6, 1995 Biological Opinion and may acquire water in excess of the amounts to be provided by Authority members under the Agreement.

APPENDIX C

MBK ENGINEERS
DATA FILES FOR THE MERCED RIVER AND PROJECT RESERVOIRS

(refer to enclosed data CD)

- Historical Water Year Index Table and Charts
- Snelling Monthly Flow
- Merced Falls Monthly
- Merced River Simulation Model Control Points
- Charts

APPENDIX D

NATURAL RESOURCE SCIENTISTS, INC.
DATA FILES
(refer to enclosed data CD)

- **Average Daily Temperatures**
  - Bagby – Air (WY 1999 – WY 2002)
  - Bagby – Water (WY 1999 – WY 2002)
  - McSwain (WY 1999 – WY 2003)
  - New Exchequer (WY 1999 – WY 2003)
  - River Mile 1 (WY 1998 – WY 2003)
  - River Mile 12 (WY 1998 – WY 2003)
  - River Mile 31 (WY 1998 – WY 2003)
  - River Mile 42 (WY 1998 – WY 2002)
  - River Mile 47 (WY 1999 – WY 2003)
  - River Mile 52 (WY 1998 – WY 2003)
- **Hourly Temperatures**
  - Bagby – Air (WY 1999 – WY 2002)
  - Bagby – Water (WY 1999 – WY 2002)
  - McSwain (WY 1999 – WY 2003)
  - New Exchequer (WY 1999 – WY 2003)
  - River Mile 1 (WY 1998 – WY 2003)
  - River Mile 12 (WY 1998 – WY 2003)
  - River Mile 31 (WY 1998 – WY 2003)
  - River Mile 42 (WY 1998 – WY 2002)
  - River Mile 47 (WY 1999 – WY 2003)
  - River Mile 52 (WY 1998 – WY 2003)
- **McClure Depth Profiles**
- **Charts**
  - Between Years
  - Within Years – 3 Reserv
  - Within Years – Bagby
  - Within Years - RM